U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1437, Supplement 38,
Vol. 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Supplement 38

Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3

Final Report
Main Report and Comment Responses

Office of Nuclear Reactor Regulation

AVAILABILITY OF REFERENCE MATERIALS IN NRC PUBLICATIONS

NRC Reference Material

As of November 1999, you may electronically access NUREG-series publications and other NRC records at NRC's Public Electronic Reading Room at http://www.nrc.gov/reading-rm.html.
Publicly released records include, to name a few, NUREG-series publications; *Federal Register* notices; applicant, licensee, and vendor documents and correspondence; NRC correspondence and internal memoranda; bulletins and information notices; inspection and investigative reports; licensee event reports; and Commission papers and their attachments.

NRC publications in the NUREG series, NRC regulations, and *Title 10, Energy*, in the Code of *Federal Regulations* may also be purchased from one of these two sources.

1. The Superintendent of Documents
   U.S. Government Printing Office
   Mail Stop SSOP
   Washington, DC 20402–0001
   Internet: bookstore.gpo.gov
   Telephone: 202-512-1800
   Fax: 202-512-2250
2. The National Technical Information Service
   Springfield, VA 22161–0002
   www.ntis.gov
   1–800–553–6847 or, locally, 703–605–6000

A single copy of each NRC draft report for comment is available free, to the extent of supply, upon written request as follows:
Address: U.S. Nuclear Regulatory Commission
Office of Administration
Mail, Distribution and Messenger Team
Washington, DC 20555-0001
E-mail: DISTRIBUTION@nrc.gov
Facsimile: 301–415–2289

Some publications in the NUREG series that are posted at NRC's Web site address http://www.nrc.gov/reading-rm/doc-collections/nuregs are updated periodically and may differ from the last printed version. Although references to material found on a Web site bear the date the material was accessed, the material available on the date cited may subsequently be removed from the site.

Non-NRC Reference Material

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions, *Federal Register* notices, Federal and State legislation, and congressional reports. Such documents as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings may be purchased from their sponsoring organization.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at—
The NRC Technical Library
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852–2738

These standards are available in the library for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from—
American National Standards Institute
11 West 42nd Street
New York, NY 10036–8002
www.ansi.org
212–642–4900

Legally binding regulatory requirements are stated only in laws; NRC regulations; licenses, including technical specifications; or orders, not in NUREG-series publications. The views expressed in contractor-prepared publications in this series are not necessarily those of the NRC.

The NUREG series comprises (1) technical and administrative reports and books prepared by the staff (NUREG–XXXX) or agency contractors (NUREG/CR–XXXX), (2) proceedings of conferences (NUREG/CP–XXXX), (3) reports resulting from international agreements (NUREG/IA–XXXX), (4) brochures (NUREG/BR–XXXX), and (5) compilations of legal decisions and orders of the Commission and Atomic and Safety Licensing Boards and of Directors' decisions under Section 2.206 of NRC's regulations (NUREG–0750).

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NUREG-1437, Supplement 38,
Vol. 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Supplement 38

Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3

Final Report
Main Report and Comment Responses

Manuscript Completed: November 2010
Date Published: December 2010

Office of Nuclear Reactor Regulation

ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) considered the environmental impacts of renewing nuclear power plant operating licenses for a 20-year period in NUREG-1437, Volumes 1 and 2, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (hereafter referred to as the GEIS),[1] and codified the results in Title 10, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," of the *Code of Federal Regulations* (10 CFR Part 51). In the GEIS (and its Addendum 1), the NRC staff identified 92 environmental issues and reached generic conclusions related to environmental impacts for 69 of these issues that apply to all plants or to plants with specific design or site characteristics. Additional plant-specific review is required for the remaining 23 issues. These plant-specific reviews are to be included in a supplement to the GEIS.

This supplemental environmental impact statement (SEIS) has been prepared in response to an application submitted to the NRC by Entergy Nuclear Operations, Inc. (Entergy), Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC (all applicants will be jointly referred to as Entergy) to renew the operating licenses for Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) for an additional 20 years under 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." This SEIS includes the NRC staff's analysis which considers and weighs the environmental impacts of the proposed action, the environmental impacts of alternatives to the proposed action, and mitigation measures available for reducing or avoiding adverse impacts. It also includes the NRC staff's recommendation regarding the proposed action.

Regarding the 69 issues for which the GEIS reached generic conclusions, neither Entergy nor the NRC staff has identified information that is both new and significant for any issues that apply to IP2 and/or IP3. In addition, the NRC staff determined that information provided during the scoping process was not new and significant with respect to the conclusions in the GEIS. Therefore, the NRC staff concludes that the impacts of renewing the operating licenses for IP2 and IP3 will not be greater than the impacts identified for these issues in the GEIS. For each of these issues, the NRC staff's conclusion in the GEIS is that the impact is of SMALL[2] significance (except for the collective offsite radiological impacts from the fuel cycle and high-level waste and spent fuel, which were not assigned a single significance level).

Regarding the remaining 23 issues, those that apply to IP2 and IP3 are addressed in this SEIS. The NRC staff determined that several of these issues were not applicable because of the type of facility cooling system or other reasons detailed within this SEIS. For the remaining applicable issues, the NRC staff concludes that the significance of potential environmental impacts related to operating license renewal is SMALL, with three exceptions—entrainment, impingement, and heat shock from the facility's heated discharge. Overall effects from entrainment and impingement are likely to be MODERATE. Impacts from heat shock potentially

(1) The GEIS was originally issued in 1996. Addendum 1 to the GEIS was issued in 1999. Hereafter, all references to the "GEIS" include the GEIS and its Addendum 1.

(2) Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

range from SMALL to LARGE depending on the conclusions of thermal studies proposed by the New York State Department of Environmental Conservation (NYSDEC). Based on corrected data received since completing the draft SEIS, NRC staff concludes that impacts to the endangered shortnose sturgeon – which ranged from SMALL to LARGE in the draft SEIS – are likely to be SMALL.

The NRC staff's recommendation is that the Commission determine that the adverse environmental impacts of license renewals for IP2 and IP3 are not so great that preserving the option of license renewal for energy planning decision makers would be unreasonable. This recommendation is based on (1) the analysis and findings in the GEIS, (2) the environmental report and other information submitted by Entergy, (3) consultation with other Federal, State, Tribal, and local agencies, (4) the NRC staff's own independent review, and (5) the NRC staff's consideration of public comments received during the scoping process and in response to the draft SEIS.

Paperwork Reduction Act Statement

This NUREG does not contain information collection requirements and, therefore, is not subject to the requirements of the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 *et seq.*). These information collections were approved by the Office of Management and Budget (OMB), approval numbers 3150-0004, 3150-0155, 3150-0014, 3150-0011, 3150-0021, 3150-0132, and 3150-0151.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

Table of Contents

Appendices

Figures

Tables

Tables

EXECUTIVE SUMMARY

By letter dated April 30, 2007, Entergy Nuclear Operations, Inc. (Entergy) submitted an application to the U.S. Nuclear Regulatory Commission (NRC) to renew the operating licenses for Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) for an additional 20-year period. If the operating licenses are renewed, State regulatory agencies and Entergy will ultimately decide whether the plant will continue to operate based on factors such as the need for power, issues falling under the purview of the owners, or other matters within the State's jurisdiction, including acceptability of water withdrawal. Two state-level issues (consistency with State water quality standards, and consistency with State coastal zone management plans) need to be resolved. On April 2, 2010, the New York State Department of Environmental Conservation (NYSDEC) issued a Notice of Denial regarding the Clean Water Act Section 401 Water Quality Certification. Entergy has since requested a hearing on the issue, and the matter will be decided through NYSDEC's hearing process. If the operating licenses are not renewed, then IP2 and IP3 must be shut down at or before the expiration date of their current operating licenses which expire September 28, 2013, and December 12, 2015, respectively.

The NRC has implemented Section 102 of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321), in Title 10, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," of the *Code of Federal Regulations* (10 CFR Part 51). In 10 CFR 51.20(b)(2), the Commission requires preparation of an environmental impact statement (EIS) or a supplement to an EIS for renewal of a reactor operating license. In addition, 10 CFR 51.95(c) states that the EIS prepared at the operating license renewal stage will be a supplement to NUREG-1437, Volumes 1 and 2, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (hereafter referred to as the GEIS).[(1)]

Upon acceptance of the IP2 and IP3 application, the NRC began the environmental review process described in 10 CFR Part 51 by publishing a notice of intent to prepare an EIS and conduct scoping. The NRC staff visited the IP2 and IP3 site in September 2007, held two public scoping meetings on September 19, 2007, and conducted two site audits on September 10–14, 2007, and September 24–27, 2007. In the preparation of this supplemental environmental impact statement (SEIS) for IP2 and IP3, the NRC staff reviewed the IP2 and IP3 environmental report (ER) and compared it to the GEIS; consulted with other agencies; conducted an independent review of the issues following the guidance in NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal," issued October 1999; and considered the public comments received during the scoping process and in response to the draft SEIS. The public comments received during the scoping process that were considered to be within the scope of the environmental review are contained in the Scoping Summary Report for Indian Point Nuclear Generating Unit Nos. 2 and 3, issued by NRC staff in December 2008. In Appendix A of this SEIS, the NRC staff adopts, by reference, the comments and responses in the Scoping Summary Report and provides information on how to electronically access the scoping summary or view a hard copy.

---

(1) The GEIS was originally issued in 1996. Addendum 1 to the GEIS was issued in 1999. Hereafter, all references to the "GEIS" include the GEIS and its Addendum 1.

The NRC staff held public meetings in Cortlandt Manor, New York, on February 12, 2009 and described the preliminary results of the NRC environmental review, answered questions, and provided members of the public with information to assist them in formulating comments on the draft SEIS. The NRC staff considered and addressed all of the comments received. These comments are reflected in the SEIS or addressed in Appendix A, Part 2, to this SEIS.

This SEIS includes the NRC staff's analysis that considers and weighs the environmental effects of the proposed action, the environmental impacts of alternatives to the proposed action, and mitigation measures for reducing or avoiding adverse effects. It also includes the NRC staff's recommendation regarding the proposed action.

The Commission has adopted the following statement of purpose and need for license renewal from the GEIS:

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decision makers.

The purpose of the NRC staff's environmental review, as defined in 10 CFR 51.95(c)(4) and the GEIS, is to determine the following:

> …whether or not the adverse environmental impacts of license renewal are so great that preserving the option of license renewal for energy planning decision makers would be unreasonable.

Both the statement of purpose and need and the evaluation criterion implicitly acknowledge that there are factors, in addition to license renewal, that will ultimately determine whether an existing nuclear power plant continues to operate beyond the period of the current operating license (or licenses).

NRC regulations (10 CFR 51.95(c)(2)) contain the following statement regarding the content of SEISs prepared at the license renewal stage:

> The supplemental environmental impact statement for license renewal is not required to include discussion of need for power or the economic costs and economic benefits of the proposed action or of alternatives to the proposed action except insofar as such benefits and costs are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation. In addition, the supplemental environmental impact statement prepared at the license renewal stage need not discuss other issues not related to the environmental effects of the proposed action and the alternatives, or any aspect of the storage of spent fuel for the facility within the scope of the generic determination in 10 CFR 51.23(a) ["Temporary storage of spent fuel after cessation of reactor operation–generic determination of no significant environmental impact"] and in accordance with 10 CFR 51.23(b).

The GEIS contains the results of a systematic evaluation of the consequences of renewing an operating license and operating a nuclear power plant for an additional 20 years. It evaluates 92 environmental issues using the NRC's three-level standard of significance—SMALL, MODERATE, or LARGE—developed using the Council on Environmental Quality (CEQ) guidelines.

The following definitions of the three significance levels are set forth in footnotes to Table B-1 of Appendix B, “Environmental Effect of Renewing the Operating License of a Nuclear Power Plant,” to 10 CFR Part 51, Subpart A, “National Environmental Policy Act—Regulations Implementing Section 102(2)”:

> SMALL—Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
>
> MODERATE—Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
>
> LARGE—Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

For 69 of the 92 issues considered in the GEIS, the analysis in the GEIS reached the following conclusions:

(1) The environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

(2) A single significance level (that is, SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal).

(3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are not likely to be sufficiently beneficial to warrant implementation.

These 69 issues were identified in the GEIS as Category 1 issues. In the absence of new and significant information, the staff relied on conclusions in the GEIS for issues designated as Category 1 in Table B-1 of Appendix B to 10 CFR Part 51, Subpart A.

Of the 23 issues that do not meet the criteria set forth above, 21 are classified as Category 2 issues requiring analysis in a plant-specific supplement to the GEIS. The remaining two issues, environmental justice and chronic effects of electromagnetic fields, were not categorized. Environmental justice was not evaluated on a generic basis and must be addressed in a plant-specific supplement to the GEIS. Information on the chronic effects of electromagnetic fields was not conclusive at the time the GEIS was prepared.

This SEIS documents the NRC staff’s consideration of all 92 environmental issues identified in the GEIS. The NRC staff considered the environmental impacts associated with alternatives to license renewal and compared the environmental impacts of license renewal and the alternatives. The alternatives to license renewal that were considered include the no-action alternative (not renewing the operating licenses for IP2 and IP3), alternative methods of power generation, and conservation. The NRC staff also considered an alternative that included continued operation of IP2 and IP3 with a closed-cycle cooling system. This alternative is considered for several reasons. First, the New York State Department of Environmental Conservation (NYSDEC) issued a preliminary determination in its 2003 draft and 2004 revised draft State Pollutant Discharge Elimination System (SPDES) permits that closed cycle cooling is the site-specific best technology available (BTA) to reduce impacts on fish and shellfish;

currently the revised draft SPDES permit is the subject of NYSDEC proceedings, and the existing SPDES permit continues in effect at this time. Second, NYSDEC affirmed this view in its April 2, 2010, Notice of Denial of Entergy's Clean Water Act Section 401 Water Quality Certification, indicating that closed cycle cooling would minimize aquatic impacts; that determination is currently subject to further State-level adjudication. Third, NYSDEC has published a draft policy on BTA indicating that "Wet closed-cycle cooling or its equivalent" is the "minimum performance goal for existing industrial facilities that operate a CWIS [cooling water intake system] in connection with a point source thermal discharge." Public comments on that draft policy were submitted through July 9, 2010.

Entergy and the NRC staff have established independent processes for identifying and evaluating the significance of any new information on the environmental impacts of license renewal. Neither Entergy nor the staff has identified information that is both new and significant related to Category 1 issues that would call into question the conclusions in the GEIS. Similarly, neither the scoping process nor the NRC staff has identified any new issue applicable to IP2 and IP3 that has a significant environmental impact. Therefore, the NRC staff relies on the conclusions of the GEIS for all of the Category 1 issues that are applicable to IP2 and IP3.

Entergy's license renewal application presents an analysis of the 21 Category 2 issues that are applicable to IP2 and IP3, plus environmental justice and chronic effects from electromagnetic fields, for a total of 23 issues. The NRC staff has reviewed the Entergy analysis and has conducted an independent assessment of each issue. Six of the Category 2 issues are not applicable because they are related to a type of existing cooling system, water use conflicts, and ground water use not found at IP2 and IP3. Entergy has stated that its evaluation of structures and components, as required by 10 CFR 54.21, "Contents of Application—Technical Information," did not identify any major plant refurbishment activities or modifications as necessary to support the continued operation of IP2 and IP3 for the license renewal period. Entergy did, however, indicate that it plans to replace reactor vessel heads and control rod drive mechanisms at IP2 and IP3. The NRC staff has evaluated the potential impacts of these activities using the framework provided by the GEIS for addressing refurbishment issues.

Seventeen environmental issues related to operational impacts and postulated accidents during the renewal term are discussed in detail in this SEIS. These include 15 Category 2 issues and 2 uncategorized issues, environmental justice and chronic effects of electromagnetic fields. The NRC staff also discusses in detail the potential impacts related to the 10 Category 2 issues that apply to refurbishment activities. The NRC staff concludes that the potential environmental effects for most of these issues are of SMALL significance in the context of the standards set forth in the GEIS with three exceptions—entrainment, impingement, and heat shock from the facility's heated discharge. The NRC staff jointly assessed the impacts of entrainment and impingement to be MODERATE based on NRC's analysis of representative important species. Impacts from heat shock potentially range from SMALL to LARGE depending on the conclusions of thermal studies proposed by the NYSDEC. Based on corrected data received since completing the draft SEIS, the NRC staff concludes that impacts to the endangered shortnose sturgeon – which ranged from SMALL to LARGE in the draft SEIS – are likely to be SMALL.

The NRC staff also determined that appropriate Federal health agencies have not reached a consensus on the existence of chronic adverse effects from electromagnetic fields. Therefore, no further evaluation of this issue is required.

For severe accident mitigation alternatives (SAMAs), the staff concludes that a reasonable, comprehensive effort was made to identify and evaluate SAMAs. Based on its review of the SAMAs for IP2 and IP3 and the plant improvements already made, the NRC staff concludes that several SAMAs may be cost-beneficial. However, these SAMAs do not relate to adequate management of the effects of aging during the period of extended operation. Therefore, they do not need to be implemented as part of license renewal pursuant to 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants."

Cumulative impacts of past, present, and reasonably foreseeable future actions were considered, regardless of what agency (Federal or non-Federal) or person undertakes such other actions. For purposes of this analysis, the NRC staff determined that the cumulative impacts to terrestrial and aquatic resources in the IP2 and IP3 environs would be LARGE, due primarily to past development and pollution, much of which preceded IP2 and IP3 or occurred as a result of other actions (for example, suburban development and hardening of the Hudson River shoreline).

The NRC staff's analysis indicates that the adverse impacts of potential alternatives will differ from those of the proposed action. Most alternatives result in smaller impacts to aquatic life, while creating greater impacts in other resource areas. Often, the most significant environmental impacts of alternatives result from constructing new facilities or infrastructure.

The recommendation of the NRC staff is that the Commission determine that the adverse environmental impacts of license renewals for IP2 and IP3 are not so great that not preserving the option of license renewal for energy planning decision makers would be unreasonable. This recommendation is based on (1) the analysis and findings in the GEIS, (2) the ER and other information submitted by Entergy, (3) consultation with other Federal, State, Tribal, and local agencies, (4) the staff's own independent review, and (5) the staff's consideration of public comments received during the scoping process and in response to the draft SEIS.

Abbreviations/Acronyms

°	degree(s)
μm	micron(s)
3D	three dimensional
ACAA	American Coal Ash Association
ac	acre(s)
AC	alternating current
ACC	averted cleanup and decontamination
ADAMS	Agencywide Documents Access and Management System
ADAPT	Atmospheric Data Assimilation and Parameterization Technique
ACEEE	American Council for an Energy Efficient Economy
AEC	Atomic Energy Commission
AFW	auxiliary feed water
AGTC	Algonquin Gas Transmission Company
ALARA	as low as reasonably achievable
ANOVA	analysis of variance
AOC	averted off-site property damage costs
AOE	averted occupational exposure costs
AOSC	averted on-site costs
APE	averted public exposure
ASA	Applied Science Associates
ASME	American Society of Mechanical Engineers
ASMFC	Atlantic States Marine Fisheries Commission
ASSS	alternate safe shutdown system
ATWS	anticipated transient without scram
AUTOSAM	Automated Abundance Sampler
BA	biological assessment
BO	Biological Opinion
Board	Atomic Safety and Licensing Board
Bq/L	becquerel per liter
Bq/kg	becquerel per kilogram
BSS	Beach Seine Survey
BTA	best technology available
BTU	British thermal unit(s)
C	Celsius
CAA	Clean Air Act
CAFTA	computer aided fault-tree analysis code
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CCF	common cause failure
CCMP	Comprehensive Conservation and Management Plan
CCW	component cooling water

CCWD	Cortlandt Consolidated Water District
CDF	core damage frequency
CDM	Clean Development Mechanism
CET	Containment Event Tree
CEQ	Council on Environmental Quality
CFR	*Code of Federal Regulations*
cfs	cubic foot (feet) per second
CHGEC	Central Hudson Gas & Electric Corporation
Ci	curie(s)
CI	confidence interval
cm	centimeter(s)
CMP	Coastal Management Plan
CMR	conditional mortality rate
CNP	Cook Nuclear Plant
CO	carbon monoxide
CO_2	carbon dioxide
COE	cost of enhancement
COL	Combined License
Con Edison	Consolidated Edison Company of New York
CORMIX	Cornell University Mixing Zone Model
CPUE	catch-per-unit-effort
CRDM	control rod drive mechanism
CST	condensate storage tank
CV	coefficient of variation
CWA	Clean Water Act
CWIS	Circulating Water Intake System
CZMA	Coastal Zone Management Act
dB(A)	decibel(s)
DBA	Design-basis accident
DC	direct current
DDT	dichloro-diphenyl-trichloroethane
DEIS	Draft Environmental Impact Statement
DF	Decontamination Factor
DNA	deoxyribonucleic acid
DNR	Department of Natural Resources
DO	dissolved oxygen
DOC	dissolved organic carbon
DOE	U.S. Department of Energy
DOS	Department of State
DOT	U.S. Department of Transportation
DPS	Distinct Population Segment
DSEIS	Draft Supplemental Environmental Impact Statement
EA	Environmental Assessment
ECL	Environmental Conservation Law
EDG	emergency diesel generator

EIA	Energy Information Administration
EIS	environmental impact statement
EFH	Essential Fish Habitat
ELF-EMF	extremely low frequency-electromagnetic field
EMR	entrainment mortality rate
Entergy	Entergy Nuclear Operations, Inc.
EOP	emergency operating procedure
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	Environmental Report
ER-M	effects-range-median
ESA	Endangered Species Act
F	Fahrenheit
F&O	Facts and Observations
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FES	Final Environmental Statement
FJS	Fall Juvenile Survey
FPC	Federal Power Commission
fps	feet per second
FPS	fire protection system
FR	*Federal Register*
FSAR	Final Safety Analysis Report
FSS	Fall Shoals Survey
ft	foot (feet)
ft^2	square feet
ft^3	cubic feet
FWS	U.S. Fish and Wildlife Service
g	gram(s)
gal	gallon(s)
gC_{eq}/kWh	gram(s) of carbon dioxide equivalents per kilowatt-hour
GEIS	*Generic Environmental Impact Statement for License Renewal of Nuclear Plants, NUREG-1437*
GHG	greenhouse gas
GL	Generic Letter
gpm	gallon(s) per minute
GW	gigawatt
ha	hectare(s)
HAP	hazardous air pollutant
HLW	high-level waste
hr	hour(s)
HRA	Human Reliability Analysis

HRERF	Hudson River Estuary Restoration Fund
HRFI	Hudson River Fisheries Investigation
HRPC	Hudson River Policy Committee
HRSA	Hudson River Settlement Agreement
IAEA	International Atomic Energy Agency
IMR	impingement mortality rate
in.	inch(es)
INEEL	Idaho National Energy and Environmental Laboratory
IP1	Indian Point Nuclear Generating Unit No. 1
IP2	Indian Point Nuclear Generating Unit No. 2
IP3	Indian Point Nuclear Generating Unit No. 3
IPE	individual plant examination
IPEEE	individual plant examination of external events
ISFSI	Independent Fuel Storage Installation
ISLOCA	Interfacing Systems Loss of Coolant Accidents
IWSA	Integrated Waste Services Association
kg	kilogram(s)
km	kilometer(s)
km^2	square kilometer(s)
kV	kilovolt(s)
kWh	kilowatt hour(s)
lb	pound(s)
L	liter(s)
LERF	Large Early Release Frequency
LLMW	low-level mixed waste
LLNL	Lawrence Livermore National Library
LOCA	loss of coolant accident
LODI	Lagrangian Operational Dispersion Integrator
LOE	Line(s) of Evidence
lpm	liters per minute
LRA	license renewal application
LR	linear regression
LRS	Long River Survey
LSE	load serving entities
m	meter(s)
mm	millimeter(s)
m^2	square meter(s)
m^3	cubic meter(s)
m^3/sec	cubic meter(s) per second
MAAP	Modular Accident Analysis Program
MACCS2	MELCOR Accident Consequence Code System 2
MBq	megabecquerel
mg	milligram(s)

mgd	million gallons per day
mg/L	milligram(s) per liter
mGy	milligray
mi	mile(s)
min	minute(s)
MIT	Massachusetts Institute of Technology
mL	milliliter(s)
MLES	Marine Life Exclusion System
MMBtu	million British thermal unit(s)
mps	meter(s) per second
mrad	millirad(s)
mrem	millirem(s)
mRNA	messenger ribonucleic acid
MSE	mean squared error
MSL	mean sea level
MSPI	Mitigating Systems Performance Indicator
mSv	millisievert
MT	metric ton(s)
MTU	metric ton of uranium
MW	megawatt
MWd	megawatt-days
MW(e)	megawatt(s) electric
MW(h)	megawatt hour(s)
MW(t)	megawatt(s) thermal
MWSF	Mixed Waste Storage Facility
NAAQS	National Ambient Air Quality Standards
NARAC	National Atmospheric Release Advisory Center
NAS	National Academy of Sciences
NEA	Nuclear Energy Agency
NEPA	National Environmental Policy Act of 1969, as amended
NESC	National Electric Safety Code
NGO	Nongovernmental Organization
NHPA	National Historic Preservation Act
NIEHS	National Institute of Environmental Health Sciences
NIRS	Nuclear Information and Resource Service
NMFS	National Marine Fisheries Service
NJDEP	New Jersey Department of Environmental Protection
NO_2	nitrogen dioxide
NO_x	nitrogen oxide(s)
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NSSS	nuclear steam supply system
NWJWW	Northern Westchester Joint Water Works
NY/NJ/PHL	New York/New Jersey/Philadelphia

NYCA	New York Control Area
NYCDEP	New York City Department of Environmental Protection
NYCRR	New York Code of Rules and Regulations
NYISO	New York Independent System Operator
NYPA	New York Power Authority
NYPSC	New York Public Service Commission
NYRI	New York Regional Interconnect, Inc.
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSERDA	New York State Energy Research and Development Authority
NYSHPO	New York State Historic Preservation Office
O_3	ozone 8-hour standard
OCNGS	Oyster Creek Nuclear Generating Station
ODCM	Offsite Dose Calculation Manual
OMB	Office of Management and Budget
OPR	Office of Protected Resources
PAB	primary auxiliary building
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
pCi/L	picoCuries per liter
pCi/kg	picoCuries per kilogram
PDS	plant damage state
PILOT	payment-in-lieu-of-taxes
PM	particulate matter
$PM_{2.5}$	particulate matter, 2.5 microns or less in diameter
PM_{10}	particulate matter, 10 microns or less in diameter
POC	particulate organic carbon
PORV	power operated relief valve
POST	Parliamentary Office of Science and Technology
ppm	parts per million
ppt	parts per thousand
PRA	probabilistic risk assessment
PSA	probabilistic safety assessment
PV	photovoltaic
PWR	pressurized water reactor
PWW	Poughkeepsie Water Works
PYSL	post yolk-sac larvae
REMP	Radiological Environmental Monitoring Program
R-EMAP	regional environmental monitoring and assessment program
RAI	request for additional information
RCP	reactor coolant pump
RCRA	Resource Conservation and Recovery Act
RCS	reactor cooling system
REMP	radiological environmental monitoring program

RHR	residual heat removal
Riverkeeper	Hudson River Fishermen's Association
RIS	Representative Important Species
RKM	river kilometer(s)
RM	river mile(s)
RMP	Risk Management Plan
ROD	Record of Decision
ROI	region of influence
ROW	right-of-way
RPC	long-term replacement power costs
rpm	revolutions per minute
RRW	risk reduction worth
RWST	refueling water storage tank

s	second(s)
SAFSTOR	safe storage condition
SAMA	severe accident mitigation alternative
SAR	Safety Analysis Report
SAV	submerged aquatic vegetation
SBO	station blackout
Scenic Hudson	Scenic Hudson Preservation Conference
SCR	selective catalytic reduction
SECPOP	sector population, land fraction and economic estimation program
SEIS	Supplemental Environmental Impact Statement
SFP	Spent Fuel Pool
SGTR	Steam Generator Tube Ruptures
SI	Safety Injection
SO_2	sulfur dioxide
SO_x	sulfur oxide(s)
SPDES	State Pollutant Discharge Elimination System
SPU	stretch power uprate
sq mi	square mile(s)
SR	segmented regression
SRP	Standard Review Plan
SRT	Status Review Team
SSBR	spawning stock biomass per-recruit
SSE	safe shutdown earthquake
Sv	person-sievert
SWS	service water system

t	ton(s)
TDEC	Tennessee Department of Environment and Conservation
TI-SGTR	thermally-induced Steam Generator Tube Ruptures
TLD	Thermoluminescent dosimeter
TOC	total organic carbon
TRC	TRC Environmental Corporation

U.S.	United States
U.S.C.	United States Code
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Atomic Energy Commission
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UWNY	United Water New York
V	volt(s)
VALWNF	value of non-farm wealth
VOC	volatile organic compound
WCDOH	Westchester County Department of Health
WISE	World Information Service on Energy
WJWW	Westchester Joint Water Works
WOE	weight of evidence
WOG	Westinghouse Owner's Group
YSL	yolk-sac larvae
YOY	young of year
yr	year(s)

1.0 INTRODUCTION

Under the U.S. Nuclear Regulatory Commission's (NRC's) environmental protection regulations in Title 10, Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," of the *Code of Federal Regulations* (10 CFR Part 51), which implement the National Environmental Policy Act of 1969, as amended (NEPA), renewal of a nuclear power plant operating license requires the preparation of an environmental impact statement (EIS). In preparing the EIS, the NRC staff is required first to issue the statement in draft form for public comment and then to issue a final statement after considering public comments on the draft. To support the preparation of the EIS, the NRC staff prepared NUREG-1437, Volumes 1 and 2, "Generic Environmental Impact Statement for License Renewal of Nuclear Plants" (hereafter referred to as the GEIS) (NRC 1996, 1999).[1] The GEIS is intended to (1) provide an understanding of the types and severity of environmental impacts that may occur as a result of license renewal of nuclear power plants under 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," (2) identify and assess the impacts that are expected to be generic to license renewal, and (3) support 10 CFR Part 51 by defining the number and scope of issues that need to be addressed by the applicants in plant-by-plant renewal proceedings. Use of the GEIS guides the preparation of complete plant-specific information in support of the operating license renewal process.

Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC, operate the Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) nuclear power reactors, respectively, as indirect wholly owned subsidiaries of Entergy Corporation and indirect wholly owned subsidiaries of Entergy Nuclear Operations, Inc. (Entergy). IP2 and IP3 are located in Buchanan, New York.

IP2 has operated under operating license DPR-26 since August 1974. The IP2 operating license will expire on September 28, 2013. IP3 has operated under operating license DPR-64 since August 1976. The IP3 operating license will expire on December 12, 2015. Indian Point Unit No. 1 (IP1) was shut down in 1974 and is currently in SAFSTOR (a decommissioning strategy that includes maintenance, monitoring, and delayed dismantlement to allow radioactivity to decay prior to decommissioning).

Entergy, Entergy Nuclear Indian Point 2, LLC, and Entergy Nuclear Indian Point 3, LLC, are joint applicants for the renewal of the operating licenses (the joint applicants will be referred to as Entergy). Entergy submitted an application to the NRC to renew the IP2 and IP3 operating licenses for an additional 20 years each under 10 CFR Part 54 on April 30, 2007 (Entergy 2007a). Pursuant to 10 CFR 54.23, "Contents of Application—Environmental Information," and 10 CFR 51.53(c), Entergy submitted an environmental report (ER) (Entergy 2007b) as part of the license renewal application in which Entergy analyzed the environmental impacts associated with the proposed license renewal action, considered alternatives to the proposed action, and evaluated mitigation measures for reducing adverse environmental effects. Entergy submitted supplemental information clarifying operating licenses and applicant names in a letter on May 3, 2007 (Entergy 2007c).

[1] The GEIS was originally issued in 1996. Addendum 1 to the GEIS was issued in 1999. Hereafter, all references to the "GEIS" include the GEIS and its Addendum 1.

This report is the plant-specific supplement to the GEIS (the supplemental EIS (SEIS)) for the Entergy license renewal application. This SEIS is a supplement to the GEIS because it relies, in part, on the findings of the GEIS. In August, 2009, the NRC staff issued a separate safety evaluation report in accordance with 10 CFR Part 54.

1.1 Report Contents

The following sections of this introduction (1) describe the background for the preparation of this SEIS, including the development of the GEIS and the process used by the NRC staff to assess the environmental impacts associated with license renewal, (2) describe the proposed Federal action to renew the IP2 and IP3 operating licenses, (3) discuss the purpose and need for the proposed action, and (4) present the status of IP2 and IP3 compliance with environmental quality standards and requirements that have been imposed by Federal, State, regional, and local agencies that are responsible for environmental protection.

The ensuing chapters of this SEIS closely parallel the contents and organization of the GEIS. Chapter 2 describes the site, power plant, and interactions of the plant with the environment. Chapters 3 and 4, respectively, discuss the potential environmental impacts of plant refurbishment and plant operation during the renewal term. Chapter 5 contains an evaluation of potential environmental impacts of plant accidents and includes consideration of severe accident mitigation alternatives. Chapter 6 discusses the uranium fuel cycle and solid waste management and greenhouse gas emissions. Chapter 7 discusses decommissioning, and Chapter 8 discusses alternatives to license renewal. Finally, Chapter 9 summarizes the findings of the preceding chapters and draws conclusions about the adverse impacts that cannot be avoided, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and the irreversible or irretrievable commitment of resources. Chapter 9 also presents the NRC staff's recommendation with respect to the proposed license renewal action.

Additional information is included in appendices. Appendix A contains public comments related to the environmental review for license renewal and the NRC staff's responses to those comments. Appendices B through G include the following:

- the preparers of the supplement (Appendix B)
- the chronology of the NRC staff's environmental review correspondence related to this SEIS (Appendix C)
- the organizations contacted during the development of this SEIS (Appendix D)
- the IP2 and IP3 compliance status in Tables E-1 and E-2 and copies of consultation correspondence prepared and sent during the evaluation process (Appendix E)
- GEIS environmental issues that are not applicable to IP2 and IP3 (Appendix F)
- the NRC staff's evaluation of severe accident mitigation alternatives (Appendix G)
- the NRC staff's evaluation of impacts of the IP2 and IP3 cooling system (Appendix H)
- statistical analyses conducted for Chapter 4 aquatic resources and appendix H (Appendix I)

1.2 Background

Use of the GEIS, which examines the possible environmental impacts that could occur as a result of renewing individual nuclear power plant operating licenses under 10 CFR Part 54, and the established license renewal evaluation process, support the thorough evaluation of the impacts of operating license renewal.

1.2.1 Generic Environmental Impact Statement

The NRC initiated a generic assessment of the environmental impacts associated with the license renewal term to improve the efficiency of the license renewal process by documenting the assessment results and codifying the results in the Commission's regulations. This assessment is provided in the GEIS, which serves as the principal reference for all nuclear power plant license renewal EISs.

The GEIS documents the results of the systematic approach that the NRC staff used to evaluate the environmental consequences of renewing the licenses of individual nuclear power plants and operating them for an additional 20 years. For each potential environmental issue, the GEIS (1) describes the activity that affects the environment, (2) identifies the population or resource that is affected, (3) assesses the nature and magnitude of the impact on the affected population or resource, (4) characterizes the significance of both beneficial and adverse effects, (5) determines whether the results of the analysis apply to all plants, and (6) considers whether additional mitigation measures would be warranted for impacts that would have the same significance level for all plants.

The NRC's standard of significance for impacts was established using the Council on Environmental Quality (CEQ) term "significantly" (40 CFR 1508.27, which requires consideration of both "context" and "intensity"). Using the CEQ terminology, the NRC established three significance levels—SMALL, MODERATE, or LARGE. The definitions of the three significance levels are set forth in the footnotes to Table B-1 of 10 CFR Part 51, Subpart A, "National Environmental Policy Act—Regulations Implementing Section 102(2)," Appendix B, "Environmental Effect of Renewing the Operating License of a Nuclear Power Plant," as follows:

> SMALL—Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
>
> MODERATE—Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
>
> LARGE—Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The GEIS assigns a significance level to each environmental issue, assuming that ongoing mitigation measures would continue.

The GEIS includes a determination of whether the analysis of the environmental issue could be applied to all plants and whether additional mitigation measures would be warranted. Issues are assigned a Category 1 or a Category 2 designation. As set forth in the GEIS, Category 1 issues are those that meet all of the following criteria:

(1) The environmental impacts associated with the issue have been

determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics.

(2) A single significance level (i.e., SMALL, MODERATE, or LARGE) has been assigned to the impacts (except for collective offsite radiological impacts from the fuel cycle and from high-level waste and spent fuel disposal).

(3) Mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

For issues that meet the three Category 1 criteria, no additional plant-specific analysis is required in this SEIS unless new and significant information is identified.

Category 2 issues are those that do not meet one or more of the criteria of Category 1; therefore, additional plant-specific review for these issues is required.

In the GEIS, the staff assessed 92 environmental issues and determined that 69 qualified as Category 1 issues, 21 qualified as Category 2 issues, and 2 issues were not categorized. The two issues not categorized are environmental justice and chronic effects of electromagnetic fields. Environmental justice was not evaluated on a generic basis and must be addressed in a plant-specific supplement to the GEIS. Information on the chronic effects of electromagnetic fields was not conclusive at the time the GEIS was prepared.

Of the 92 issues, 11 are related only to refurbishment, 6 are related only to decommissioning, 67 apply only to operation during the renewal term, and 8 apply to both refurbishment and operation during the renewal term. A summary of the findings for all 92 issues in the GEIS is codified in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B.

1.2.2 License Renewal Evaluation Process

An applicant seeking to renew its operating license is required to submit an ER as part of its application. The license renewal evaluation process involves careful review of the applicant's ER and assurance that all new and potentially significant information not already addressed in or available during the GEIS evaluation is identified, reviewed, and assessed to verify the environmental impacts of the proposed license renewal.

In accordance with 10 CFR 51.53(c)(2) and (3), the ER submitted by the applicant must do the following:

- provide an analysis of the Category 2 issues in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, in accordance with 10 CFR 51.53(c)(3)(ii)
- discuss actions to mitigate any adverse impacts associated with the proposed action and environmental impacts of alternatives to the proposed action

In accordance with 10 CFR 51.53(c)(2), the ER does not need to do the following:

- consider the economic benefits and costs of the proposed action and alternatives to the proposed action except insofar as such benefits and costs are either (1) essential for making a determination regarding the inclusion of an alternative in the range of alternatives considered or (2) relevant to mitigation
- consider the need for power and other issues not related to the environmental effects of the proposed action and the alternatives
- discuss any aspect of the storage of spent fuel within the scope of the generic determination in 10 CFR 51.23(a) in accordance with 10 CFR 51.23(b)
- pursuant to 10 CFR 51.23(c)(3)(iii) and (iv), contain an analysis of any Category 1 issue unless there is significant new information on a specific issue

New and significant information is (1) information that identifies a significant environmental issue not covered in the GEIS and codified in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, or (2) information that was not considered in the analyses summarized in the GEIS and that leads to an impact finding that is different from the finding presented in the GEIS and codified in 10 CFR Part 51.

In preparing to submit its application to renew the IP2 and IP3 operating licenses, Entergy developed a process to ensure that (1) information not addressed in or available during the GEIS evaluation regarding the environmental impacts of license renewal for IP2 and IP3 would be properly reviewed before submitting the ER and (2) such new and potentially significant information related to renewal of the licenses for IP2 and IP3 would be identified, reviewed, and assessed during the period of NRC review. Entergy reviewed the Category 1 issues that appear in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, to verify that the conclusions of the GEIS remain valid with respect to IP2 and IP3. This review was performed by personnel from Entergy who were familiar with NEPA issues and the scientific disciplines involved in the preparation of a license renewal ER.

The NRC staff also has a process for identifying new and significant information. That process is described in detail in NUREG-1555, “Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal,” issued March 2000 (NRC 2000). The search for new information includes (1) review of an applicant’s ER and the process for discovering and evaluating the significance of new information, (2) review of records of public comments, (3) review of environmental quality standards and regulations, (4) coordination with Federal, State, Tribal, and local environmental protection and resource agencies, and (5) review of the technical literature. New information discovered by the NRC staff is evaluated for significance using the criteria set forth in the GEIS. For Category 1 issues where new and significant information is identified, reconsideration of the conclusions for those issues is limited in scope to the assessment of the relevant new and significant information; the scope of the assessment does not include other facets of the issue that are not affected by the new information.

Chapters 3 through 7 discuss the environmental issues considered in the GEIS that are applicable to IP2 and IP3. At the beginning of the discussion of each set of issues, there is a table that identifies the issues to be addressed and lists the sections in the GEIS where the issue is discussed. Category 1 and Category 2 issues are listed in separate tables. For

Category 1 issues for which there is no new and significant information, the table is followed by a set of short paragraphs that state the GEIS conclusion codified in Table B-1 of 10 CFR Part 51, Subpart A, Appendix B, followed by the staff's analysis and conclusion. For Category 2 issues, in addition to the list of GEIS sections where the issue is discussed, the tables list the subparagraph of 10 CFR 51.53(c)(3)(ii) that describes the analysis required and the SEIS sections where the analysis is presented. The SEIS sections that discuss the Category 2 issues are presented immediately following the table.

The NRC prepares an independent analysis of the environmental impacts of license renewal and compares these impacts with the environmental impacts of alternatives. The evaluation of the Entergy license renewal application began with the publication of a notice of acceptance for docketing, notice of opportunity for a hearing, and notice of intent to prepare an EIS and conduct scoping in the *Federal Register,* May 11, 2007 (NRC 2007; 72 FR 26850). A public scoping meeting was held on June 27, 2007, in Cortlandt Manor, New York. Comments received during the scoping period have been summarized by the NRC in a summary report issued in December of 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML083360115). The NRC staff adopts by reference the scoping summary report in Part 1 of Appendix A to this SEIS.

The NRC staff followed the review guidance contained in NUREG-1555, Supplement 1 (NRC 2000). The NRC staff, and the contractor retained to assist the NRC staff, visited the IP2 and IP3 site on September 11 and 12, 2007, and again on September 24 and 25, 2007, to gather information and to become familiar with the site and its environs. The NRC staff also reviewed the comments received during scoping and consulted with Federal, State, Tribal, regional, and local agencies. A list of the organizations consulted is provided in Appendix D. Other documents related to IP2 and IP3 were reviewed and are referenced within this SEIS.

This SEIS presents the NRC staff's analysis that considers and weighs the environmental effects of the proposed renewal of the operating licenses for IP2 and IP3, the environmental impacts of alternatives to license renewal, and mitigation measures available for avoiding adverse environmental effects. Chapter 9, "Summary and Conclusions," provides the NRC staff's recommendation to the Commission on whether the adverse environmental impacts of license renewal are so great that preserving the option of license renewal for energy-planning decision makers would be unreasonable.

The NRC staff issued a draft SEIS in December 2008. A 75-day comment period began on the date of publication of the U.S. Environmental Protection Agency Notice of Filing of the draft SEIS to allow members of the public to comment on the preliminary results of the NRC staff's review. During this comment period, a public meeting was held in Cortlandt Manor, New York, on February 12, 2009. During this meeting, the NRC staff described the preliminary results of the NRC environmental review and answered questions to provide members of the public with information to assist them in formulating their comments. The comments received, and the NRC staff's responses to those comments, are presented in Appendix A to this SEIS.

1.3 The Proposed Federal Action

The proposed Federal action is renewal of the operating licenses for IP2 and IP3 (IP1 was shut down in 1974). IP2 and IP3 are located on approximately 239 acres of land on the east bank of the Hudson River at Indian Point, Village of Buchanan, in upper Westchester County, New York, approximately 24 miles north of the New York City boundary line. The facility has two Westinghouse pressurized-water reactors. IP2 is currently licensed to generate 3216 megawatts thermal (MW(t)) (core power) with a design net electrical capacity of 1078 megawatts electric (MW(e)). IP3 is currently licensed to generate 3216 MW(t) (core power) with a design net electrical capacity of about 1080 MW(e). IP2 and IP3 cooling is provided by water from the Hudson River to various heat loads in both the primary and secondary portions of the plants. The current operating license for IP2 expires on September 28, 2013, and the current operating license for IP3 expires on December 12, 2015. By letter dated April 23, 2007, Entergy submitted an application to the NRC (Entergy 2007a) to renew the IP2 and IP3 operating licenses for an additional 20 years.

1.4 The Purpose and Need for the Proposed Action

Although a licensee must have a renewed license to operate a reactor beyond the term of the existing operating license, the possession of that license is just one of a number of conditions that must be met for the licensee to continue plant operation during the term of the renewed license. Once an operating license is renewed, State regulatory agencies and the owners of the plant will ultimately decide whether the plant will continue to operate based on factors such as the need for power or matters within the State's jurisdiction—including acceptability of water withdrawal, consistency with State water quality standards, and consistency with State coastal zone management plans—or the purview of the owners, such as whether continued operation makes economic sense.

Thus, for license renewal reviews, the NRC has adopted the following definition of purpose and need (GEIS Section 1.3):

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and where authorized, Federal (other than NRC) decision makers.

This definition of purpose and need reflects the Commission's recognition that, unless there are findings in the safety review required by the Atomic Energy Act of 1954, as amended, or findings in the NEPA environmental analysis that would lead the NRC to reject a license renewal application, the NRC does not have a role in the energy-planning decisions of State regulators and utility officials as to whether a particular nuclear power plant should continue to operate. From the perspective of the licensee and the State regulatory authority, the purpose of renewing the operating licenses is to maintain the availability of the nuclear plant to meet system energy requirements beyond the current term of the plant's licenses.

1.5 Compliance and Consultations

Entergy is required to hold certain Federal, State, and local environmental permits, as well as meet relevant Federal and State statutory requirements. In its ER, Entergy provided a list of the authorizations from Federal, State, and local authorities for current operations as well as environmental approvals and consultations associated with the IP2 and IP3 license renewals. Authorizations and consultations relevant to the proposed operating license renewal actions are included in Appendix E.

The NRC staff has reviewed Entergy's list and consulted with the appropriate Federal, State, Tribal, and local agencies to identify any compliance or permit issues or significant environmental issues of concern to the reviewing agencies. These agencies did not identify any new and significant environmental issues. The ER states that Entergy is in compliance with applicable environmental standards and requirements for IP2 and IP3. The NRC staff has not identified any environmental issues that are both new and significant.

Two state-level issues, consistency with State water quality standards, and consistency with State coastal zone management plans, have yet to be resolved. On April 2, 2010, the New York State Department of Environmental Conservation (NYSDEC) issued a Notice of Denial regarding the Clean Water Act Section 401 Water Quality Certification. Entergy has since requested a hearing on the issue, and the matter will be decided through NYSDEC's hearing process.

1.6 References

10 CFR Part 51. *Code of Federal Regulations*, Title 10, *Energy,* Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

10 CFR Part 54. *Code of Federal Regulations*, Title 10, *Energy,* Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants."

40 CFR Part 1508. *Code of Federal Regulations*, Title 40, *Protection of Environment*, Part 1508, "Terminology and Index."

Entergy Nuclear Operations, Inc. (Entergy). 2007a. "Indian Point, Units 2 & 3, License Renewal Application." April 23, 2007. ADAMS Accession No. ML071210512.

Entergy Nuclear Operations, Inc. (Entergy). 2007b. "Applicant's Environment Report, Operating License Renewal Stage." (Appendix E to "Indian Point, Units 2 & 3, License Renewal Application".) April 23, 2007. ADAMS Accession No. ML071210530.

Entergy Nuclear Operations, Inc. (Entergy). 2007c. Letter from Fred Dacimo, Indian Point Energy Center Site Vice President, to the U.S. NRC regarding Indian Point Nuclear Generating Units Nos. 2 and 3. Docket Nos. 50-247, 50-286. May 3, 2007. ADAMS Accession No. ML071280700.

National Environmental Policy Act of 1969 (NEPA). 42 *United States Code* 4321, *et seq*.

U.S. Nuclear Regulatory Commission (NRC). 1996. "Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants." NUREG-1437, Volumes 1 and 2, Washington, DC.

U.S. Nuclear Regulatory Commission (NRC). 1999. "Generic Environmental Impact Statement for License Renewal of Nuclear Plants Main Report," Section 6.3, "Transportation," Table 9.1, "Summary of Findings on NEPA Issues for License Renewal of Nuclear Power Plants." NUREG-1437, Volume 1, Addendum 1, Washington, DC.

U.S. Nuclear Regulatory Commission (NRC). 2000. "Standard Review Plans for Environmental Reviews for Nuclear Power Plants, Supplement 1: Operating License Renewal." NUREG-1555, Supplement 1, Washington, DC.

U.S. Nuclear Regulatory Commission (NRC). 2007. "Entergy Nuclear Operations, Inc.; Notice of Receipt and Availability of Application for Renewal of Indian Point Nuclear Generating Unit Nos. 2 and 3; Facility Operating License Nos. DPR-26 and DPR-64 for an Additional 20-Year Period." *Federal Register*, Volume 72, Number 91, p. 26850. May 11, 2007.

U.S. Nuclear Regulatory Commission (NRC). 2009. "Summary Report: Indian Point Nuclear Generating Station Unit Nos. 2 and 3." Washington, DC.

2.0 DESCRIPTION OF NUCLEAR POWER PLANT AND SITE AND PLANT INTERACTION WITH THE ENVIRONMENT

Indian Point Nuclear Generating Unit Nos. 2 and 3 (IP2 and IP3) are located on approximately 239 acres (97 hectares (ha)) of land in the Village of Buchanan in upper Westchester County, New York. The facility is on the eastern bank of the Hudson River at river mile (RM) 43 (river kilometer (RKM) 69) about 2.5 miles (mi) (4.0 kilometers (km)) southwest of Peekskill, the closest city, and about 24 mi (39 km) north of New York City.

Both IP2 and IP3 use Westinghouse pressurized-water reactors and nuclear steam supply systems (NSSSs). Primary and secondary plant cooling is provided by a once-through cooling water intake system that supplies cooling water from the Hudson River. The plant and its surroundings are described in Section 2.1, and the plant's interaction with the environment is presented in Section 2.2.

Indian Point Nuclear Generating Station Unit No. 1 (IP1, now permanently shut down) shares the site with IP2 and IP3. IP1 is located between IP2 and IP3. IP1 was shut down on October 31, 1974, and is in a safe storage condition (SAFSTOR) awaiting final decommissioning.

2.1 Plant and Site Description and Proposed Plant Operation During the Renewal Term

The entirety of the Indian Point site is surrounded by a perimeter fence, establishing an area known as the "owner controlled area." Security personnel patrol all roads within the site. Within the fence lies an area of greater security known as the "protected area." The protected area is more heavily guarded and controlled by a second fence and an intrusion detection system. The protected area is accessible only through manned security buildings and gates requiring electronic identification. In addition, spaces within the protected area designated as "vital areas" have additional access controls (Entergy 2006a).

The area within a 6-mi (10-km) radius of the IP2 and IP3 site includes the Village of Buchanan, located about 0.5 mi (0.8 km) southeast of the site, and the City of Peekskill, located 2.5 mi (4.0 km) northeast. In the 2000 U.S. census, populations of these towns were 2,189 and 22,441, respectively. The largest town within a 6-mi (10-km) radius of the site is Haverstraw, New York, with a 2000 population of approximately 33,811 (USCB 2000). Haverstraw is located to the southwest on the western bank of the Hudson River. Several other small villages, including Verplanck and Montrose, lie within a 6-mi (10-km) radius of the IP2 and IP3 site. The area within a 6-mi (10-km) radius of the site also includes several thousand acres of the Bear Mountain State Park located across the Hudson River, the nearly 2000-acre (809-ha) Camp Smith (a New York State military reservation) located 2.3 mi (3.7 km) north of the site, and a portion—about 2000 acres (809 ha)—of the U.S. Military Academy at West Point.

The area within a 50-mi (80-km) radius of the site includes parts of New York, New Jersey, and Connecticut. New York City, located approximately 24 mi (39 km) south of the plant, is the largest city within 50 mi (80 km) with a 2006 population of approximately 8,214,426 (USCB 2006). Other population centers include Danbury and Stamford, Connecticut; Newark, New Jersey; and Poughkeepsie, New York. The area within a 50-mi (80-km) radius also includes all of the U.S. Military Academy at West Point, located 7.5 mi (12 km) northwest of the site, and the Picatinny Arsenal, located 35.5 mi (57.1 km) southwest of the site in New Jersey (Entergy 2007a).

The region surrounding the Indian Point site has undulating terrain with many peaks and valleys. Dunderberg Mountain lies on the western side of the Hudson River 1 mi (1.6 km) northwest of the site. North of Dunderberg Mountain, high grounds reach an elevation of 800 feet (ft) (244 meters (m)) above the western bank of the Hudson River. To the east of the site lie the Spitzenberg and Blue Mountains. These peaks are about 600 ft (183 m) in height. There is also a weak, poorly defined series of ridges that run in a north-northeast direction east of IP2 and IP3. The Timp Mountains are west of the facility. These mountains rise to a maximum elevation of 846 ft (258 m). Elevations south of the site are 100 ft (30.5 m) or less and gradually slope toward the Village of Verplanck (Entergy 2007a).

The site location and features within 50-mi (80-km) and 6-mi (10-km) radii are illustrated in Figures 2-1 and 2-2, respectively.

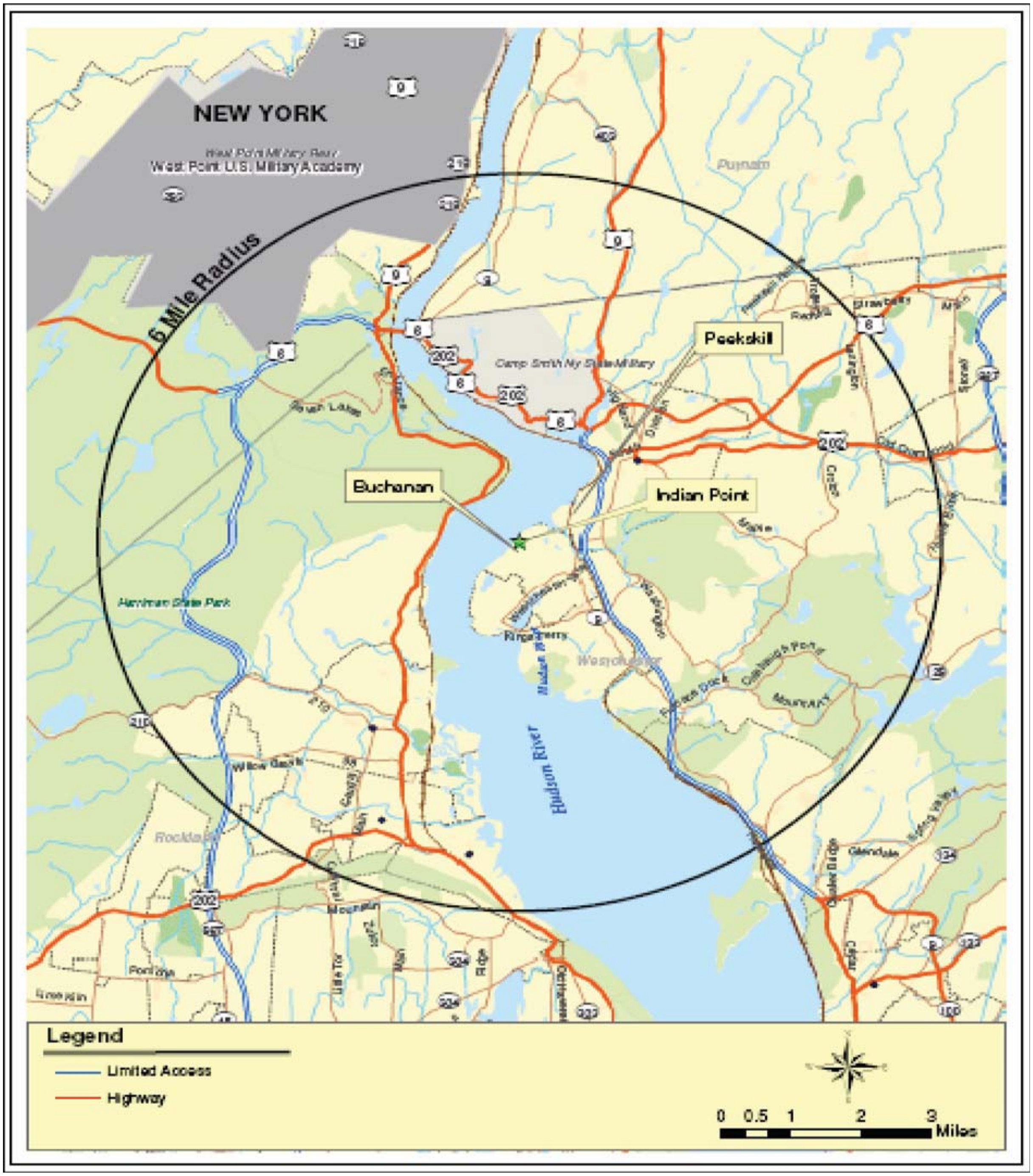
2.1.1 External Appearance and Setting

As discussed in Section 2.1, the immediate area around the Indian Point site is completely enclosed by a security fence. Access to the site is controlled at a security gate on Broadway (main entrance). Controlled access to the site is also available using the existing wharf on the Hudson River. The wharf is used to receive heavy equipment shipped to the site by barge. There are no rail lines that service the site. The nearest residence is less than 0.5 mi (0.8 km) from IP2 and IP3 and about 100 m (328 ft) beyond the site boundary to the east-southeast (ENN 2007a).

The facility can be seen easily from the river. Surrounding high ground and vegetation make it difficult to see the facility from beyond the security fence on land, except from Broadway. The 334-ft (102-m) tall superheater stack for IP1, the 134-ft (40.8-m) tall IP2 and IP3 turbine buildings, and the 250-ft (76.2-m) tall reactor containment structures are the tallest structures on the site (Entergy 2007a).

Source: Entergy 2007a

Figure 2-1. Location of IP2 and IP3, 50-mi (80-km) radius



Source: Entergy 2007a

Figure 2-2. Location of IP2 and IP3, 6-mi (10-km) radius

Other visible IP2 and IP3 site features include auxiliary buildings, intake structures, the discharge structure, electrical switchyard, and associated transmission lines (Entergy 2007a). The site boundary and general facility layout are depicted in Figures 2-3 and 2-4, respectively.

The facility contains several stationary bulk petroleum and chemical storage tanks. Bulk chemical storage tanks are registered with the New York State Department of Environmental Conservation (NYSDEC) via Hazardous Substance Bulk Storage Registration Certificates. The tanks and their contents are managed in accordance with the NYSDEC Chemical Bulk Storage Regulations. The IP2 bulk petroleum storage tanks are registered with NYSDEC via a Major Oil Storage Facility License, while the IP3 tanks are registered with the Westchester County Department of Health via a Petroleum Bulk Storage Registration Certificate.

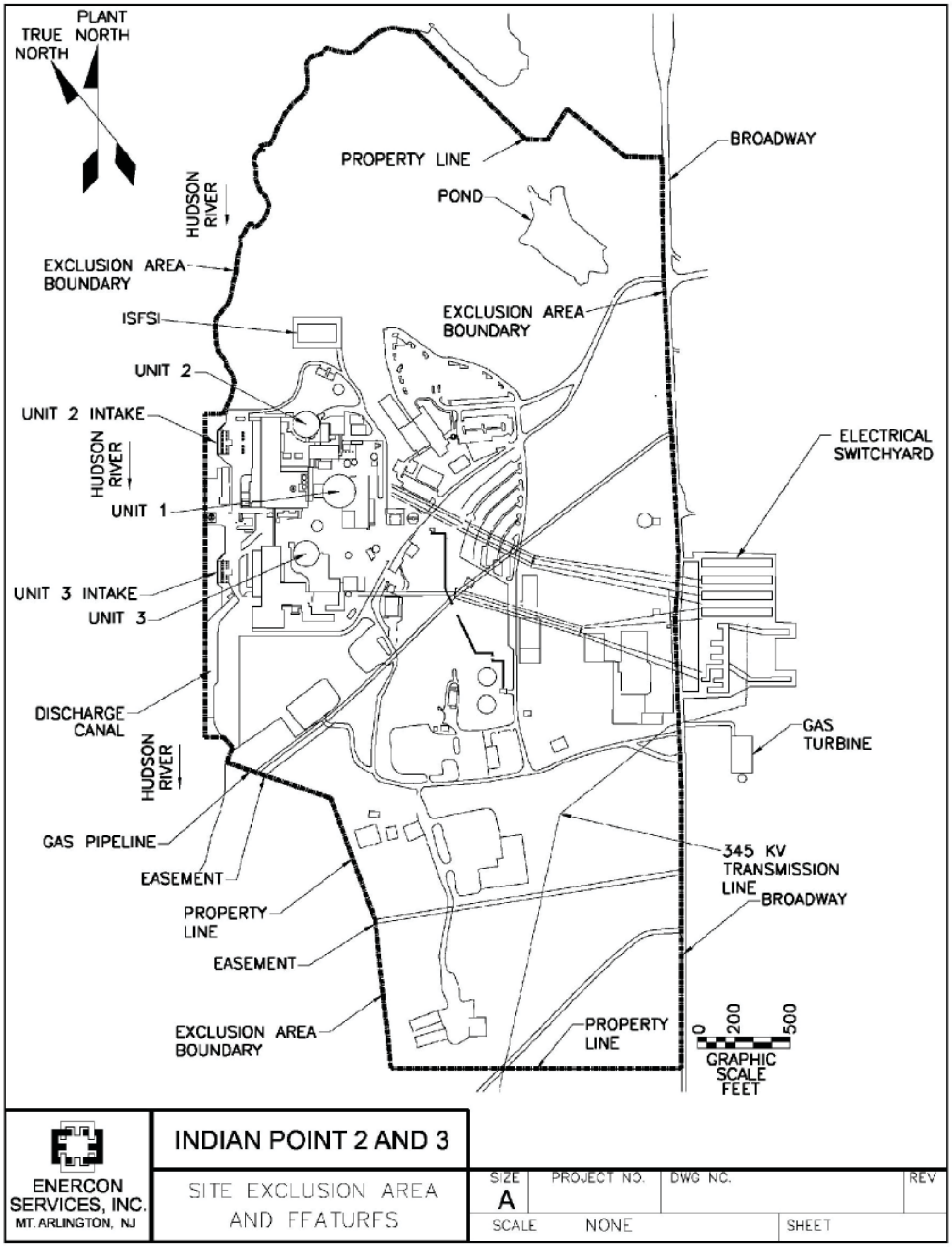
IP2 and IP3 each use two main transformers to increase voltage from their respective turbine generators. The transformers increase generator output from 22 kilovolts (kV) to 345 kV. Power is then delivered to the Consolidated Edison Company (Con Edison) transmission grid by way of two double-circuit 345-kV lines. These lines connect the main onsite transformers to the offsite Buchanan substation which is located immediately across Broadway near the main entrance to the site. The lines that connect the transformers to the substation are about 2000 ft (610 m) in length and, except for the terminal 100 ft where they cross over Broadway (a public road) and enter the substation, lines are located within the site boundary (Entergy 2007a). The 345-kV transmission lines that distribute power from the substation are shown in Figure 2-3.

2.1.2 Reactor Systems

As noted in Section 2.0, both IP2 and IP3 employ Westinghouse pressurized-water reactors and four-loop NSSSs. Each NSSS loop contains a reactor coolant pump and a steam generator. The reactor coolant system transfers the heat generated in the reactor core to the steam generators, which produce steam to drive the electrical turbine generators (Entergy 2007b).

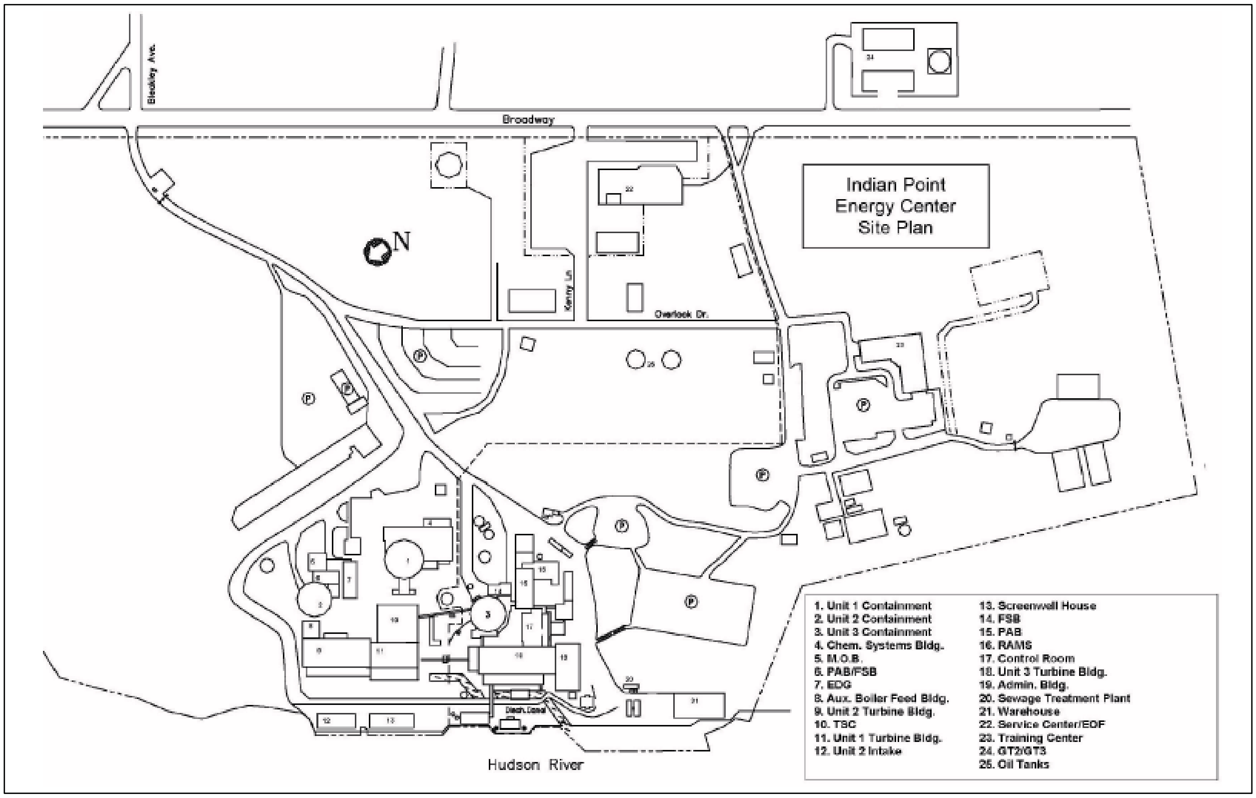
IP2 is currently licensed to operate at a core power of 3216 megawatt thermal (MW(t)), which results in a turbine generator output of approximately 1078 megawatt electric (MW(e)). IP3 is currently licensed to operate at 3216 MW(t), which results in a turbine generator output of approximately 1080 MW(e). IP2 and IP3 have similar designs with independent functional and safety systems. The units share the following systems (Entergy 2007b):

- discharge canal, outfall structure, and associated instrumentation and sampling systems
- electrical supplies and interties
- station air interties
- demineralized water, condensate makeup, and hydrogen interties
- city water and fire protection interties
- dedicated No. 2 fuel oil systems for diesel generators
- sewage treatment facility
- auxiliary steam system intertie



1 Source: Entergy 2007a

2 **Figure 2-3. IP2 and IP3 property boundaries and environs**



Source: Entergy 2007a

Figure 2-4. IP2 and IP3 site layout

- service boiler fuel oil supply system
- liquid steam generator blowdown, radioactive waste processing, and discharge (to IP1) facilities

The nuclear fuel for IP2 and IP3 is made of low-enriched (less than 5 percent by weight uranium-235) uranium dioxide pellets stacked in pre-pressurized tubes made from zircaloy or ZIRLO. The fuel tube rods have welded end plugs. Based on core design values, IP2 and IP3 operate at an individual rod average fuel burnup of no more than 62,000 megawatt-days per metric ton of heavy metal. This ensures that peak burnups remain within the acceptable limits specified in Table B-1 of Appendix B, “Environmental Effect of Renewing the Operating License of a Nuclear Power Plant,” to Subpart A, “National Environmental Policy Act—Regulations Implementing Section 102(2),” of Title 10, Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” of the *Code of Federal Regulations* (10 CFR Part 51) (Entergy 2006a). Reactor fuel that has exhausted a certain percentage of its fissile uranium content so that it is no longer an efficient fissile fuel source is referred to as spent fuel. The spent fuel is removed from the reactor core and replaced by fresh fuel during routine refueling outages. Refueling outages at IP2 and IP3 typically occur every 24 months. The spent fuel assemblies are then stored in the spent fuel pool (SFP) in the fuel storage building.

Located north of IP2 inside the protected area fence, the spent fuel will be transferred to dry storage (Entergy 2007a) at an onsite independent spent fuel storage installation (ISFSI). The first fuel was moved from IP2 to the ISFSI pad, which is approximately 100 ft (30.5 m) wide by 200 ft (61.0 m) long, during the first week of January 2008 (Entergy 2008).

IP2 and IP3 containment buildings completely enclose each unit's reactor and the reactor coolant system. The containment buildings are designed to minimize leakage of radioactive materials to the environment if a design-basis loss-of-coolant accident were to occur. The containment structures have an outer shell of reinforced concrete and an inner steel liner (Entergy 2007b).

The IP2 containment building contains a containment purge supply and exhaust system and a containment pressure relief system. The purge supply and exhaust system provides fresh air to the containment and filters air released from containment. The containment pressure relief system regulates normal pressure in the containment during reactor power operation (Entergy 2007b).

The IP3 containment building contains a vapor containment heating and ventilation purge system and a vapor containment pressure relief system. The heating and ventilation system regulates fresh air flow into the containment and filters air before its dispersion to the environment. The vapor containment pressure relief system regulates pressure changes in containment during reactor power operation (Entergy 2007b).

2.1.3 Cooling and Auxiliary Water Systems

IP2 and IP3 have once-through condenser cooling systems that withdraw water from and discharge it to the Hudson River. The systems are described in detail in the IP2 and IP3 environmental report (ER) (Entergy 2007a). This section provides a general description based on the information provided by Entergy in the ER.

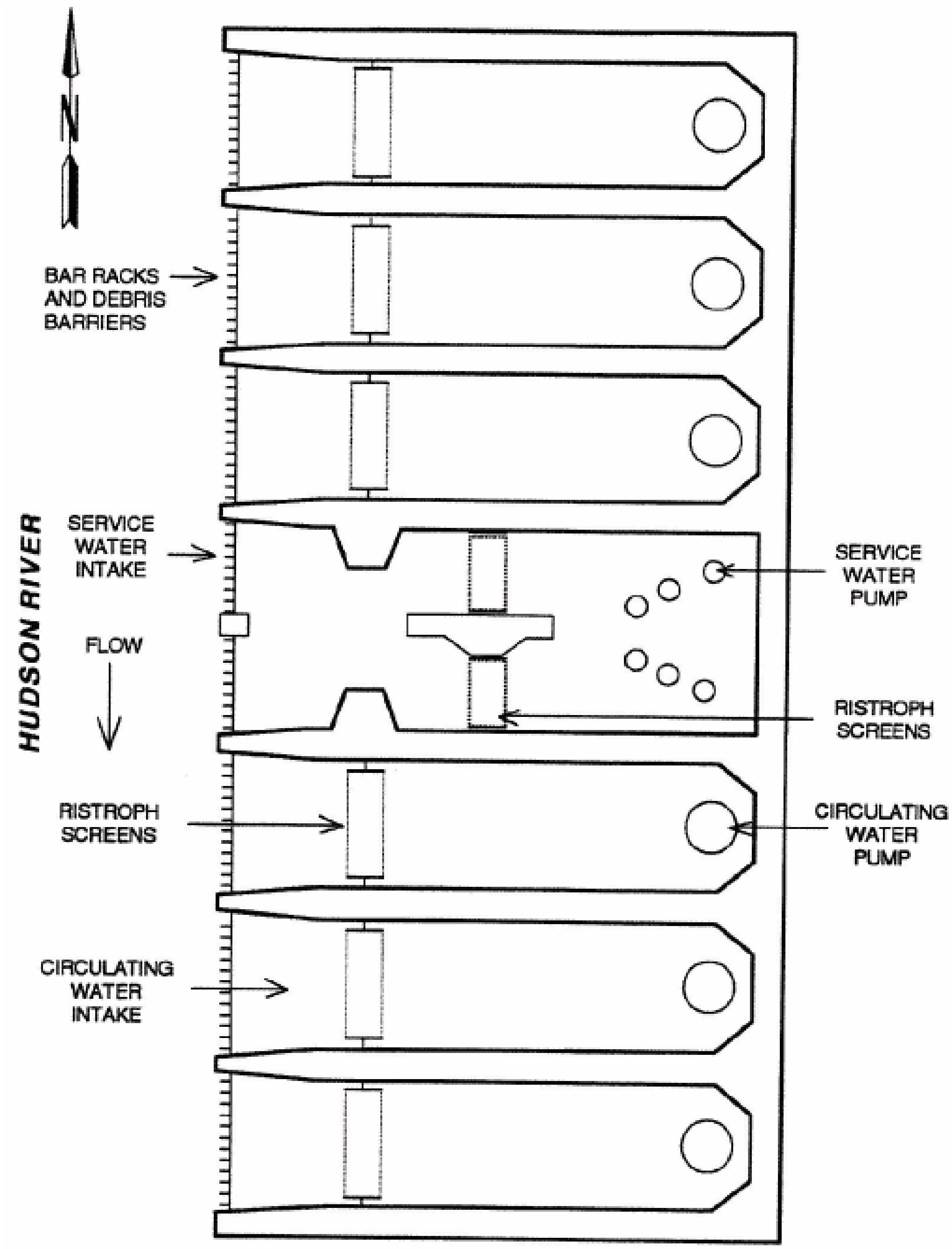
The maximum design flow rate for each cooling system is approximately 1,870 cubic feet per second (cfs), 840,000 gallons per minute (gpm), or 53.0 cubic meters per second (m^3/s).

Two shoreline intake structures—one for each unit—are located along the Hudson River on the northwestern edge of the site and provide cooling water to the site. Each structure consists of seven bays, six for circulating water and one for service water. The IP2 intake structure has seven independent bays, while the IP3 intake structure has seven bays that are served by a common plenum. In each structure, six of the seven bays contain cooling water pumps, and the seventh bay contains service/auxiliary water pumps. Before it is pumped to the condensers, river water passes through traveling screens in the intake structure bays to remove debris and fish.

The six IP2 circulating water intake pumps are dual-speed pumps. When operated at high speed (254 revolutions per minute (rpm)), each pump provides 312 cfs (140,000 gpm; 8.83 m^3/s) and a dynamic head of 21 ft (6.4 m). At low speed (187 rpm), each pump provides 187 cfs (84,000 gpm; 5.30 m^3/s) and a dynamic head of 15 ft (4.6 m). The six IP3 circulating water intake pumps are variable-speed pumps. When operated at high speed (360 rpm), each pump provides 312 cfs (140,000 gpm; 8.83 m^3/s); at low speed, it provides a dynamic head of 29 ft (8.8 m) and 143 cfs (64,000 gpm; 4.05 m^3/s). In accordance with the October 1997 Consent Order (issued pursuant to the Hudson River Settlement Agreement; see

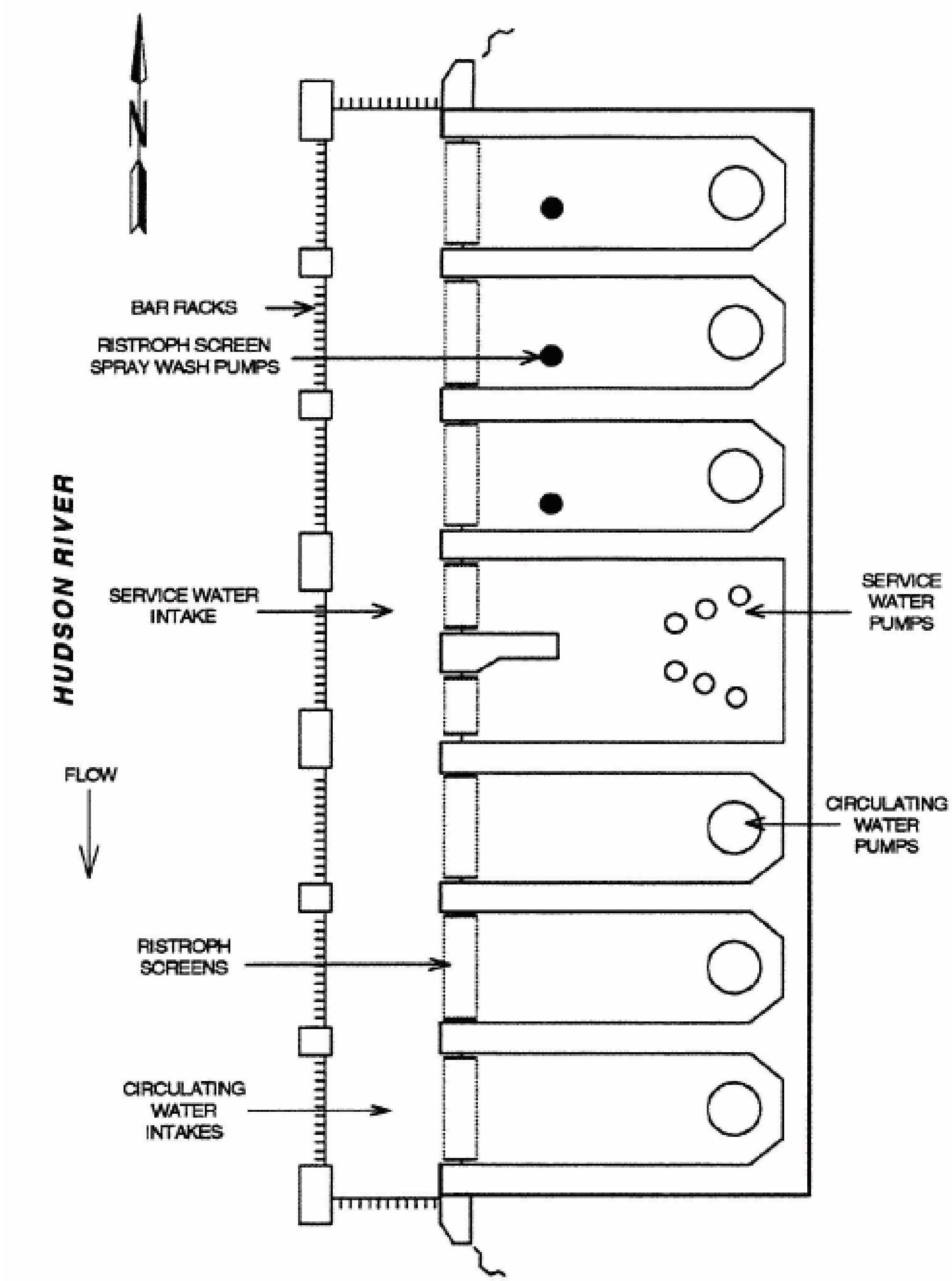
Section 2.2.5.3 for more information), the applicant adjusts the speed of the intake pumps to mitigate impacts to the Hudson River.

Each coolant pump bay is about 15 ft (4.6 m) wide at the entrance, and the bottom is located 27 ft (8.2 m) below mean sea level. Before entering the intake structure bays, water flows under a floating debris skimmer wall, or ice curtain, into the screen wells. This initial screen keeps floating debris and ice from entering the bay. At the entrance to each bay, water also passes through a subsurface bar screen to prevent additional large debris from becoming entrained in the cooling system. Next, smaller debris and fish are screened out using modified Ristroph traveling screens. Figures 2-5 through 2-8 illustrate the IP2 and IP3 intake structures and bays.



Source: Entergy 2007a

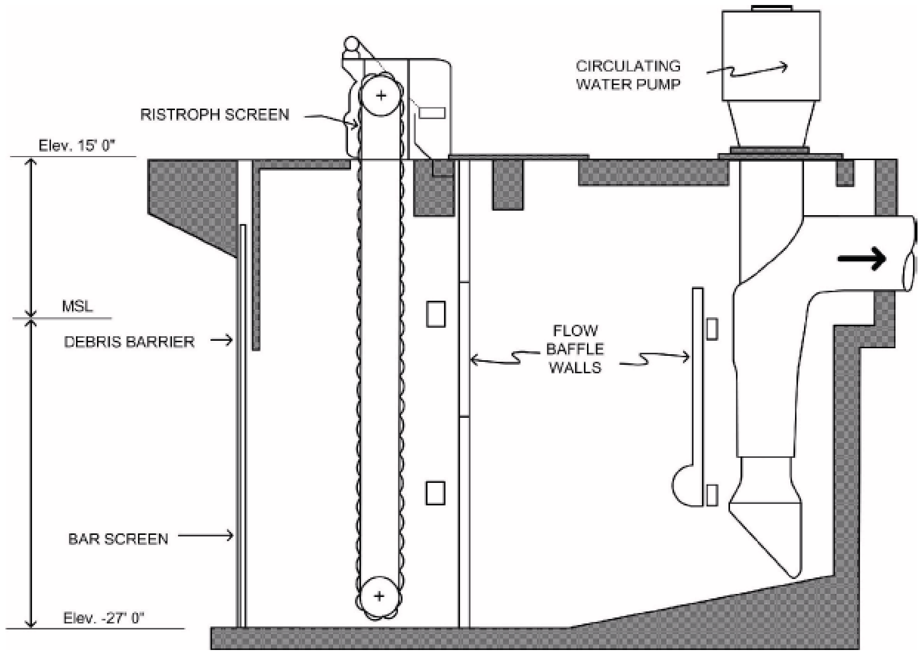
Figure 2-5. IP2 intake structure



1 Source: Entergy 2007a

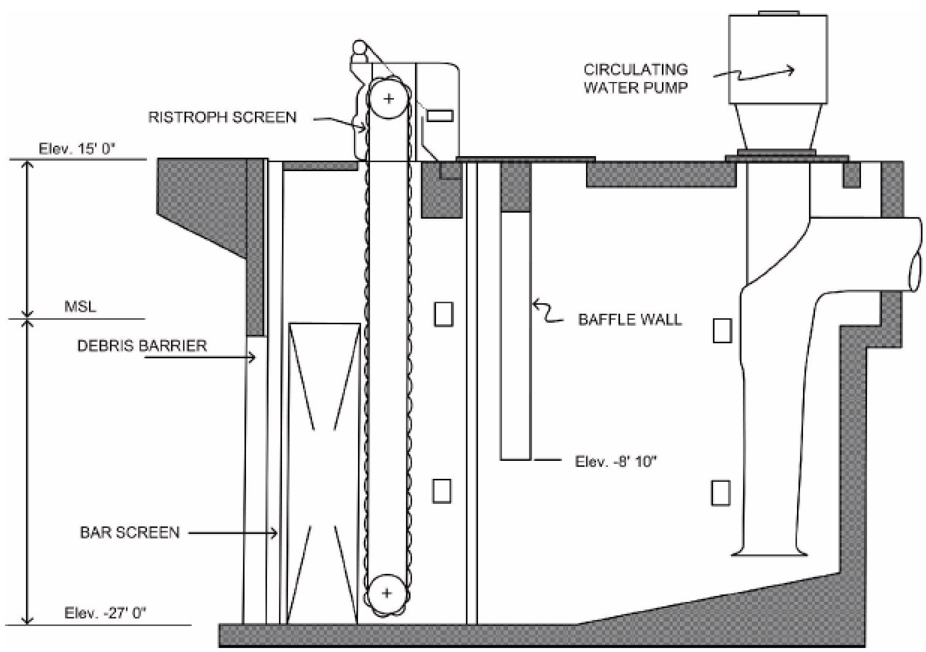
2 **Figure 2-6. IP3 intake structure**

3



Source: Entergy 2007a

Figure 2-7. IP2 intake system



Source: Entergy 2007a

Figure 2-8. IP3 intake system

The modified Ristroph traveling screens consist of a series of panels that rotate continuously. As each screen panel rotates out of the intake bay, impinged fish are retained in water-filled baskets at the bottom of each panel and are carried over the headshaft, where they are washed out onto a mesh using low-pressure sprays from the rear side of the machine. The 0.25-by-0.5-inch (in.) (0.635-by-1.27 centimeters (cm)) mesh is smooth to minimize fish abrasion by the mesh. Two high-pressure sprays remove debris from the front side of the machine after fish removal.

From the mesh, fish return to the river via a 12-in. (30-cm) diameter pipe. For IP2, the pipe extends 200 ft (61.0 m) into the river north of the IP2 intake structure and discharges at a depth of 35 ft (11 m). The IP3 fish return system discharges to the river by the northwest corner of the discharge canal.

After moving through the condensers, cooling water is discharged to the discharge canal via a total of six 96-in. (240-cm) diameter pipes. The cooling water enters below the surface of the 40-ft (12-m) wide canal. The canal discharges to the Hudson River through an outfall structure located south of IP3 at about 4.5 feet per second (fps) (1.4 meters per second (mps)) at full flow. As the discharged water enters the river, it passes through 12 discharge ports (4-ft by 12-ft each (1-m by 3.7-m)) across a length of 252 ft (76.8 m) about 12 ft (3.7 m) below the surface of the river. The increased discharge velocity, about 10 fps (3.0 mps), enhances mixing to minimize thermal impact.

The discharged water is at an elevated temperature, and therefore, some water is lost because of evaporation. Based on conservative estimates, the staff of the U.S. Nuclear Regulatory Commission (NRC) estimates that this induced evaporation resulting from the elevated discharge temperature would be less than 60 cfs (27,000 gpm or 1.7 m^3/s). This loss is about 0.5 percent of the annual average downstream flow of the Hudson River, which is more than 9000 cfs (4 million gpm or 255 m^3/s). The average cooling water transient time ranges from 5.6 minutes for the IP3 cooling water system to 9.7 minutes for the IP2 system.

Auxiliary water systems for service water are also provided from the Hudson River via the dedicated bays in the IP2 and IP3 intake structures. The primary role of service water is to cool components (e.g., pumps) that generate heat during operation. Secondary functions of the service water include the following:

- protect equipment from potential contamination from river water by providing cooling to intermediate freshwater systems
- provide water for washing the modified Ristroph traveling screens
- provide seal water for the main circulating water pumps

The IP2 service water bay has six identical centrifugal sump-type pumps, each having a capacity of at least 11 cfs (5000 gpm; 0.31 m^3/s) at 220-ft (67-m) total design head. The IP3 service water bay also has 6 similar pumps, each rated at 13 cfs (6000 gpm; 0.378 m^3/s) and 195-ft (59.4-m) total design head. The average approach velocity at the entrance to each service water bay when all pumps are operating is about 0.2 fps (0.06 mps). Each service water bay also contains two Ristroph screens to reduce fish entrainment.

Additional service water is provided to the nonessential service water header for IP2 through the IP1 river water intake structure. The IP1 intake includes four intake bays each with a coarse bar screen and a single 0.125-in. (0.318-cm) mesh screen. The intake structure contains two 36-cfs (16,000-gpm; 1.0-m^3/s) spray wash pumps. The screens are washed automatically and materials are sluiced to the Hudson River.

2.1.4 Radioactive Waste Management Systems and Effluent Control Systems

IP2 and IP3 radioactive waste systems are designed to collect, treat, and dispose of radioactive and potentially radioactive wastes that are byproducts of plant operations. These byproducts include activation products resulting from the irradiation of reactor water and impurities therein (principally metallic corrosion products) and fission products resulting from their migration through the fuel cladding or uranium contamination within the reactor coolant system. Operating procedures for radioactive waste systems are designed to ensure that radioactive wastes are safely processed and discharged from the plant within the limits set forth in 10 CFR Part 20, “Standards for Protection against Radiation”; Appendix I, “ Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion ‘As Low as is Reasonably Achievable’ for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents,” to 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities”; the plant’s technical specifications; and the IP2 and IP3 Offsite Dose Calculation Manual (ODCM) (Entergy 2007a).

Radioactive wastes resulting from plant operations are classified as liquid, gaseous, or solid. Liquid radioactive wastes are generated from liquids received directly from portions of the reactor coolant system or were contaminated by contact with liquids from the reactor coolant system. Gaseous radioactive wastes are generated from gases or airborne particulates vented from reactor and turbine equipment containing radioactive material. Solid radioactive wastes are solids from the reactor coolant system, solids that came into contact with reactor coolant system liquids or gases, or solids used in the reactor coolant system or steam and power conversion system operation or maintenance.

As indicated in Section 2.1.2, reactor fuel that has exhausted a certain percentage of its fissile uranium content is referred to as spent fuel. Spent fuel assemblies are removed from the reactor core and replaced with fresh fuel assemblies during routine refueling outages, typically every 24 months. Spent fuel assemblies are then stored for a period of time in the Spent Fuel Pit (SFP) in the fuel storage building and may later be transferred to dry storage at a recently constructed onsite ISFSI. Entergy has constructed an ISFSI in the north end of the IP2 and IP3 site in an area that was previously undeveloped. The facility is planned to hold up to 78 Holtec International HI-STORM 100S(B) casks (Entergy 2007a).

The IP2 and IP3 ODCM contains the methodology and parameters used to calculate offsite doses resulting from radioactive gaseous and liquid effluents and the gaseous and liquid effluent monitoring alarm and trip setpoints used to verify that radioactive discharges meet regulatory limits. The ODCM also contains the radioactive effluent controls and radiological environmental monitoring activities and descriptions of the information that should be included in the annual Radiological Environmental Operating Report and annual Radioactive Effluent Release Report (Entergy 2007a).

2.1.4.1 Liquid Waste Processing Systems and Effluent Controls

The liquid waste processing system collects, holds, treats, processes, and monitors all liquid radioactive wastes for reuse or disposal.

IP2

In IP2, the liquid waste holdup system collects low-level radioactive waste from throughout the facility and holds the waste until it can be processed. During normal plant operations the system receives input from numerous sources, such as equipment drains and leak lines, chemical laboratory drains, decontamination drains, demineralizer regeneration, reactor coolant loops and reactor coolant pump secondary seals, valve and reactor vessel flange leak lines, and floor drains. Liquid waste is divided into two general classifications—high-quality liquid waste from the reactor coolant drain tank and routine liquid waste from the waste holdup tank which contains reactor coolant. The IP2 liquid wastes are transferred from the waste holdup tank to the IP1 waste collection system (described later in this section). The liquid waste can also be transferred from the waste holdup tank to the waste condensate tank, where its radioactivity can be analyzed to determine whether the waste is acceptable for discharge into the condenser circulating water and into the Hudson River.

In the event of primary reactor coolant water (radioactive) leakage into the secondary-side water (nonradioactive) system, potentially contaminated water that collects in the secondary-side drains may be collected and sent to a collection point in the auxiliary boiler feedwater building for eventual processing.

IP3

In IP3, the liquid waste holdup system collects low-level radioactive waste from throughout the facility and holds the waste until it can be processed. During normal plant operations, the system receives input from numerous sources, such as equipment drains and leak lines, radioactive chemical laboratory drains, decontamination drains, demineralizer regeneration, reactor coolant loops and reactor coolant pump secondary seals, valve and reactor vessel flange leak-offs, and floor drains. The system consists of three tanks—a 24,500 gallon (gal) (92,700 liter (L)) waste holdup tank located in the waste holdup pit, and the two 62,000 gal (235,000 L) waste holdup tanks located in the liquid radioactive waste storage facility.

The liquid radioactive waste storage facility, which houses the 62,000 gal (235,000 L) waste tanks, is an underground concrete structure. The 62,000 gal (235,000 L) tanks are supported on concrete piers. The building is supported on hard rock. The foundation consists of a rigid 2 in. (5.0 cm) thick slab that is waterproofed. The reinforced concrete walls of the building are also waterproofed. The roof is made of 3 in. (7.6 cm) reinforced concrete poured on a steel deck and beam system.

When the waste has been sampled and analyzed and found to be acceptable for discharge, it is pumped from the waste holdup tank to the monitor tanks. When one monitor tank is filled, it is isolated, and the waste liquid is recirculated and sampled for radioactive and chemical analysis while the second tank is in service accumulating waste. If the waste material in the filled monitor tank meets release standards, the waste liquid is pumped to the service water discharge for release into the Hudson River. If it does not meet applicable release standards, it is returned to the waste holdup tanks for additional processing. Entergy performs radioactive and chemical analyses to determine the amount of radioactivity released. There is also a radiation monitor which provides surveillance over the operation to ensure that the discharge is within applicable radiation standards. If the radioactivity in the liquid waste being discharged exceeds the radiation standard, the discharge is terminated.

IP1

Radioactive waste storage and processing facilities located in IP1 provide additional waste processing services for IP2. IP1 contains four tanks with a capacity of 75,000 gal (284,000 L) each. From these tanks, the liquid can be processed by use of sluicable demineralizer vessels. There is also a portable demineralization system located in the IP1 Chemical System Building to process liquid waste. This system uses a number of inline ion exchanger resin beds and filters to remove radionuclides and chemicals from the waste stream. Once the contents of the waste tanks meet release criteria, the liquid waste is discharged into the river.

Liquid Releases

Liquid releases to the Hudson River are limited to the extent possible to satisfy the dose design objectives of Appendix I to 10 CFR Part 50. IP2 and IP3 have controls, described in their ODCMs, for limiting the release of radioactive liquid effluents. The controls are based on the concentrations of radioactive materials in liquid effluents and the calculated projected dose to a hypothetical member of the public. Concentrations of radioactive material that may be released in liquid effluents are limited to the concentrations specified by 10 CFR Part 20. For the calendar year, the ODCM limits the dose to a member of the public from liquid effluents to 3 millirem (mrem) (0.03 millisievert (mSv)) to the total body and 10 mrem (0.10 mSv) to any organ (Entergy 2007a).

Entergy maintains radioactive liquid effluent discharges in accordance with the procedures and methodology described in the ODCM. The liquid radioactive waste processing system is used to reduce radioactive materials in liquid effluents before discharge to meet the as low as reasonably achievable (ALARA) dose objectives in Appendix I to 10 CFR Part 50.

The NRC staff reviewed the IP2 and IP3 radioactive effluent release reports for 2002 through 2006 for liquid effluents (Entergy 2003a, 2003b, 2004, 2005a, 2006b, 2007c) to determine whether releases were reasonable. In 2006, 5.99×10^{7} gal (2.27×10^{8} L) of radiological liquid effluents diluted with 1.47×10^{12} gal (5.58×10^{12} L) of water were discharged from the IP2 and IP3 site. The amount of radioactivity discharged in the form of fission and activation products from the IP2 and IP3 site in 2006 totaled 5.92×10^{-2} curies (Ci) (2.19×10^{3} megabecquerels (MBq)). A total of 1.56×10^{3} Ci (5.77×10^{7} MBq) of tritium was released from the IP2 and IP3 site in 2006. A total of 3.82×10^{-1} Ci (1.41×10^{4} MBq) of dissolved and entrained gases was released in liquid discharges from the IP2 and IP3 site in 2006 (Entergy 2007c). The liquid discharges for 2006 are consistent with the radioactive liquid effluents discharged from 2002 through 2005. In section 2.2.7, NRC staff reviewed the most-recent effluent release reports (2009; Entergy 2010) and confirmed that radioactive wastes reported by Entergy remain reasonable and are within applicable limits. The NRC staff expects variations in the amount of radioactive effluents released from year to year by Entergy based on the overall performance of the plant and the number and scope of maintenance and refueling outages. The liquid radioactive wastes reported by Entergy are reasonable and are within applicable limits, and the NRC staff noted no unusual trends.

Though Entergy has indicated that it may replace IP2 and IP3 reactor vessel heads and control rod drive mechanisms during the period of extended operation, such replacement actions are not likely to result in a significant increase of liquid radioactive effluents being discharged compared to the amount discharged during normal plant operations. This is based on consideration that liquids generated, processed, and released during the outage will likely be offset by the amount of liquid waste that would not be generated, processed, and released during normal plant operations during the outage period. Based on the NRC staff's evaluation of recent historical releases in the previous paragraph and based on the NRC staff's expectation that no significant increase in liquid effluents from the potential replacement of the reactor heads and control rod drive mechanisms is likely to occur, the NRC staff expects similar quantities of radioactive liquid effluents to be generated during normal operation and outages from IP2 and IP3 during the period of extended operation.

Releases to Groundwater

In addition to the planned radioactive liquid discharges made through the liquid waste processing system, Entergy identified a new release pathway as a result of the discovery of tritium contamination in the ground outside the IP2 SFP. This release was listed as an abnormal release in the 2006 radioactive effluent release report. The applicant included a detailed radiological assessment of all the liquid effluent releases and the projected doses in its 2006 annual radioactive effluent release report (Entergy 2007c). The following information is from that report.

The applicant estimated that approximately 0.19 Ci ($7.03x10^3$ MBq) of tritium migrated directly to the Hudson River by the groundwater flow path in 2006, resulting in an approximate total body dose of $2.10x10^{-6}$ mrem ($2.10x10^{-8}$ mSv). The amount of tritium released through this pathway is approximately 0.015 percent of the tritium released to the river from routine releases. Tritium releases in total (groundwater as well as routine liquid effluent) represent less than 0.001 percent of the Federal dose limits for radioactive effluents from the site. Strontium-90, nickel-63, and cesium-137 collectively contributed approximately $5.70x10^{-4}$ Ci (21.1 MBq) from the groundwater pathway, which resulted in a calculated annual dose of approximately $1.78x10^{-3}$ mrem ($1.78x10^{-5}$ mSv) to the total body, and $7.21x10^{-3}$ mrem ($7.21x10^{-5}$ mSv) to the critical organ, which was the adult bone (primarily because of strontium-90). Storm drain releases to the discharge canal were conservatively calculated to be approximately $9.40x10^{-2}$ Ci ($3.48x10^3$ MBq) of tritium, resulting in an approximate total body dose of $2.00x10^{-8}$ mrem ($2.00x10^{-10}$ mSv). Entergy asserts that the annual dose to a member of the public from the combined groundwater and storm water pathways at IP2 and IP3 remains well below NRC and U.S. Environmental Protection Agency (EPA) radiation protection standards (Entergy 2007c). The NRC staff further discusses releases to groundwater, including inspection results, in Section 2.2.7 of this SEIS.

2.1.4.2 Gaseous Waste Processing Systems and Effluent Controls

IP2

The gaseous radioactive waste processing system and the plant ventilation system control, collect, process, store, and dispose of gaseous radioactive wastes generated as a result of normal operations. During plant operations, gaseous waste is generated by degassing the reactor coolant and purging the volume control tank, displacing cover gases as liquid accumulates in various tanks, equipment purging, and sampling operations and automatic gas analysis for hydrogen and oxygen in cover gases. The majority of the gas received by the waste disposal system during normal plant operations is cover gas displaced from the chemical and volume control system holdup tanks as they fill with liquid.

Vented gases flow to a waste gas compressor suction header. One of two compressors is in continuous operation, with the second unit designed to operate as a backup for peak load conditions. From the compressors, gas flows to one of four large gas decay tanks. The control arrangement on the gas decay tank inlet header allows plant personnel to place one large tank in service and to select a second large tank for backup. When the tank in service becomes pressurized to a preset level, a pressure transmitter automatically opens the inlet valve to the backup tank, closes the inlet valve to the filled tank, and triggers an alarm to alert personnel to select a new backup tank. Gas held in the decay tanks can either be returned to the chemical and volume control system holdup tanks or be discharged to the environment, provided that the gas meets radiation limits.

Six additional small gas decay tanks are available for use during degassing of the reactor coolant system before the reactor is brought to a cold shutdown. The reactor coolant fission gas activity is distributed among the six tanks through a common inlet header. A radiation monitor in the sample line to the gas analyzer checks the gas decay tank radioactivity inventory each time a sample is taken for hydrogen-oxygen analysis. An alarm notifies plant personnel when the inventory limit is approached so that another tank can be placed into service.

Before a tank’s contents can be discharged into the environment, they must be sampled and analyzed to verify that sufficient decay of the radioactive material has occurred and to document the amount of radioactivity that will be released. If appropriate radioactivity criteria are met, the gas is discharged to a plant vent at a controlled rate and checked by a radiation monitor in the vent. In addition to the radiation monitor, gas samples are manually taken and analyzed to ensure that radiation protection limits are maintained. During a release, a trip valve in the discharge line closes automatically when there is an indication of a high radioactivity level in the plant vent (Entergy 2007a).

IP3

The gaseous radioactive waste processing system and the plant ventilation system control, collect, process, store, and dispose of gaseous radioactive wastes generated as a result of normal operations. During plant operations, gaseous waste is generated by degassing the reactor coolant and purging the volume control tank, displacement of cover gases as liquid accumulates in various tanks, equipment purging, sampling operations and automatic gas analysis for hydrogen and oxygen in cover gases, and venting of actuating nitrogen for pressure control valves.

The majority of the gas received by the waste disposal system during normal operations is cover gas displaced from the chemical and volume control system holdup tanks as they fill with liquid. Since this gas must be replaced when the tanks are emptied during processing, facilities are provided to return gas from the decay tanks to the holdup tanks. A backup supply from the nitrogen header is provided for makeup if the return flow from the gas decay tanks is not available.

Gases vented to the vent header flow to the waste gas compressor header. One of the two compressors is in continuous operation with the second unit as a backup for peak load conditions. From the compressors, gas flows to one of four large gas decay tanks. The control arrangement on the gas decay tanks inlet header allows for the operation of one tank with a second tank as backup. When the tank in service is filled, a pressure transmitter automatically opens the inlet valve to the backup tank and closes the valve of the filled tank and sounds an alarm. Plant personnel then select a new tank to be the backup and repeat the process.

Gases are held in the decay tanks to reduce the amount of radioactivity released into the environment. These gases can either be returned to the chemical and volume control system holdup tanks or discharged to the environment if the radioactivity meets radiation standards.

There are six additional small gas decay tanks for use during degassing of the reactor coolant before the reactor is brought to a cold shutdown. The reactor coolant fission gas activity inventory is distributed equally among the six tanks through the use of a common header. The total radioactivity in any one gas decay tank is controlled in order to limit the potential radiological consequences if any tank ruptures.

Before a tank's contents can be released into the environment, they must be sampled and analyzed to verify that there was sufficient decay and to provide a record of the type and quantity of radioactivity to be released. Once these steps are completed, the gas may be released to the plant vent at a controlled rate and monitored by a radiation monitor. The radiation monitor, upon detecting high radioactivity levels, can automatically close the discharge line to the plant vent. Samples are also taken manually to document releases (Entergy 2007a).

Gaseous Releases

Entergy maintains radioactive gaseous effluents in accordance with the procedures and methodology described in the ODCM. The gaseous radioactive waste processing system is effectively used to reduce radioactive materials in gaseous effluents before discharge to meet the ALARA dose objectives in Appendix I to 10 CFR Part 50.

The NRC staff reviewed the IP2 and IP3 annual radioactive effluent release reports from 2002 through 2006 for gaseous effluents (Entergy 2003a, 2003b, 2004, 2005a, 2006b, 2007c) to determine whether the releases were reasonable. There were no abnormal gaseous releases from IP2 and IP3 in 2006. The amount of radioactivity discharged in the form of fission and activation gases from the operating reactors at the IP2 and IP3 site in 2006 totaled 2.20×10^{2} Ci (8.14×10^{6} MBq). A total of 20.8 Ci (7.69×10^{5} MBq) of tritium was released from the IP2 and IP3 site in 2006. A total of 7.87×10^{-4} Ci (29.1 MBq) of radioiodines and 4.76×10^{-5} Ci (1.76 MBq) of particulates was released from the IP2 and IP3 site in 2006 (Entergy 2007c). The gaseous discharges for 2006 are consistent with the radioactive gaseous effluents discharged from 2002 through 2005. In section 2.2.7, NRC staff reviewed the most-recent effluent release reports (2009; Entergy 2010a) and confirmed that radioactive releases reported by Entergy remain reasonable and within applicable limits. The NRC staff expects variations in the amount of radioactive effluents released from year to year based on the overall performance of the plant and the number and scope of maintenance and refueling outages. The gaseous radioactive wastes reported by Entergy are reasonable and is within applicable limits, and the NRC staff noted no unusual trends.

Though Entergy has indicated that it may replace IP2 and IP3 reactor vessel heads and control rod drive mechanisms during the period of extended operation, such replacement actions are not likely to result in a significant increase in discharges of gaseous radioactive effluents above the amount discharged during normal plant operations. This is based on consideration that any gaseous effluents released during the outage will be offset by the amount of gaseous effluents that would not be generated, processed, and released during normal plant operations. Based on the NRC staff's evaluation of recent historical releases in the previous paragraph and based on the NRC staff's expectation that no significant increase in gaseous effluents from the potential replacement of the reactor heads and control rod drive mechanisms will occur, the NRC staff expects that similar quantities of radioactive gaseous effluents will be generated during normal operations and outages at IP2 and IP3 during the period of extended operation.

2.1.4.3 Solid Waste Processing

IP2 and IP3 solid radioactive wastes include solidified waste derived from processed liquid and sludge products; spent resins, filters, and paper; and glassware used in the radiation-controlled areas of the plant. Waste resin is stored in the spent resin storage tank to allow radioactive decay. When a sufficient volume of resin is accumulated, it is moved from storage and placed into a high-integrity container. The wet waste is then dewatered and prepared for transportation in accordance with the plant's process control program. The process control program contains the criteria and requirements that the waste must meet to comply with NRC and U.S. Department of Transportation (DOT) requirements for transportation of radioactive waste on the public roads. The other solid radioactive wastes, such as paper, rags, and glassware, are also processed for shipping in accordance with the process control program. Entergy, when possible, sends the solid radioactive waste to a material recovery center or to a facility licensed to incinerate and perform other techniques to reduce the waste volume before disposal. Additional interim radioactive waste storage space is located in the IP1 containment.

IP2

At IP2, the original four steam generators are stored in the Original Steam Generator Storage Facility. The facility is made of reinforced concrete and is designed to contain contaminated materials and allow for decontamination of materials if necessary. The structure is built to prevent both the intrusion of water into the facility and the leakage of contaminated water from the facility. The floor of the facility is sloped to direct any liquids to a sump. The floor slab and lower portion of the walls have a protective coating to facilitate decontamination, if required. A passive high-efficiency filter is used to prevent airborne contamination from being vented outside the facility. This facility is located within the owner-controlled area outside of the protected area.

IP3

At IP3, solid radioactive waste (dry activated waste or solidified resins) may be stored in the IP3 Interim Radioactive Waste Storage Facility before being shipped off site. The facility is a concrete structure designed to minimize the impact of stored materials on the public and the environment. It is shielded to limit the offsite annual radiation dose to less than 5 mrem (0.05 mSv). As at IP2, a reinforced concrete structure is used to store the original four steam generators, which were removed in 1989. This structure, called the Replaced Steam Generator Storage Facility, is shielded to reduce radiation exposure, and all openings are sealed with no provision for ventilation. There is a locked and locally alarmed labyrinth entrance that allows for periodic surveillance of the steam generators. There are no gaseous or liquid releases from this facility.

Solid Waste Shipment

IP2 and IP3 radioactive waste shipments are packaged in accordance with NRC and DOT requirements. The type and quantities of solid radioactive waste generated at and shipped from the site vary from year to year, depending on plant activities (i.e., refueling outage, maintenance work, and fuel integrity). Entergy ships radioactive waste to the Studsvik facility in Erwin, Tennessee, the Race facility in Memphis, Tennessee, or the Duratek facility in Oak Ridge, Tennessee, where the wastes undergo additional processing before being sent to a facility for disposal. In the recent past, Entergy had shipped waste to the Barnwell facility in Barnwell County, South Carolina, or the Envirocare facility in Clive, Utah, for disposal (Entergy 2007a). In July 2008, however, the State of South Carolina closed access to radioactive waste generators in States that are not part of the Atlantic Low-Level Waste Compact. New York is not in this compact. (Envirocare, however, remains open for Class A wastes.)

In the near term, Entergy is working to address the loss of the low-level solid radioactive waste disposal repository in Barnwell, South Carolina. During the NRC environmental site audit, IP2 and IP3 staff indicated that they would be able to safely store their low-level waste on site in existing onsite buildings. Entergy indicates that it is currently developing a comprehensive plan to address the potential need for long-term storage. The radiation dose from the storage of low-level radioactive waste would be required to continue to result in doses to members of the public that are below the limits in 10 CFR Part 20 and 40 CFR Part 190, “Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle,” which apply to all operations and facilities at the site.

In 2006, Entergy made a total of 49 shipments of Class A, B, and C solid radioactive waste to offsite processing vendors. The solid waste volumes were 5.31×10^4 cubic feet (1.50×10^3 m^3) of resins, filters, evaporator bottoms, and dry active waste, with an activity of 9.49×10^2 Ci (3.51×10^7 MBq). Entergy shipped no irradiated components or control rods in 2006 (Entergy 2007c). The solid waste volumes and radioactivity amounts generated in 2006 are typical of annual waste shipments made by Entergy. The NRC staff expects variations in the amount of solid radioactive waste generated and shipped from year to year based on the overall performance of the plant and the number and scope of maintenance work and refueling outages. The NRC staff finds that the volume and activity of solid radioactive waste reported by Entergy are reasonable, and no unusual trends were noted.

Entergy has indicated that it may replace IP2 and IP3 reactor vessel heads and control rod drive mechanisms during the period of extended operation (Entergy 2008), and such replacement actions are likely to result in a small increase in the amount of solid radioactive waste generated. This is partly because the number of personnel working at the plant will increase, leading to increased use of protective clothing and safety equipment and an increased use of filters. Also, work activities will create a general increase in debris that will have to be disposed of as radioactive waste. However, the increased volume is expected to be within the range of solid waste that can be safely handled by IP2 and IP3 during the period of extended operation. In the GEIS (NRC 1996), NRC indicated that doses from onsite storage of assemblies removed during refurbishment would be “very small and insignificant.” Retired vessel heads will likely be stored on site in a concrete building (Entergy 2008), subject to regular monitoring and dose limits under 10 CFR Part 20 and 40 CFR Part 190.

2.1.5 Nonradioactive Waste Systems

IP2 and IP3 generate solid, hazardous, universal, and mixed waste from routine facility operations and maintenance activities.

2.1.5.1 Nonradioactive Waste Streams

Nonradioactive waste is produced during plant maintenance, cleaning, and operational processes. Most of the wastes consist of nonhazardous waste oil and oily debris and result from operation and maintenance of oil-filled equipment.

The facility generates solid waste, as defined by the Resource Conservation and Recovery Act (RCRA), as part of routine plant maintenance, cleaning activities, and plant operations. These solid waste streams include nonradioactive resins and sludges, putrescible wastes, and recyclable wastes.

Universal wastes constitute a majority of the remaining waste volumes generated at the facility. Universal waste is hazardous waste that has been specified as universal waste by EPA. Universal wastes, including mercury-containing equipment, batteries, fluorescent bulbs, and pesticides, have specific regulations (40 CFR Part 273, "Standards for Universal Waste Management") to ensure proper collection and recycling or treatment.

Hazardous wastes routinely make up a small percentage of the total wastes generated at the IP2 and IP3 facility and include spent and expired chemicals, laboratory chemical wastes, and other chemical wastes (Entergy 2007a). Hazardous waste is nonradioactive waste that is listed by EPA as hazardous waste or that exhibits characteristics of ignitability, corrosivity, reactivity, or toxicity (40 CFR Part 261, "Identification and Listing of Hazardous Waste"). RCRA, as well as the NYSDEC regulatory requirements set forth in Title 6 of the New York Codes, Rules, and Regulations (NYCRR) Parts 371-376, that regulate storage and handling of hazardous waste and require a hazardous waste permit for facilities that store large quantities of hazardous waste for more than 90 days.

Low-level mixed waste (LLMW) is waste that exhibits hazardous characteristics and contains low levels of radioactivity. LLMW at IP2 and IP3 is regulated under RCRA and NYSDEC regulatory requirements as set forth in 6 NYCRR Parts 373 and 374.

IP2 has mixed waste storage facilities covered by a Permit, NYD991304411, issued by NYSDEC under 6 NYCRR Part 373, for the accumulation and temporary storage of mixed wastes onsite for more than 90 days. Mixed wastes are temporarily stored onsite for more than 90 days at IP3 based on a mixed waste conditional exemption for Permit NYD085503746, per 6 NYCRR Part 374-1.9.

Some amounts of chemical and biocide wastes are produced at the facility from processes used to control the pH in the coolant, to control scale, to control corrosion, to regenerate resins, and to clean and defoul the condensers. These waste liquids are typically discharged in accordance with the site's State Pollutant Discharge Elimination System (SPDES) Permit, NY-0004472, along with cooling water discharges (Entergy 2007a).

Hazardous and universal wastes are collected in central collection areas. The materials are received in various forms and are packaged to meet all regulatory requirements before final disposition at an appropriate offsite facility. Entergy tracks wastes like waste oil, oily debris, glycol, lighting ballasts containing polychlorinated biphenyls (PCBs), fluorescent lamps, batteries, and hazardous wastes (i.e., paints, lead abatement waste, broken lamps, off-specification and expired chemicals)—by volume at the facility. The total amount of tracked hazardous and universal wastes for 2006 was 17,987 pounds (lb) (8,158 kilograms (kg)) with waste oil making up 70 percent of the total weight (Entergy 2007a).

Most sanitary wastewater from the IP2 and IP3 facility operations is transferred to the Village of Buchanan publicly owned treatment works system. A few isolated areas at the facility have their own septic tanks. Although the sanitary wastewaters are nonradioactive, a radiation monitoring system continuously monitors the effluent from the protected area (Entergy 2007a).

The testing of the emergency generators and boiler operations generates nonradioactive gaseous effluents. Emissions are managed in accordance with IP2 and IP3 air quality permits, 3-5522-00011/00026 and 3-5522-00105/00009, respectively (Entergy 2007a).

2.1.5.2 Pollution Prevention and Waste Minimization

Entergy's Waste Minimization Plan describes programs that have been implemented at the facility. This plan is used in conjunction with other waste minimization procedures, waste management procedures (including on-site recycling), chemical control procedures, and other site-specific procedures to reduce waste generation (Entergy 2007a).

2.1.6 Facility Operation and Maintenance

Maintenance activities conducted at IP2 and IP3 include inspection, testing, and surveillance to maintain licensing requirements and to ensure compliance with environmental and safety requirements. Various programs and activities currently exist at the facility to maintain, inspect, test, and monitor the performance of facility equipment. These maintenance activities include inspection requirements for reactor vessel materials, in-service inspection and testing of boilers and pressure vessels, the maintenance structures monitoring program, and water chemistry maintenance.

Additional programs include those implemented to meet technical specification surveillance requirements, those implemented in response to the NRC generic communications, and various periodic maintenance, testing, and inspection procedures. Certain program activities are performed during the operation of the unit, while others are performed during scheduled refueling outages. As mentioned in Section 2.1.2, Entergy typically refuels IP2 and IP3 on 24-month cycles.

2.1.7 Power Transmission System

The applicant has identified two 345-kV transmission lines that connect IP2 and IP3 to the Con Edison electrical transmission grid. Feeder W95 and feeder W96 deliver power from IP2 and IP3, respectively, to the Buchanan substation located across Broadway near the entrance to the IP2 and IP3 site. Other than these two transmission lines, no other lines or facilities were constructed specifically to connect the two generating units to the existing transmission grid. Because the Buchanan substation and the regional transmission system to which it connects were designed and constructed before IP2 and IP3 (Entergy 2007a; NRC 1975; USAEC 1972), they are beyond the scope of this evaluation.

Each of the W95 and W96 lines is approximately 2000 ft (610 m) long. The lines are within the site except for the terminal 100-ft (30.5-m) segments that cross Broadway and enter the substation. In addition to transmitting the output power from IP2 and IP3 off site, the transmission system also provides IP2 and IP3 with the auxiliary power necessary for startup and normal shutdown. Offsite (standby) power is supplied to IP2 and IP3 by 138-kV input lines that use the same transmission towers as the W95 and W96 output lines (Entergy 2005b; NRC 1975). The W95 and W96 lines are each within a separate right-of-way (ROW), so the ROWs total approximately 4000 ft (1220 m) in length. About 500 ft (150 m) of this ROW length is vegetated; the remainder crosses roads, parking lots, buildings, and other facilities. In the vegetated segments, the NRC staff observed that the ROW is approximately 150 ft (46 m) wide, the growth of trees is prevented, and a cover of mainly grasses and forbs is maintained.

2.2 Plant Interaction with the Environment

2.2.1 Land Use

Within the 239-acre (97-ha) Indian Point site, IP2 and IP3 (see Figure 2-3) are located north and south, respectively, of IP1, which is in SAFSTOR until it is eventually decommissioned. The developed portion of the IP2 and IP3 site is approximately 124.3 acres (50.3 ha), or over half the site (see Figure 2-3). The remaining portions of the site are unused, undeveloped, and include fields and forest uplands (approximately 112.4 acres (45.5 ha) and wetlands, streams, and a pond (2.4 acres (0.97 ha)). Much of the site (approximately 159 acres (64.3 ha)) has been disturbed at some time during the construction and operation of the three units (ENN 2007b).

The immediate area around the station is completely enclosed by a fence with access to the station controlled at a security gate. The plant site can be accessed by road or from the Hudson River. Land access to the plant site is from Broadway (main entrance). The existing wharf is used to receive heavy equipment as needed, although access to the site from the river is controlled by site access procedures. The plant site is not served by railroad. The exclusion area, as defined by 10 CFR 100.3, “Definitions,” surrounds the site as shown in Figure 2-3 (Entergy 2007a).

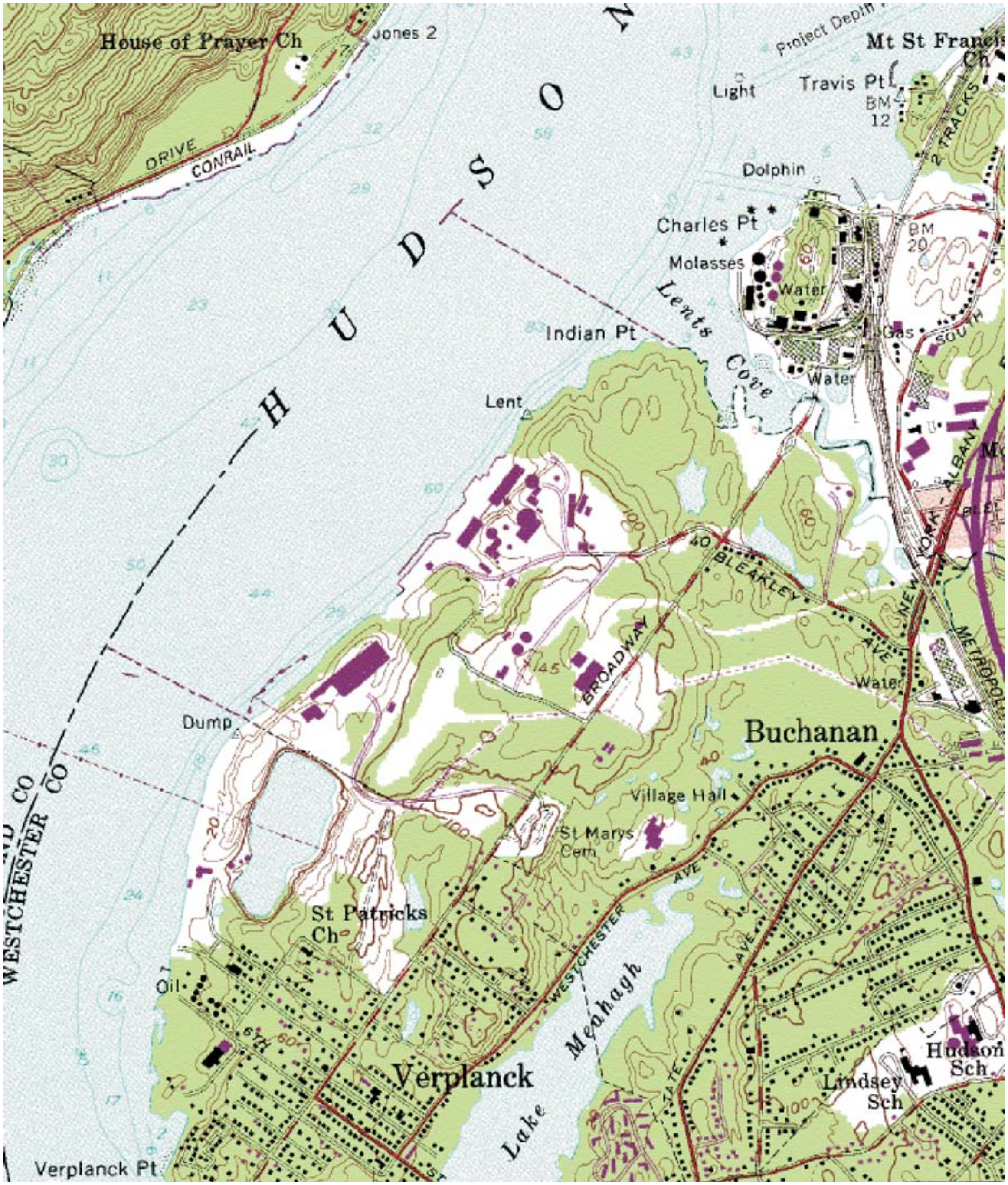
2.2.2 Water Use

The Hudson River is an important regional resource of significant aesthetic value in addition to providing transportation, recreation, and water supply. The Hudson River at IP2 and IP3 is tidally influenced and becomes increasingly so as it proceeds south. IP2 and IP3 have a once-through condenser cooling system that withdraws water from the Hudson River. The same amount of water that is withdrawn for condenser cooling is discharged. However, the discharged water is at an elevated temperature and, therefore, can induce some additional evaporation. The NRC staff conservatively estimates that this induced evaporation from elevated discharge temperature is less than 60 cfs (1.7 m^3/s). The remaining consumptive water uses are insignificant relative to induced evaporation.

2.2.3 Water Quality

Being tidally influenced, the salinity of the Hudson River varies as upstream flows and tides fluctuate. The salinity decreases when stream flows increase and tides drop. The salinity increases during periods of low flow and high tides. The periodic higher salinity levels limit some of the uses that a lower salinity river might support (e.g., drinking water supply).

Discharges to the Hudson River are regulated by the Clean Water Act (CWA). The CWA is administered by EPA. EPA has delegated responsibility for administration of the National Pollutant Discharge Elimination System to NYSDEC. The IP2 and IP3 ownership submitted timely and sufficient applications to renew its SPDES permits before the expiration of those permits in 1992. The 1987 SPDES permit for the facility remains in effect while NYSDEC administrative proceedings continue. Pursuant to the New York State Administrative Procedure Act, the facility SPDES permit does not expire until NYSDEC makes its final determination. To date, this final determination has not been made. In 1991, NYSDEC, the facility owners, and several stakeholder groups entered



Source: Maptech, Inc.

Figure 2-9. Topographic features surrounding IP2 and IP3

into a consent order (issued pursuant to the Hudson River Settlement Agreement; see Section 2.2.5.3 for more information) to mitigate impacts of the thermal plume entering the Hudson River from the plant's discharge. On April 2, 2010, the New York State Department of Environmental Conservation (NYSDEC) issued a Notice of Denial regarding the IP2 and IP3 Clean Water Act Section 401 Water Quality Certification. Entergy has since requested a hearing on the issue, and the matter will be decided through NYSDEC's hearing process.

IP2 and IP3 do not intentionally discharge contaminants in a manner that would contaminate the groundwater beneath the site. However, in 2005, tritium was located beneath the IP2 and IP3 site. During a subsequent subsurface monitoring program at the site, radioactive forms of cesium, cobalt, nickel, and strontium also were found. The radiological impact of these leaks on groundwater is discussed in Section 2.2.7 of this SEIS (the leaks are also mentioned in Section 2.1.4.1 of this SEIS).

2.2.4 Meteorology and Air Quality

2.2.4.1 Climate

IP2 and IP3 are located in the Village of Buchanan, New York, in Westchester County on the eastern bank of the Hudson River at approximately RM 43 (RKM 69). The river bisects the area within a 6-mi (9.7-km) radius of the site and geographically separates Westchester County from Rockland County to the west. The Hudson River flows northeast to southwest at the site but turns sharply northwest approximately 2 mi northeast of the plant. The western bank of the Hudson River is flanked by the steep, heavily wooded slopes of the Dunderberg and West Mountains to the northwest (elevations 1086 and 1257 ft (331 and 383 m) above mean sea level (MSL), respectively) and Buckberg Mountain to the west-southwest (elevation 793 ft (242 m) above MSL). These peaks extend to the west and gradually rise to slightly higher peaks (Entergy 2007a).

The climate is continental, characterized by rapid changes in temperature, resulting in hot summers and cold winters. The area, being adjacent to the St. Lawrence River Valley storm track, is subject to cold air masses approaching from the west and north. It has a variable climate, characterized by frequent and swift changes. The climate is also subject to some modification by the Atlantic Ocean. The moderating effect on temperatures is more pronounced during the warmer months than in winter when bursts of cold air sweep down from Canada. In the warmer seasons, temperatures rise rapidly in the daytime. However, temperatures also fall rapidly after sunset so that the nights are relatively cool. Occasionally, there are extended periods of oppressive heat up to a week or more in duration. Winters are usually cold and sometimes fairly severe. Furthermore, the area is also close to the path of most storm and frontal systems that move across the North American continent. Weather conditions often approach from a westerly direction, and the frequent passage of weather systems often helps reduce the length of both warm and cold spells. This is also a major factor in keeping periods of prolonged air stagnation to a minimum (NOAA 2004).

The State of New York has a climate that varies greatly. For example, the average January temperature ranges from 14° Fahrenheit (F) (-10° Celsius (C)) in the central Adirondack Mountains to 30°F (-1.1°C) on Long Island. The average July temperature in the central Adirondacks is 66°F (19°C), and 74°F (23°C) on Long Island. The highest temperature ever recorded in the State was 108°F (42°C) at Troy on July 22, 1926. The lowest recorded temperature, -52°F (-47°C), occurred at Old Forge, in the Fulton Chain of Lakes area, on February 18, 1979 (World Book Encyclopedia 2006). In Westchester County, where IP2 and IP3 are located, temperatures are mild in the summer and cold in the winter. Buchanan, New York, has a mean daily maximum temperature range from 28°F (-2.2°C) in winter to 87°F (31°C) in summer. The mean daily minimum temperatures range from about 20°F (-6.7°C) in winter to about 72°F (22°C) in summer (Indian Point Energy Center 2004).

Precipitation varies considerably in New York. The areas of Tug Hill, the southwestern slopes of the Adirondacks, the central Catskills, and the southeast areas usually receive 44 in. (110 cm) of rain a year, while other portions of the State get only 36 in. (91 cm). The Great Lakes, with their broad expanse of open water, supply moisture for abundant winter snowfall. Syracuse, Rochester, and Buffalo routinely receive annual snowfalls that are the highest for any major city in the United States (World Book Encyclopedia 2006). Most of the precipitation in this area is derived from moisture-laden air transported from the Gulf of Mexico and cyclonic systems moving northward along the Atlantic coast. The annual rainfall is rather evenly distributed over the year. Also, being adjacent to the track of storms that move through the Saint Lawrence River Valley, and under the influence of winds that sweep across Lakes Erie and Ontario to the interior of the State, the area is subject to cloudiness and winter snow flurries. Furthermore, the combination of a valley location and surrounding hills produces numerous advection fogs which also reduce the amount of sunshine received (NOAA 2004).

In the IP2 and IP3 Buchanan area, precipitation averages 37 in. (94 cm) per year and is distributed rather evenly throughout the 12-month period. The lowest amount is in February, and the highest is in May (Indian Point Energy Center 2004). Although the Village of Buchanan area is subject to a wide range of snowfall amounting to as little as 20 in. (51 cm) or as much as 70 in. (180 cm), Westchester County snowfall amounts typically average between approximately 25 to 55 in. (64 to 140 cm) per year (NRCC 2006).

Wind velocities are moderate. The north-south Hudson River Valley has a marked effect on the lighter winds, and in the warm months, average wind direction is usually southerly. For the most part, the winds at Buchanan have northerly and westerly components. Destructive winds rarely occur. Tornadoes, although rare, have struck the area, causing major damage (NOAA 2004).

On average, seven tornadoes strike New York every year (USDOC 2006a). Westchester County has had a total of eight tornadoes since 1950, seven of which have been F1 or less (“weak” tornadoes). The eighth tornado, which struck portions of Westchester County on July 12, 2006, was rated as an F2 at its maximum intensity (briefly a “strong” tornado) but was an F1 for most of its existence. Based on climatic data compared to other regions of the United States, the probability of a tornado striking the IP2 and IP3 site is small, and tornado intensities in Westchester County are relatively low (USDOC 2006b).

2.2.4.2 Meteorological System

Entergy’s meteorological system consists of three instrumented towers, redundant power and ventilation systems, redundant communication systems, and a computer processor/recorder.

Entergy describes the primary system as a 122-m (400-ft) instrumented tower located on the site that provides the following:

- wind direction and speed measurement at a minimum of two levels, one of which is representative of the 10-m (33-ft) level

- standard deviations of wind direction fluctuations as calculated at all measured levels
- vertical temperature difference for two layers (122–10 m (400–33 ft) and 60–10 m (197–33 ft))
- ambient temperature measurements at the 10-m (33-ft) level
- precipitation measurements near ground level
- Pasquill stability classes as calculated from temperature difference (Indian Point Energy Center 2005)

The meteorological measurement system is located in a controlled environmental housing and connected to a power supply system with a redundant power source. A diesel generator provides immediate power to the meteorological tower system within 15 seconds after an outage trips the automatic transfer switch. Support systems include an uninterruptible power supply, dedicated ventilation systems, halon fire protection, and dedicated communications (Indian Point Energy Center 2005).

Entergy indicates that the meteorological system transmits 15-minute average data simultaneously to two loggers at the primary tower site. One data logger transmits to a computer that determines joint frequency distributions, and the second transmits to a computer in the Buchanan Service Center that allows remote access to the data. Meteorological data can be transmitted simultaneously to emergency responders and the NRC in a format designated by NUREG-0654/FEMA-REP-1. Fifteen-minute averages of meteorological parameters for the preceding 12 hours are available from the system (Indian Point Energy Center 2005).

The backup meteorological system is independent of the primary system and consists of a backup tower located approximately 2700 ft (833 m) north of the primary tower and a data acquisition system located in the Emergency Operations Facility. The backup system provides measurements at the 10-m (33-ft) level of wind direction and speed and an estimate of atmospheric stability (Pasquill category using sigma theta, which is a standard deviation of wind fluctuation). The backup system provides information in real-time mode. Changeover from the primary system to the backup system occurs automatically. In the event of a failure of the backup meteorological measurement system, a standby backup system exists at the 10-m (33-ft) level of the Buchanan Service Center building roof. It also provides measurements of the 10-m (33-ft) level of wind direction and speed and an estimate of atmospheric stability (Pasquill category using sigma theta, which is a standard deviation of wind fluctuations). The changeover from the backup system to the standby system also occurs automatically. As in the case of the primary system, the backup meteorological measurement system and associated controlled environmental housing system are connected to a power system which is supplied from redundant power sources. In addition to the backup meteorological measurement system, a backup communications line to the meteorological system is operational. During an interim period, the backup communications are provided via telephone lines routed through a telephone company central office separate from the primary circuits (Indian Point Energy Center 2005).

2.2.4.3 Air Quality

Under the Clean Air Act, EPA established National Ambient Air Quality Standards (NAAQS) for specific concentrations of certain pollutants, called criteria pollutants. Areas in the United States having air quality as good as or better than these standards (i.e., pollutant levels lower than the

NAAQS) were designated as attainment areas for the various pollutants. Areas with monitored pollutant levels greater than these standards are designated as nonattainment areas. Areas in the United States whose pollutant levels were greater than the NAAQS and are now lower than the NAAQS are designated as maintenance areas.

Four states are located within a 50-mi (80-km) radius of the site. These include Pennsylvania's, Connecticut, New York, and New Jersey. The 50-mi (80-km) radius includes nonattainment areas for the ozone (O_3) 8-hour standard, particulate matter less than 10 microns in diameter (PM_{10}), and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). The portion of Pennsylvania (Pike County) located within the 50-mi (80-km) radius is in attainment for all criteria pollutants.

The currently designated nonattainment areas for Connecticut counties within a 50-mi (80-km) radius of the site are as follows:

- Fairfield and New Haven*—O_3 and $PM_{2.5}$
- Litchfield—O_3

The currently designated nonattainment areas for New Jersey counties within a 50-mi (80-km) radius of the site are as follows:

- Bergen, Essex, Hudson, Morris, Passaic, Somerset, and Union*—O_3 and $PM_{2.5}$
- Sussex*—O_3

The currently designated nonattainment areas for New York counties within a 50-mi (80-km) radius of the site are as follows:

Bronx, Kings, Nassau, Orange, Queens, Richmond, Rockland, Suffolk, and Westchester*—O_3 and $PM_{2.5}$

- Dutchess and Putnam—O_3
- New York*—O_3, PM_{10}, and $PM_{2.5}$

Note that the counties labeled with an "*" are part of the EPA-designated "New York—New Jersey—Long Island Nonattainment Area" (EPA 2006a).

New York State air permits for IP2 and IP3, 3-5522-00011/00026 and 3-5522-000105/00009, respectively, regulate emissions from boilers, turbines, and generators. These permits restrict nitrogen oxides (NOx) emissions to 23.75 tons (t) (22 metric tons (MT)) per year per station by restricting engine run time and fuel consumption. IP2 and IP3 are not subject to the Risk Management Plan (RMP) requirements described in 40 CFR Part 68, as no RMP-regulated chemicals stored on site exceed the threshold values listed in 40 CFR Part 68 (Entergy 2007a).

There are no Mandatory Class I Federal areas designated by the National Park Service, U.S. Fish and Wildlife Service (FWS), or the U.S. Forest Service within 50 mi (80 km) of the site. Class I areas are locations in which visibility is an important attribute. As defined in the Clean Air Act, they include several types of areas that were in existence as of August 7, 1977—national parks over 6000 acres (2430 ha), national wilderness areas, and national memorial parks over 5000 acres (2020 ha), and international parks (NPS 2006a). The closest Class I

Area is Lye Brook Wilderness Area, Vermont, approximately 150 mi (240 km) east-northeast of IP2 and IP3 (NPS 2006b).

2.2.5 Aquatic Resources

In this section, the NRC staff describes the physical, chemical, and biological characteristics of the Hudson River estuary. In addition, the NRC staff describes the major anthropogenic events that have influenced the estuary and the history of regulatory action over the past 50 years.

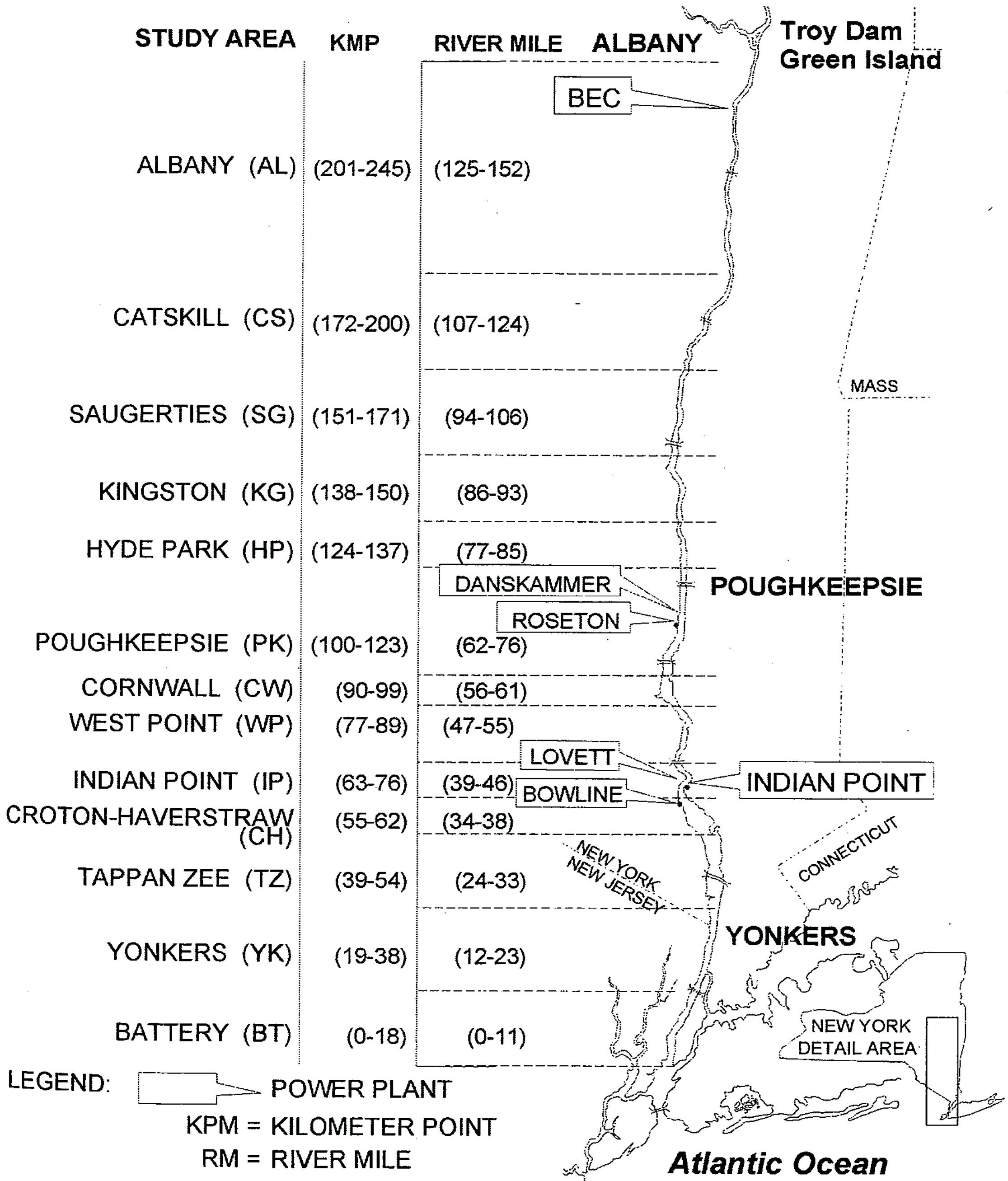
2.2.5.1 The Hudson River Estuary

Watershed Description

The Hudson River originates at Tear-of-the-Clouds in the Adirondack Mountains of northern New York State. From its source, the river flows south 315 mi (507 km) to its mouth at the Battery, at the south end of the island of Manhattan. The Hudson River basin extends 128 mi (206 km) from east to west and 238 mi (383 km) from north to south and drains an area of 13,336 square miles (sq mi) (34,540 sq km), with most of this area located in the eastern-central part of New York State and small portions in Vermont, Massachusetts, Connecticut, and New Jersey (Abood et al. 2006). The basin is bounded by the St. Lawrence and Lake Champlain drainage basins to the north; the Connecticut and Housatonic River basins to the east; the Delaware, Susquehanna, Oswego, and Black River basins to the west; and the basins of small tributaries and New York Harbor on the south. From the Troy Dam to the Battery, the lower Hudson River basin is about 154 mi (248 km) long and drains an area of about 5277 sq mi (13,670 sq km). The average slope of the lower Hudson River, defined in terms of the half-tide level, is about 0.6 m (2 ft) over 150 mi (240 km) (Abood et al. 2006). During the development of the multi-utility studies in the 1970s, the lower portion of the Hudson River from the Troy Dam to the Battery was divided into 13 study areas (river segments), depicted in Figure 2-10. The study area and river segment designations identified in the figure will be used to discuss monitoring results and data collection locations throughout this document.

Lower Hudson River Basin Habitats

The lower Hudson River estuary contains a variety of habitats, including tidal marshes, intertidal mudflats, and subtidal aquatic beds. These habitats exist throughout the length of the river and can be freshwater, brackish, or saline. The freshwater communities are generally located north of Newburgh (CHGEC 1999), with brackish communities found farther south. There are four locations within the estuary designated as National Estuarine Research Reserve System Sites by the National Oceanic and Atmospheric Administration (NOAA) and NYSDEC, including, from north to south, Stockport Flats, Tivoli Bay, Iona Island, and Piermont Marsh (NOAA 2008), as shown in Figure 2-11. The lower Hudson River basin also contains Haverstraw Bay, shown in Figure 2-11, a significant nursery area for a variety of fish, including striped bass, white perch, Atlantic tomcod, and Atlantic sturgeon, and a wintering area for the federally listed endangered shortnose sturgeon (FWS 2008a).



Source: Abood et al. 2006

Figure 2-10. Hudson study area and river segments

Figure 2-11. Hudson river area and national estuarine research sites

Community type and habitat characteristics are influenced by the extent of tidal excursions, which are controlled by tidal stage and river flow. During drought periods, the 100 milligrams per liter (mg/L) (0.1 parts per thousand (ppt)) salinity front can extend up to 130 km (81 mi) above the ocean entrance (Abood et al. 2006).

In general, narrow, shallow river reaches with high current flow have extensive bottom scour and low organic carbon levels. The coarse gravel substrate provides spawning habitat for some species. Similar characteristics can also be found where tributaries to the main river stem join the Hudson. High current speeds through deep basins can generate turbulent flow that keeps weakly swimming zoo- and icthyoplankton suspended in the water column and away from silty nearshore locations and potential predators. Shallow, shore-zone habitats often support submerged aquatic vegetation that provides habitat and protection for juvenile fish and other aquatic communities. Broad, shallow basins often create depositional environments where fine sediments, high levels of organic carbon, and nutrients are present. These environments are generally highly productive and may serve as nursery areas for juvenile fish species (CHGEC 1999).

Human activities, however, have significantly affected the lower Hudson River estuary. Increasing human populations along the estuary throughout recent history have contributed to increased habitat alteration. Section 2.2.5.2 examines human influences in greater detail.

The construction of railroad lines along the banks of the river disrupted the connection of the river to marshland and wetland habitats. Construction of causeways interfered with or completely blocked tributary inlets, disrupting sediment transport and other natural phenomena. Anthropogenic activities also resulted in the dredging of some habitats and the filling of others. The historical impacts to the lower Hudson River habitats are discussed later in this section.

To describe the predominant habitat features associated with the lower Hudson River estuary, Central Hudson Gas and Electric Corporation (CHGEC; 1999) divided the lower river from the Troy Dam to the Battery into five subsections of roughly comparable volume consisting of one or more of the regions and river segments identified in Figure 2-10. Beginning at the Troy Dam, the first subsection extends from RM 152 to 94 (RKM 245 to 151) and includes the Albany, Catskill, and Saugerties study areas. This subsection of the river is relatively narrow and has extensive shoals and numerous tributaries. Within this subsection and approximately 6.2 mi (10 km) south of the Troy Dam, the river is about 574 ft (175 m) wide—the narrowest part of the lower Hudson (Abood et al. 2006). The slope of the river is also greatest in this subsection and generates current velocities greater than in other areas.

The second subsection of the river defined by CHGEC (1999) extends from RM 93 to 56 (RKM 150 to 90) and includes the Kingston, Hyde Park, Poughkeepsie, and Cornwall study areas. This subsection contains a series of progressively deeper basins, and the volume of this area is approximately 1.5 times larger than that of the adjacent upriver areas. Shallow shoreline and shoal areas are common only in the southernmost end of this subsection.

The third subsection of the river defined by CHGEC (1999) extends from RM 55 to 39 (RKM 89 to 63), and includes the West Point and IP2 and IP3 study areas. At this location, the Hudson Highlands land mass forced glaciers through a narrow constriction, resulting in the deepest and most turbulent flow observed in the lower Hudson. Within this subsection, the river channel narrows abruptly, bends sharply to the east, and reaches a depth of over 150 ft (46 m). At the lower portions of this subsection, the river bottom consists of a series of progressively shallower gouges that result in a corrugated bottom that ends in shallow water behind the Hudson Highlands. The IP2 and IP3 and Bowline Point power stations (along with the no-longer-operating Lovett station) are located within this river subsection.

The fourth subsection of the river defined by CHGEC (1999) is located from RM 38 to 24 (RKM 62 to 39) and includes the Croton-Haverstraw and Tappan Zee study areas (Figure 2-10). This is the widest and shallowest portion of the lower Hudson River and has the most extensive shoal and shore zone areas. The presence of slow-moving currents and shoal areas results in the deposition of suspended sediment, organic carbon, and nutrients. The major source of suspended sediment to the Hudson is associated with watershed basin runoff and erosion, and basin-wide loads have been estimated at 800,000 tons per year (t/yr; 726,000 MT/yr) (Abood et al. 2006). The presence of slow-moving currents, shoal and shore-zone habitat, and high carbon and nutrient inputs makes this a highly productive portion of the lower Hudson River and provides important spawning and nursery areas for juvenile fish.

The fifth subsection of the river defined by CHGEC (1999) begins at RM 24 (RKM 38) and extends to the river's entrance into New York Harbor, encompassing the Yonkers and Battery study areas. In this subsection, the river again constricts and gradually deepens as it enters New York Harbor. In this location, the river is generally straight and contains few shoal areas or shore-zone habitats. The final 12 mi (19 km) of the lower Hudson have extensive armoring and contain little remaining natural shoreline (CHGEC 1999).

<u>Sampling Strata Definitions</u>

In order to effectively sample and study the lower Hudson, researchers have attempted to define specific zones, habitats, or locations within the river. These specific locations, often called strata, provide researchers with a quantitative way to sample the environment and integrate the resulting information. A variety of attempts have been made to define the channel morphology and thus the potential strata of the lower Hudson. Miller et al. (2006) describe three major habitat areas in the lower Hudson:

(1) Intertidal: Areas exposed at low tide and submerged at high tide that include mud flats, sand, broadleaf marsh, and emergent intertidal vegetation.

(2) Shallows: Areas of the river less than 6.6 ft (2.0 m) deep at mean low tide. This habitat supports submerged aquatic vegetation (SAV) in the river and is considered one of the most productive habitats in the estuary and of great ecological importance.

(3) Deepwater: Areas of the river greater than 6.6 ft (2.0 m) deep at mean low tide. This area represents the limit of light penetration and generally does not support SAV.

During the development of the Hudson River Utilities studies of the lower Hudson River in the 1970s, the study areas and river segments were divided into four primary strata to support fish and plankton investigations. These strata provide a geomorphological basis for partitioning the river and are still used to define sampling locations (ASA 2007):

(4) Shore: The portion of the Hudson River estuary extending from the shore to a depth of 10 ft (3.0 m). This area was primarily sampled by beach seine.

(5) Shoal: The portion of the Hudson River extending from the shore to a depth of 20 ft (6.1 m) at mean low tide.

(6) Bottom: The portion of Hudson River extending from the bottom to 10 ft (3.0 m) above the bottom where the river depth is greater than 20 ft (6.1 m) mean low tide.

(7) Channel: The portion of the Hudson River not considered bottom where river depth is greater than 20 ft (6.1 m) at mean low tide.

<u>Hydrodynamics and Flow Characteristics</u>

In the lower Hudson River, freshwater flow is one of the most important factors in determining and influencing the physical, chemical, and biological processes in the estuary and the resulting interactions within the food web. Hydrodynamics and flow characteristics are controlled by a complex series of interactions that include short- and long-term fluctuations in meteorological conditions, precipitation and runoff in the upstream portion of the watershed, the influence of tides and currents in downstream portions of the river, and the presence of a “salt wedge” that moves up- or downstream depending on river flow and tidal fluctuation (Blumberg and Hellweger 2006). Freshwater flow varies throughout the year, with maximum flow occurring during the months of March through May, with low-flow conditions beginning in June and continuing until November (Abood et al. 2006). Under normal conditions, approximately 75 percent of the total freshwater flow enters the lower Hudson River at Troy, with the remaining portion contributed by tributaries discharging into the upper reach of the estuary (CHGEC 1999; Abood et al. 2006). Because of tidal oscillation in the estuary, it is not possible to accurately measure freshwater flow in the lower estuary. Freshwater flow is, however, monitored by the U.S. Geological Survey (USGS) at Green Island, the farthest downstream USGS gauge above tidewater (CHGEC 1999; Abood et al. 2006). Data recorded from this gauge from 1948 to 2006 show that the mean annual flow was approximately 14,028 cfs (397.23 m^3/s). The lowest recorded annual flow was 6400 cfs (180 m^3/s) in 1965; the highest was 22,100 cfs (626 m^3/s) in 1976. Measured flows from Green Island from 1996 to 2006 ranged from 11,400 cfs (323 m^3/s) in 2002 to over 18,000 cfs (510 m^3/s) in 1996 (USGS 2008).

<u>Salinity</u>

CHGEC (1999) describes four salinity habitat zones in the Hudson River:

(8) polyhaline (high salinity): RM 1–19 (RKM 1–31)

(9) mesohaline (moderate salinity): RM 19–40 (RKM 31–64)

(10) oligohaline (low salinity): RM 40–68 (RKM 64–109)

(11) tidal freshwater: RM 68–152 (RKM 109–245)

The IP2 and IP3 and Bowline Point facilities are located in the oligohaline zone and generally experience salinities of 0.5 to 5 ppt. The actual salinity present at a given time and place can vary considerably in the lower regions of the river because of salinity intrusion, which occurs throughout the year. The typical tidal excursion in the lower Hudson River is generally 3 to 6 mi (5 to 10 km), but can extend up to 12 mi (19 km) upstream. During the spring, the salt front is located between Yonkers and Tappan Zee and moves upstream to just south of Poughkeepsie during the summer (Blumberg and Hellweger 2006). Abood et al. (2006) report that, during drought periods, the salt front (defined as water with a salinity of 100 mg/L (0.1 ppt)) can extend up to RM 81. Stratification also occurs within this salt-intruded reach. Studies by Abood et al. (2006) suggest that from 1997–2003, salinity in the Hudson River has increased approximately 15 percent for a given flow rate. The authors suggest that this conclusion be viewed with caution and that further analysis is required to confirm this finding. Real-time monitoring of the salt front position on the lower Hudson River is provided by USGS and can be accessed via its Web site (USGS 2008).

Temperature

Water temperatures in the Hudson River vary seasonally, with a maximum temperature of 25°C (77°F) occurring in August and a minimum temperature of 1°C (34°F) occurring in January–February. The magnitude and distribution of water temperatures in the estuary are influenced by a variety of factors and complex relationships. Abood et al. (2006) identified four categories of parameters that play a significant role in water temperature—(1) atmospheric conditions, including radiation, evaporation, and conduction, (2) hydrodynamic conditions, including channel geometry, flow, and dispersion, (3) boundary conditions associated with the temperature of the ocean and freshwater, and (4) anthropogenic inputs, including those associated with activities that use river water for cooling purposes. The four parameters are interrelated and collectively influence temperature ranges and distributions in the estuary. Anthropogenic influences are of particular concern because they generally represent a constant influence on the system that may be controlled or managed, unlike those influences associated with climate, river morphology/geometry, and natural interactions between the river and ocean. Abood et al. (2006) indicate that the greatest percentage of artificial (anthropogenic) heat input into the lower Hudson River estuary is associated with the use of river water for condenser cooling in support of electrical power generation. The authors indicate that there are currently six power plants operating in the lower Hudson River estuary, with a total electrical generation of approximately 6000 MW(e), that use the Hudson River as cooling water. These plants collectively use 4.6 million gpm (290 m^3/s) and produce approximately $8x10^{11}$ British thermal units per day (Btu/day) ($2.3x10^8$ kilowatt-hours per day (kWh/day), or 9800 MW of thermal power output). Anthropogenic activities can also result in a net cooling effect on the river. An example given by Abood et al. (2006) suggests that a 1-million-gallon-per-day (mgd) (3800-m^3/day) sewage effluent facility discharging water at 18°C (64°F) during the summer would cool the river because river ambient temperatures are higher.

Attempts to determine long-term changes to the temperature of the lower Hudson River are often confounded by changes in measurement locations and procedures, especially in long-term studies.

An analysis of long-term temperature trends in the lower Hudson River was attempted by Ashizawa and Cole (1994), using data obtained from the Poughkeepsie Water Works (PWW), which processes drinking water. This facility is located in the Poughkeepsie study area approximately 30 mi (48 km) upstream from IP2 and IP3 (Figure 2-10). A nearly continuous data set is available from PWW, beginning in 1908 and continuing to the present day. The data set represents water withdrawn from the Hudson River approximately 14 ft (4.3 m) below low tide. The results of the study show that the overall mean annual water temperature at the intake location was 12.2°C (54°F), and that water temperatures were highly correlated with air temperature during the winter and spring months. Although the overall trends in temperature suggested a gradual warming, the authors concluded that the relationship was not monotonic (i.e., showing change in only one direction over time). Rather, there were periods of both increasing and decreasing temperatures, with episodes of statistically significant warming occurring approximately 22.7 percent of the time and episodes of significant cooling occurring 11.5 percent of the time. During the period from 1918 to 1990, the authors observed a significant increase in temperature, with a rate of warming of 0.12°C (0.22°F) per decade. The sharpest increase during that time occurred from 1971 to 1990 at 0.46°C (0.83°F) per decade; the sharpest cooling occurred from 1908 to 1923 at 0.79°C (1.42°F) per decade. The authors noted that there has been only one cooling event since 1923 (1968 to 1977), which occurred during a time of greater than average rainfall and record-setting freshwater flows, illustrating the complex relationships between weather, river flow, hydrodynamic connections, and anthropogenic effects discussed earlier.

Dissolved Oxygen

As discussed above, obtaining reliable data and trends associated with temperature and dissolved oxygen (DO) can be problematic in dynamic, open-ended systems. Measurements obtained during routine sampling within the river provide only a snapshot of actual conditions; measurements taken continuously from fixed, known locations provide long-term records, but only for the point or area of interest. Declines in DO can be caused by both natural and anthropogenic activities and may be transient or persist episodically or continually through time.

In some cases, observed declines in DO at specific times and locations in the Hudson River have been at least partially attributed to the appearance of invasive species, such as zebra mussels (Caraco et al. 2000). Even episodic events can have serious implications for fish and invertebrate communities and dramatically alter marine and estuarine food webs. To evaluate long-term DO trends in the lower Hudson River, Abood et al. (2006) examined two long-term data sets of DO observations collected by the New York City Department of Environmental Protection (NYCDEP) and covering the lower reaches of the river. Measurements of DO taken in August from 1975 to 2000 during the Long River Surveys indicate the lowest percent saturation (less than 75 percent) at West Point and the highest (greater than 90 percent) at the Kingston and Catskill reaches (Figure 2-10). Percent saturation at the river segment encompassing IP2 and IP3 was approximately 76 percent. Based on the NYCDEP data set, the authors concluded that there has been a substantial increase in DO since the early 1980s, probably resulting from the significant upgrades to the Yonkers and North River Sewage Treatment Plants in the lower reach of the Hudson.

Organic Matter

Organic matter can enter and influence a food web from two sources—autochthonous inputs, which are produced within the aquatic system, and allochthonous inputs, which are imported to the aquatic system from the surrounding terrestrial watershed (Caraco and Cole 2006). In the lower Hudson River, autochthonous sources of carbon originating within the river are associated with the primary production of phytoplankton and macrophyte communities. Studies by Caraco and Cole (2006) of the Hudson River from Albany to Newburgh during May–August 1999 and 2000 concluded that runoff from the upper Hudson and Mohawk River watershed was responsible for the majority of the allochthonous sources of carbon, represented as dissolved organic carbon (DOC) and particulate organic carbon (POC). Inputs from sewage, adjoining marshes, and tributaries accounted for less than 25 percent of the inputs. Total organic carbon (TOC) inputs were on average highest at the uppermost stretch of the Hudson and decreased down river by over twofold. Allochthonous loads were approximately fourfold lower in 1999 than in 2000 for all three river sections studied. The authors noted that the importance of allochthonous and autochothonous loads varied more than thirtyfold across space and time and that the variation was related to hydrologic inputs. During the summer of 1999 (the driest in

15 years), loadings of allochthonous inputs were low, but phytoplankton biomass and primary productivity were high. The resulting ratio of autochthonous/allochthonous inputs was tenfold greater than that measured during the summer of 2000 (the wettest in 15 years). These data suggest to the NRC staff that variations in sources and the importance of carbon inputs can be influenced by a variety of nonanthropogenic factors and result in changes to food web structure and function that directly impact higher trophic levels.

Nitrogen loading to rivers and estuaries comes primarily from forest and agricultural drainage, discharge from sewage treatment plants, and from nonpoint sources associated with urbanization. The most common forms of nitrogen in these systems are amino compounds originating from plant and animal proteins (CHGEC 1999). In the Hudson River, nitrate is the major contributor to the total nitrogen load, and in the lower Hudson River, approximately half of the total inorganic nitrogen loading is attributed to wastewater treatment systems and urban runoff (CHGEC 1999).

Total nitrogen and ammonia concentrations in the Hudson from Troy to Yonkers (obtained from EPA STORET) show differing trends from 1975 through 1992. Total nitrogen concentrations appear to vary without trend, while ammonia concentrations appear to be highest in river stretches near Yonkers and at locations upstream of Poughkeepsie (CHGEC 1999).

Phosphorus, in the form of phosphates, enters river systems as leachates from rock formations and soil. Additional inputs are associated with wastewater treatment plant discharges. Inorganic phosphates are used by plants and converted to organic forms that are used by animals (CHGEC 1999). Total phosphorus concentrations in the Hudson River during August 1974 suggest that the highest concentrations are associated with the lower 25 RM (40 RKM). Ortho-phosphorus concentrations from the EPA STORET database from 1975 through 1992 suggest that the highest concentrations are associated with the Yonkers-Piermont and Glenmont-Troy areas of the upper river.

The distribution and ratios of allochthonous and autochthonous nutrient inputs form the basis of complex food webs that can have large influences on upper trophic levels. Macronutrients such as carbon, nitrogen, phosphorus, and silicon are used by plants as raw materials to produce new biomass through photosynthesis. In some freshwater systems, the lack or excess of a specific macronutrient can limit growth or contribute to eutrophication and result in basinwide impacts to aquatic resources.

2.2.5.2 Significant Environmental Issues Associated with the Hudson River Estuary

Early Settlement

Anthropogenic impacts to the Hudson River ecosystem have existed for many centuries, with a possible origin approximately 11,000 years ago, after the retreat of the Wisconsin-stage ice sheet (CHGEC 1999). Swaney et al. (2006) categorized changes in watershed characteristics and effects based on four broad time scales—pre-European settlement, precolonial and colonial settlement, 19^{th} century, and 20^{th} century (Table 2-1). To put the scale of the anthropogenic impacts to the Hudson River watershed in context, the human population within the watershed has grown from approximately 230,000 at the time of the first census in 1790 to approximately 5 million today (not including parts of the boroughs of New York City outside the watershed, such as Queens). In 1609, the Hudson River watershed was almost entirely forested; by 1880, 68 percent of the watershed was farmland. Available records show that from the early 18^{th} century to 1993, nearly 800 dams were constructed in the watershed, ranging in height from 2 to

700 ft (0.6 to 213 meters) (Swaney et al. 2006). A brief chronology of significant events that occurred from pre-European settlement to modern times is presented below.

Before settlement by European explorers, impacts associated with aboriginal populations were restricted to those from activities associated with hunting and gathering, and localized fires. During precolonial and colonial settlement, immigrants cleared large portions of forest cover to accommodate agriculture. These activities altered watershed dynamics and increased settlement loads and temperature in streams and rivers. Dramatic anthropogenic impacts occurred during the 19th century as populations along rivers, streams, and coastal areas increased, land clearing continued, and construction of roads, bridges, railroads, canals, and industrial centers occurred to support the emerging industrial revolution. The emergence of tanning and logging activities resulted in large-scale clearing of forests, construction of roads that were later expanded into highways and railroad lines, and the development of dams and canals to control floods and divert water for human needs. All of these activities resulted in profound changes to the dynamics of the Hudson River watershed. In some cases, the presence of railroad lines or highways effectively isolated nearby wetland communities from the main stem of the river; in other cases, wetland and marsh areas were filled and destroyed. Dredging and dam development significantly altered the flow characteristics of the Hudson River and influenced the migratory patterns of many species (Swaney et al. 2006).

During the latter part of the 19th century, the growing human population created increased pollution and nutrient loading, which remained unregulated until the mid-20th century. Anthropogenic impacts occurring during the 20th century include the expansion of human population centers, further development of infrastructure to support industrial development (highways, roads, rail lines, factories), and a gradual shift in agricultural practices from traditional methods to new technologies that used specialized fertilizers, pesticides, and other agrochemicals. Industrialization during the 19th and 20th centuries also provided pathways for invasive species and nuisance organisms to colonize new habitats via canals, ship ballast water, and accidental or deliberate agricultural introductions (Swaney et al. 2006).

During the latter part of the 20th century, environmental awareness of degraded conditions resulted in the creation of important environmental laws and monitoring programs and significant improvements to wastewater treatment facilities. The laws and activities resulted in significant improvements to some water-quality parameters and a new awareness of emerging threats (e.g., the presence of endocrine-disrupting pharmaceuticals, nanomaterials, and other contaminants or constituents). A brief description of some of the significant environmental issues and anthropogenic events is presented below (Swaney et al. 2006).

Dredging, Channelization, and Dam Construction

As described above, dredging, channelization, and dam construction within the Hudson River watershed has occurred for over 200 years. The U.S. Army Corps of Engineers (USACE) has maintained a shipping channel from the ocean to the Port of Albany since the late 18th century and dredges the channel on an as-needed basis (CHGEC 1999). Dredging in some river segments occurs every 5 years (Miller et al. 2006). In some cases, dredging has significantly changed the hydrodynamic characteristics of the river and resulted in significant losses of intertidal and shallow water nursery habitats for fish (Miller et al. 2006). As described above, from the early 18th century to 1993, nearly 800 dams were constructed in the watershed, ranging in height from 2 to 700 ft (0.6 to 213 m) (Swaney et al. 2006). A study of the inorganic and organic content of marshes within the watershed by Peteet et al. (2006) revealed a pattern of decreasing inorganic content with the arrival of the Europeans to the present day that was probably the result of the construction of tributary dams. The presence of dams, river channelization, and shoreline armoring to protect road and rail lines disconnects or interferes with normal river processes and often results in an overall decrease of sediment transport into and through the estuary. Because these structures are now an existing part of the landscape, in most cases, it is extremely difficult or impossible to restore historical river structure and function.

Industry and Water Use Impacts

As described above, anthropogenic impacts on the watershed from aboriginal cultures were generally small and restricted to effects associated with hunter-gatherer community activities and the presence of fires. Before the 1900s, the dominant industries were those of the primary sector (agriculture, forestry, fishing, and mining). During the 1900s, there was an increase in the use of the Hudson River to provide transportation, drinking water, and water for industrial activities. During the development of industrial activity, there was a progressive increase in secondary sector industries, including the manufacture of food products, textiles, pulp and paper products, chemical, machinery, and transportation-related goods (CHGEC 1999).

The Hudson River was and is used as a source of potable water, a location for permitted waste disposal, a mode of transportation, and a source of cooling water by industry and municipalities. As of 1999, at least five municipalities use the lower Hudson as a source of potable water, and Rohmann et al. (1987) identified 183 separate industrial and municipal discharges to the Hudson and Mohawk rivers. The chemical industry has the greatest number of industrial users, followed by oil, paper, and textile manufacturers; sand, gravel, and rock processors; power plants; and cement companies (CHGEC 1999).

Table 2-1. Historical Impacts on the Hudson River Watershed

Pre-European Settlement	
Aboriginal agriculture	Localized fires and associated changes in biomass, habitat, and nutrient dynamics
Precolonial and Colonial Settlement	
Land clearing	Removal of forest cover and changes in habitat and streamflow characteristics
19th Century	
Tanning	Preferential clearing of forests leading to increased sediment and organic loads to water bodies
Logging	Extensive clearing of forests that affects water quality and habitat
Agriculture	Clearing of forests, use of fertilizers and nitrogen-fixing crops
Canal and dam development	Increase of waterborne invasive species, wetland drainage, flow alterations, habitat fragmentation
Railroad development	Increased access to forests leading to risk of fire; terrestrial, wetland, and aquatic habitat loss
Road development	Increases in impervious surfaces and runoff
Urbanization and industrialization	Increased pollution from unregulated sewage and factory waste discharges
Dam development for water supply infrastructure needs	Changes in flow regime and sediment transport
Highway and road development	Increase in impervious surfaces and runoff, impacts to terrestrial communities
Agriculture decline	Changes in land use practices (reforestation or increased land development)
Changing agricultural practices	Increased inorganic nutrients (fertilizers) and changes in organic (manure) loads
Urban development and sprawl	Impervious surface impacts, increased runoff, construction impacts, stream channelization

Adapted from: Swaney et al. 2006

At present, there are 11 facilities along the lower Hudson River with water discharges of 50 mgd (189,000 m^3/day) or greater (Table 2-2). Of these, two are associated with wastewater discharge, and nine are associated with power generation. Between Poughkeepsie and Yonkers (RM 24–77 (RKM 39–124)), there are four steam power generating stations that use water from the Hudson River for condenser cooling (Danskammer Point, Roseton, IP2 and IP3, and Bowline Point). Of these, IP2 and IP3 have traditionally used the greatest quantity of water for cooling (2800 mgd, or 10.6 million m^3/day), and Danskammer Point the least. Presently, Roseton operates intermittently, based on energy needs and the current prices of oil and natural gas. Excluding the water use of Roseton, the IP2 and IP3 facility accounts for 60 percent of the water use from RM 24–77 (RKM 39–124). Impacts associated with industrial water use can include impingement or entrainment of fish, larval forms, and invertebrates from water intake; heat or cold shock associated with water discharges; and the cumulative effects of the discharge of low levels of permitted chemicals (CHGEC 1999).

Municipal Wastewater Treatment Plants

Wastewater collection and sewage treatment construction began in New York City in the late 17th century, and many of the sewer systems were connected in lower and central Manhattan Island between 1830 and 1870. The first wastewater treatment system was constructed in 1886 and included a screen system designed to protect bathers on Coney Island (Brosnan and O’Shea 1996.)

In 2004, the NYSDEC identified 610 municipal wastewater treatment plants in New York State (NYSDEC 2004a). These facilities produce a total discharge flow of approximately 3694 mgd (13.98 million m^3/day). In the lower Hudson River basin, there are 78 secondary treatment facilities with a total flow of 556 mgd (2.1 million m^3/day), 41 tertiary facilities with a total flow of 11 mgd (42,000 m^3/day), and 10 other/unknown facilities with a total flow of approximately 1 mgd (3800 m^3/day). The total flow associated with all 129 facilities is approximately 568 mgd (2.15 million m^3/day). There are 33 facilities that use what is described as less than primary, primary, or intermediate treatment. A total of 404 facilities employ secondary treatment, and 173 employ tertiary treatment (NYSDEC 2004a).

As discussed above, the increasing populations along the Hudson River and within the watershed resulted in an increased discharge of sewage into the Hudson and an overall degradation of water quality. Beginning in 1906 with the creation of the Metropolitan Sewerage Commission of New York, a series of studies was conducted to formulate plans to improve water quality within the region (Brosnan and O’Shea 1996). In the freshwater portion of the lower Hudson River, the most dramatic improvements in wastewater treatment were made between 1974 and 1985, resulting in a decrease in the discharge of suspended solids by 56 percent.

Improvements in the brackish portion of the river were even greater. In the New York City area, the construction and upgrading of water treatment plants reduced the discharge of untreated wastewater from 450 mgd (1.7 million m^3/day) in 1970 to less than 5 mgd (19,000 m^3/day) in 1988 (CHGEC 1999). The discharge of raw sewage was further reduced between 1989 and 1993 by the implementation of additional treatment programs (Brosnan and O’Shea 1996).

During the 1990s, three municipal treatment plants located in the lower Hudson River converted to full secondary treatment—North River (1991), North Bergen MUA-Woodcliff (1991), and North Hudson Sewerage Authority West New York (1992). In addition, the North Hudson

Sewerage Authority-Hoboken plant, located on the western bank of the Hudson River opposite Manhattan Island, went to full secondary treatment in 1994 (CHGEC 1999). Upgrades to the Yonkers Joint Treatment plant in 1988 and the Rockland County Sewer District #1 in 1989 also resulted in improvements in water quality in the brackish portion of the Hudson River. In the mid-1990s, the Rockland County Sewer District #1 and Orangetown Sewer District plants were also upgraded(CHGEC 1999).

Table 2-2. Facilities Discharging at Least 50 mgd (190,000 m^3/day) into the Lower Hudson River

Facility	Activity	Location			Discharge (mgd)
		Region	RM	RKM	
59th Street Station	Power generation	Battery (BT)	7	11	70
North River	Wastewater discharge	Battery (BT)	10	16	170
Yonkers	Wastewater discharge	Yonkers (YK)	17	27	92
Bowline Point	Power generation	Croton-Haverstraw (CH)	37	60	912
Lovett	Power generation	Indian Point	42	68	496
Indian Point	Power generation	Indian Point	43	69	2,800
Westchester Resource Recovery	Power generation	Indian Point	43	69	55
Danskammer Point	Power generation	Poughkeepsie (PK)	66	106	457
Roseton[a]	Power generation	Poughkeepsie (PK)	67	108	926
Bethlehem	Power generation	Albany (AL)	140	225	515
Empire State Plaza	Power generation	Albany (AL)	146	235	108

[a] Roseton currently operates intermittently based on availability and cost of oil and natural gas.

Adapted from: Entergy 2007a

A review of long-term trends in DO and total coliform bacteria concentrations by Brosnan and O'Shea (1996) has shown that improvements to water treatment facilities have improved water quality. The authors noted that, between the 1970s and 1990s, DO concentrations in the Hudson River generally increased. The increases coincided with the upgrading of the North River plant to secondary treatment in spring 1991. DO, expressed as the average percent saturation, exceeded 80 percent in surface waters and 60 percent in bottom waters during summers in the early 1990s. DO minimums also increased from less than 1.5 mg/L in the early 1979s to greater than 3.0 mg/L in the 1990s, and the duration of low DO (hypoxia) events was also reduced (Brosnan and O'Shea 1996). Similar trends showing improvements in DO were noted by Abood et al. (2006) from an examination of two long-term data sets collected by NYCDEP in the lower reaches of the river. Brosnan and O'Shea (1996) also noted a strong decline in total coliform bacteria concentrations that began in the 1970s and continued into the 1990s, coinciding with sewage treatment plant upgrades.

Chemical Contaminants

The lower Hudson River currently appears on the EPA 303-d list as an impaired waterway because of the presence of polychlorinated biphenyls (PCBs) and the need for fishing restrictions (EPA 2004). The following is a description of the chemical contaminants in the river.

Chemical contaminants in the Hudson River and surrounding watershed generally fall into three major categories—(1) pesticides and herbicides, including dichloro-diphenyl-trichloroethane (DDT) and its metabolites, aldrin, lindane, chlordane, endrin, heptachlor, and toxaphene, (2) heavy metals, including arsenic, cadmium, chromium, copper, inorganic and methylated mercury, lead, and zinc, and (3) other organic contaminants, including PCBs, and polycyclic aromatic hydrocarbons (PAHs) (CHGEC 1999). In addition, there is a growing concern that the discharge of pharmaceuticals and hormones via wastewater may pose a risk to aquatic biota and human communities (NOAA 2008b). There is also a concern that waste products or residuals associated with the emerging nanotechnology market could create a new source of environmental risk (EPA 2007b).

Pesticides and herbicides generally enter the Hudson River via runoff from agricultural activities in the upper watershed and have a high affinity to binding with organic carbon. In the Hudson and Raritan River basins, the use of DDT, once a common pesticide, peaked in 1957 and subsequently decreased until the compound was banned in the early 1970s (Phillips and Hanchar 1996). Sediment contaminant trends suggest that the concentration of DDT in sediment has generally decreased since the 1970s and is currently at or near the effects-range-median (ER-M), which is the median sediment concentration for a particular chemical or contaminant at which adverse biological effects have been observed (Steinberg et al. 2004). In the lower Hudson River, comparison of the EPA-sponsored regional environmental monitoring and assessment program (R-EMAP) results from 1993 to 1994 and 1998 show that the concentrations of the metals cadmium, nickel, lead, and silver have generally declined and are at or below ER-M. The concentrations of mercury, however, continue to be above ER-M at many locations in the lower river (Steinberg et al. 2004).

Contamination of the sediment, water, and biota of the Hudson River estuary resulted from the manufacture of capacitors and other electronic equipment in the towns of Fort Edward and Hudson Falls, New York, from the 1940s to the 1970s. Investigations conducted by EPA and others over the past 25 years have delineated the extent and magnitude of contamination, and numerous cleanup plans have been devised and implemented. Recently, EPA Region 2 released a “Fact Sheet” describing a remedial dredging program designed to remove over 1.5 million cubic yards (1.15 million m^3) of contaminated sediment covering 400 acres (160 ha) extending from the Fort Edwards Dam to the Federal Dam at Troy (EPA 2008a). Phase 1 of the project was completed in October 2009, and resulted in the removal of 293,000 cubic yards of PCB-contaminated sediment from the river. While this volume exceeded established goals for Phase 1, removal was completed for only 10 of 18 targeted areas due to the presence of contamination in some areas that was deeper than expected, and the presence of woody debris and PCB oil in the sediment that complicated the removal effort. Phase 2 of the project will begin with removal actions at areas that were not completed under Phase 1 (EPA 2009). Concentrations of PCBs in river sediments below the Troy Dam are much lower. Work summarized by Steinberg et al. (2004) suggests that the sediment-bound concentrations of PCBs and dioxins have generally declined in the lower Hudson River since the 1970s and are now at or below ER-M limits.

Chemical contaminants present in the tissues of fish in the Hudson River estuary have been extensively studied for many years and resulted in the posting of consumption advisories by the States of New York and New Jersey. Current information summarized in Steinberg et al. (2004) suggests that many recreationally and important fish and shellfish still contain levels of metals, pesticides, PCB, and dioxins above U.S. Food and Drug Association (FDA) guidance values for commercial sales. Tissue concentrations of mercury were of concern only for striped bass; other fish and shellfish, including flounder, perch, eels, blue crab, and lobster, contained concentrations of mercury in their tissues well below the FDA limit for commercial sale of 2 parts per million (ppm). Concentrations of chlordane in white perch, American eels, and the hepatopancreas (green gland) of blue crab were also above FDA guidelines. Concentrations of DDT in the tissues of most recreationally and commercially valuable fish and shellfish in the estuary were below the 2 ppm FDA limit with the exception of American eel. The concentrations of 2,3,7,8-TCDD (commonly referred to as dioxin) and total PCBs in fish and shellfish tissues were often above FDA guidance limits, suggesting that fish and shellfish obtained from some locations within the estuary should be eaten in moderation or not at all. A detailed list of fish consumption advisories for both New York and New Jersey may be found in the *Health of the Harbor* report published by the Hudson River Foundation in 2004 (Steinberg et al. 2004).

Steinberg et al (2004) found that although a wide variety of contaminants still exists in sediment, water, and biota in the lower Hudson River, the overall levels appear to be decreasing because of the imposition of strict discharge controls by Federal and State regulatory agencies and improvements in wastewater treatment. These trends appear to be confirmed by the results of a NOAA-sponsored toxicological evaluation of the estuary in 1991, as described in Wolfe et al. (1996). Employing a combination of bioassay tests using amphipods, bivalve larvae, and luminescent bacteria and measurements of contaminants in a variety of environmental media, the NOAA study showed that spatial patterns of toxicity generally corresponded to the distributions of toxic chemicals in the sediments. Areas that exhibited the greatest sediment toxicity were the upper East River, Arthur Kill, Newark Bay, and Sandy Hook Bay. The lower Hudson River adjacent to Manhattan Island, upper New York Harbor, lower New York Harbor off Staten Island, and parts of western Raritan Bay generally showed lower toxicity. The supporting sediment chemistry, including acid-volatile sulfide and simultaneously extracted metals, suggests that metals were generally not the cause of the observed toxicity, with the possible exception of mercury. Among all contaminants analyzed, toxicity was most strongly associated with PAHs, which were substantially more concentrated in toxic samples than in nontoxic samples, and which frequently exceeded sediment quality criteria (Wolfe et al. 1996).

There is continuing concern, however, that legacy PCB waste may still pose a threat to invertebrate, fish, and human populations. A study by Achman et al. (1996) suggests that PCB concentrations in sediment measured at several locations in the lower Hudson River from the mouth to Haverstraw Bay are above equilibrium with overlying water and may be available for transfer within the food web. The authors concluded in some locations within the lower Hudson River, the sediments could act as a source of PCBs and pose a long-term chronic threat, but that fate and transport modeling would be required to fully understand the implications of this potential contaminant source.

Nonpoint Pollution

Nonpoint pollution can include the intentional or unintentional discharges of chemicals and constituents into rivers, streams, and estuaries. This section briefly summarizes three types of nonpoint pollution that may affect fish and shellfish resources in the Hudson River estuary—coliform bacteria that affect shellfish resources or swimmers, floatable debris, and surface slicks. All information is derived from Steinberg et al. (2004).

Levels of coliform bacteria in the Hudson River estuary have generally decreased from 1974 to 1998, primarily in response to wastewater treatment improvements. At present, only stretches of the river near the southern end of the island of Manhattan have geometric mean coliform concentrations of 201–2000 coliform cells/100 mL. The incidence of shellfish-related illness in New York State has also decreased from a high of over 100 reported cases per year in 1982 to only a few in 1999. Steinberg et al. (2004) caution, however, that the incidence of shellfish-related illness is probably underreported and likely misdiagnosed when reported.

Common floatable debris found on New York beaches includes cigarette butts, food containers and wrappings, plastic and glass, and medical waste. The amount of debris removed from New York Harbor annually has generally exceeded 5000 t (4500 MT) since 1988, with no apparent downward trend. The presence of surface slicks in the harbor has appeared to decline since 1994.

Invasive or Exotic Species

The presence of invasive or exotic species in the Hudson River estuary has been documented for over 200 years and probably began occurring after the Wisconsin-stage ice sheet receded over 10,000 years ago. In a compilation of information concerning the distribution of exotic organisms in the freshwater portions of the Hudson River basin, Mills et al. (1996) determined that at least 113 nonindigenous species of vertebrates, plants, and invertebrates have established populations in the Hudson River Basin. The list would undoubtedly be larger if better information was available concerning the historical populations of small invertebrates and algae. Most invasive species arrive through unintentional releases (e.g., from ship ballast water or agricultural cultivation activities) or via vectors introduced by the construction of canals.

While the presence of new or exotic species can result in a benefit (e.g., the largemouth and smallmouth bass recreational fishery), many have had a negative impact on their new environment. A classic example of the latter is the appearance of the zebra mussel in the freshwater portion of the Hudson River in 1991. Beginning in early fall 1992, zebra mussels have been dominant in the freshwater tidal Hudson, constituting more than half of heterotrophic biomass and filtering a volume of water equal to all of the water in the estuary every 1–4 days during the summer (Strayer 2007). The impacts of this species on the freshwater portions of the Hudson River are presented in Section 2.2.5.6.

The impacts of other invasive aquatic species are discussed elsewhere in this chapter. The issue is of magnitude significant enough to result in Federal actions to control future introductions. In 1992, the U.S. Congress passed an amendment to Public Law 101-646, the "Nonindigenous Aquatic Nuisance Species Act," extending some of the Great Lakes-oriented provisions of that Act and the regulations that followed from it to the Hudson River. In particular, as of late 1994, vessels entering the Hudson River with foreign ballast water must have exchanged that water in midocean and must arrive with a salinity of at least 30 ppt (Mills et al. 1996).

2.2.5.3 Regulatory Framework and Monitoring Programs

The regulatory framework, actions, and authorities governing environmental permitting and monitoring on the Hudson River are complex and have evolved significantly over time. The following is a chronological description of the major activities that have occurred over the past four decades.

Early Environmental Investigations

Early biological studies of the Hudson River began as a river survey program known as the Hudson River Fisheries Investigation (HRFI) which occurred from 1965 to 1968 under the direction of the Hudson River Policy Committee (HRPC) (Barnthouse and Van Winkle 1988). The investigations were intended to address the potential entrainment impacts of the proposed Cornwall pumped storage facility on striped bass. The objective of the HRFI program was to define the spatial and temporal distribution of striped bass eggs, larvae, and juveniles in relation to the intake to better understand the potential impacts of facility operation. The summary report produced by HRPC concluded that entrainment impacts associated with the operation of the Cornwall facility would be negligible, and this conclusion formed the basis of the decision by the Federal Power Commission (FPC) to license the facility in 1971. These conclusions were challenged on the grounds that an erroneous method had been used to estimate striped bass entrainment. This challenge ultimately resulted in a halt to the construction of the Cornwall facility in 1974 pending resolution of this issue (Barnthouse and Van Winkle 1988; Christensen and Englert. 1988).

During this period, IP1 was in operation, IP2 and IP3 were under construction, and a modest fish sampling program was being conducted in the area of Indian Point by New York University and Raytheon (Barnthouse and Van Winkle 1988). The enactment of the National Environmental Policy Act of 1969 (NEPA) on January 1, 1970, and the interpretation that it required the Atomic Energy Commission (AEC) to explicitly consider nonradiological impacts in its licensing decisions had immediate and dramatic impacts on IP2 and IP3. During the permitting process for IP2, the major point of contention again centered on whether facility operation would significantly affect striped bass eggs, larvae, and juveniles because of entrainment. The Consolidated Edison Company of New York, the owner of IP2 at the time, concluded in its ER that entrainment impacts would be insignificant. The environmental impact statement (EIS) prepared by the AEC staff in 1972 expressed concern about the impacts of thermal discharges, entrainment, and impingement associated with cooling system operation and concluded that "The operation of IP1 and IP2 with the present once-through cooling system has the potential for a long-term environmental impact on the aquatic biota inhabiting the Hudson River which [sic] would result in permanent damage to and severe reduction in the fish population, particularly striped bass, in the Hudson River, Long Island Sound, the adjacent New Jersey coast, and the New York Bight" (USAEC 1972). The final conclusion reached by AEC for IP2 was a recommendation that an operating license be issued with the following conditions to protect the environment—(1) once-through cooling was permitted only until January 1, 1978, and thereafter a closed-cycle system would be required, (2) the applicant would evaluate the economic and environmental impacts of an alternative closed-cycle system and submit this evaluation to AEC by July 1, 1973, (3) after approval by AEC, the required closed-cycle system would be designed, built, and placed in operation no later than January 1, 1978 (USAEC 1972).

The USAEC results published in 1972 were influenced to a great extent by the results of an entrainment model developed by C.P. Goodyear of the Oak Ridge National Laboratory (described in Hall 1977), and during subsequent years, the use of numerical simulation models to assess the impacts of entrainment from once-through facilities received a great deal of attention. As the models were developed, there was much debate concerning the assumptions used by the modelers, and the predictive ability of the models was the subject of numerous scientific symposia, peer-reviewed journal articles, and hearings. This information formed the basis of the decisions handed down by the Atomic Safety and Licensing Board in 1973 and the Atomic Safety and Licensing Appeals Board in 1974. These decisions stipulated that IP2 would be allowed to operate using once-through cooling but only until May 1, 1979. Unless the operator of the facility could demonstrate through new studies that the environmental impacts of once-through cooling were negligible, cooling towers would have to be installed (Barnthouse et al. 1984).

In late 1974, FPC held hearings to reconsider the Cornwall facility application. Recent data and numerical models that had been developed for IP2 were also evaluated. Because the information and assessment presented at the hearings provided conflicting conclusions concerning impacts, FPC was unable to determine the magnitude of potential environmental impacts, and the hearings were adjourned without resolution concerning plant licensing. In 1975, the NRC, the successor agency to AEC, published an EIS for IP3 that once again expressed concern associated with the impacts of the once-through cooling system, including impacts associated with entrainment, impingement, and thermal releases. Using a combination of entrainment modeling and an improved striped bass life-cycle model, the NRC concluded that impingement and entrainment impacts were “likely to result in a substantial decrease in the Hudson River spawned striped bass population” (NRC 1975). The NRC indicated that the applicant, who had used different parameters in its impingement and entrainment simulation modeling, did not share this conclusion. The NRC agreed to allow IP3 to operate as a once-through facility but required the applicant to comply with a variety of technical specifications including the collection of additional environmental data to evaluate the impact of entrainment, impingement, and thermal discharges. The applicant was also required to comply with the license conditions agreed to in 1974 that required a cessation of once-through cooling by 1979 unless new evidence demonstrated that environmental impacts were negligible (NRC 1975; Barnthouse et al. 1984).

<u>Pollutant Discharge Elimination System Permitting</u>

On October 28, 1975, EPA gave its approval to NYSDEC to issue SPDES permits in the State of New York. Before that time, national pollutant discharge elimination system (NPDES) (the federally administered analog to SPDES for States in which EPA has not granted authority to discharge to waters of the United States) permits were issued directly by EPA. Issues considered by EPA before the issuance of the 1975 permits included the thermal impacts of once-through cooling and fish mortalities associated with the cooling water intakes. During this time, scientists representing both the applicants and the regulatory agencies had embarked on ambitious programs to better understand the impacts of once-through cooling systems on sensitive fish species. This included a large-scale field program and the use and refinement of numerical simulation models to better understand entrainment impacts.

Depending on the model used and the assumptions employed, the impacts of once-through cooling ranged from negligible to catastrophic (Barnthouse et al. 1984). Further, although field collections were occurring, the amount of information available to be used as input data or to calibrate model output was limited. As a result, the EPA deemphasized the use of simulation modeling to estimate entrainment impacts and, in 1975, issued permits for IP2 and IP3, Bowline Units 1 and 2, and Roseton Unit 1 that required the construction of cooling towers. The utility companies contested the permits and requested adjudicatory hearings. In 1977, the owners of IP2 and IP3, Bowline, and Roseton facilities sought an administrative adjudicatory hearing against the EPA NPDES permits issued in 1975 to overturn the cooling water intake conditions and other requirements. The EPA hearings began in 1977 and ended in 1980 with the Hudson River Settlement Agreement (HRSA).

Hudson River Settlement Agreement

After a number of years of adjudicatory proceedings, the owners of IP2 and IP3, Roseton, and Bowline facilities signed the HRSA. The 10-year agreement was intended to resolve the disputes related to the issuance of the 1975 NPDES permits and provide the necessary funding to support a long-term investigation of the lower Hudson River estuary. Parties to the agreement, which was effective for the 10-year period from May 10, 1981, to May 10, 1991, included EPA, the New York State Attorney General, NYSDEC, the Scenic Hudson Preservation Conference (Scenic Hudson), the Hudson River Fishermen's Association (the predecessor to Riverkeeper), and the Natural Resources Defense Council (NYSDEC 2003a). HRSA provided for mitigative measures to reduce fish mortalities at each generation station from impingement and entrainment during once-through cooling operation, seasonal outages during sensitive aquatic life stages, and the installation of variable speed pumps at IP2 and IP3 within 3½ years of the effective date of the agreement to allow for more efficient use of cooling water. In addition, HRSA established a biological monitoring program of fish species at various life stages within the lower Hudson River to better understand spatial and temporal trends.

In 1982, NYSDEC, under authority from EPA, issued SPDES permits to each of the facilities covered by HRSA. The permits included limitations on thermal releases and incorporated the terms of HRSA in the permit language to ensure that the environmentally protective mitigative measures stipulated in the agreement were included as conditions. These permits expired in 1987, and NYSDEC issued SPDES permit renewals to each of the three HRSA facilities. Permits for IP2 and IP3, Bowline Point 1 and 2, and Roseton 1 and 2 became effective on October 1, 1987, and have been administratively continued by the NYSDEC since October 1,1992 (NYSDEC 2003a). HRSA conditions were incorporated into the permit language as before. Before the permits expired in 1992, NYSDEC received timely renewal applications, and the department and the applicants executed an agreement on May 15, 1991, to continue the mitigative measures described in HRSA until the SPDES renewal permits were issued. The agreement also stipulated that the parties would negotiate in good faith to resolve issues associated with impingement, entrainment, and thermal discharges, and to resolve issues associated with mitigation and alternatives (NYSDEC 2003a).

In response to a lawsuit filed in 1991 by Riverkeeper, Scenic Hudson, and the Natural Resources Defense Council, a consent order was signed by all parties on March 23, 1992, which stipulated that the operators of IP2 and IP3, Roseton, and Bowline would continue the HRSA mitigative measures, such as timed outages to reduce impacts to fish, and continue to fund the ongoing environmental studies of the lower Hudson River. The 1992 consent order was extended by the parties on four separate occasions, with the fourth extension expiring on February 1, 1998. At present, there has been no agreement on a fifth consent order because of the ongoing SPDES renewal process, but the operators of IP2 and IP3, Roseton, and Bowline have agreed to continue the mitigative measures included in their existing SPDES permit and to follow the provisions of the fourth consent order until new SPDES permits are issued (NYSDEC 2003b). The major monitoring and assessment programs conducted under HRSA that form the basis for the staff's assessment of impacts are discussed below.

<u>Environmental Studies in the Lower Hudson Estuary</u>

Numerous environmental studies were conducted in the Hudson River in support of HRSA and by other organizations to develop a baseline and to assess changes to key components of the ecosystem over time. A general description of the studies evaluated during the development of this SEIS is presented in Table 2-3. Other studies are cited throughout the description and historical assessment of impacts; however, only the data obtained from these studies were made available for further analysis.

Impingement losses associated with IP2 and IP3 were studied annually from 1975 to 1990. Data from 1975 to 1980 provided for analysis were weekly estimates of the total number impinged, organized by operating unit and taxon. From 1979 to 1980, estimates were further delineated by life stage (young of the year, yearling, yearling or older). Data from 1981 to 1990 included seasonal estimates of the total number impinged by operating unit, taxon, and life stage.

As a part of the HRSA, IP2 and IP3 were required to replace the existing debris screens in 12 of the intake bays with angled screens and fish bypass systems. A subsequent analysis, however, showed that the angled screen system did not significantly reduce impingement mortality, and so the HRSA settlement parties rejected this mitigation option (Fletcher 1990). Con Edison and the New York Power Authority elected to install and test a Ristroph screen system at IP2 and IP3. The trial machine, referred to as "screen version 1" by Fletcher (1990), was installed in a single intake bay of IP2 and IP3 and evaluated from January 16 to April 19, 1985. At the request of the Hudson River Fishermen's Association, Fletcher (1990) evaluated the design of the trial machine, conducted flume tests, and suggested improvements to the design that were incorporated into "screen version 2." This final design, also known as a modified Ristroph screen, was installed in all intake bays of IP2 and IP3. As it was not required by the NYSDEC, no further studies were conducted after the installation of the modified Ristroph system at IP2and IP3 to determine actual mortality of key species, and no additional impingement monitoring was conducted.

Ichthyoplankton entrainment losses associated with IP2 and IP3 were studied between May and August in 1981, 1983 through 1985, and in 1987, as well as between January and August 1986. Data provided for this analysis were the combined IP2 and IP3 weekly mean densities (number/1000 m^3) of each life stage (egg, yolk-sac larvae, post-yolk-sac larvae, and juvenile) by taxon.

Data from the three field surveys from the Hudson River Estuary Monitoring Program were also provided for this analysis (Long River Survey (LRS), Fall Juvenile Survey (FJS), and the Beach Seine Survey (BSS)). All three data sets include the annual total catch and volume sampled per taxon from 1974 through 2005, the annual abundance index per taxon and life stage from 1974 through 2005, and the weekly regional density of each life stage by taxon from 1979 through 2005.

Table 2-3. Hudson River Environmental Studies Table
(Information used in SEIS to assess impacts; data provided by Entergy)

Study	Study Dates	Information Available
Impingement Abundance[1]	1975–1990	Number of fish impinged at IP2 and IP3.
Entrainment Abundance Studies	1981 1983–1987	Entrainment density by species and life stage for IP2 and IP3 combined.
Longitudinal River Ichthyoplankton Surveys	1974–2004	Standing crop, temporal and geographic distributions, and growth rates for ichthyoplankton forms of fish species, with an emphasis on Atlantic tomcod, American shad, striped bass, white perch, and bay anchovy. Sampling generally occurred in spring, summer, and fall.
Fall Juvenile Surveys	1974–2005	Standing crop and temporal and geographic indices for young-of-the-year fish in shoal, bottom, and channel habitats in the estuary with an emphasis on Atlantic tomcod, American shad, striped bass, and white perch. Surveys generally conducted in midsummer and fall.
Beach Seine Surveys	1974–2005	Abundance and distribution of young-of-the-year fish in the shore-zone habitat in the estuary, with an emphasis on American shad, Atlantic tomcod, striped bass, and white perch. Surveys generally conducted in summer and fall.

2.2.5.4 Potentially Affected Fish and Shellfish Resources

The Hudson River estuary is home to a large and diverse assemblage of fish and shellfish. Species richness and abundance vary according to season and location and can be influenced by climatological changes that affect water temperature, salinity, and sediment load. Waldman et al. (2006) report that 212 species of fish have been recorded north of the southern tip of Manhattan Island, with the largest contributions associated with temperate marine strays (65), introduced species (28), and freshwater species surviving the Pleistocene glaciations in the Atlantic coast refugia (21). The authors also note that only 10 diadromous (traveling between fresh- and salt-water) species are known to occur in the Hudson River Estuary.

The NRC staff identified 18 aquatic representative important species (RIS) to use in assessing the impacts of IP2 and IP3 (Table 2-4). This list contains RIS identified in past analyses conducted by NYSDEC, the NRC, and the current and past owners of IP2 and IP3. The aquatic RIS identified in this section are meant to represent the overall aquatic resource and reflect the

[1] Entergy re-submitted this data to NRC on November 24, 2009, because the data Entergy initially provided to NRC staff contained errors that caused some impingement numbers to appear artificially high. The new data are publicly available through ADAMS at ML093420528. NRC staff relied on the new impingement data – along with the other data listed in Table 2-3 – for its analysis in this SEIS.

complexity of the Hudson River ecosystem by encompassing a broad range of attributes, such as biological importance, commercial or recreational value, trophic position, commonness or rarity, interaction with other species, vulnerability to cooling system operation, and fidelity or transience in the local community. Table 2-5 provides the locations in the Hudson River estuary where specific RIS and life stages represented at least 10 percent of the total number collected in reference surveys or studies.

What follows is a discussion of life histories, abundance data, and other information for each aquatic RIS. Unless otherwise noted, information on impingement or entrainment trends are from electronic data provided to NRC staff by Entergy or its contractors. The significance of impingement and entrainment, and the presence of other potential environmental stressors on aquatic RIS is discussed in Chapter 4 and Appendixes H and I.

Table 2-4. Aquatic Representative Important Species

Common Name	Scientific Name	Occurrence and Status	Predator/Prey Relationships
Alewife	*Alosa pseudoharengus*	Anadromous	Juveniles eat insect larvae and amphipods; adults eat zooplankton, small fish, and fish eggs. Species is prey of bluefish, weakfish, and striped bass.
Atlantic menhaden	*Brevoortia tyrannus*	Permanent or seasonal resident	Juveniles and adults eat phytoplankton, zooplankton, copepods, and detritus. Species is prey of bluefish and striped bass.
American shad	*Alosa sapidissima*	Anadromous	Juveniles and adults primarily eat zooplankton, small crustaceans, copepods, mysids, small fish, and fish eggs. Species is prey of oceanic species.
Atlantic sturgeon	*Acipenser oxyrinchus*	Candidate for Federal endangered status; Anadromous	Juveniles and adults are bottom feeders, subsisting on mussels, worms, shrimp, and small fish.
Atlantic tomcod	*Microgadus tomcod*	Anadromous permanent or seasonal resident	Diet includes crustaceans, polychaete worms, mollusks, and small fish. Juveniles are prey of striped bass when anchovies are scarce.
Bay anchovy	*Anchoa mitchilli*	Estuarine	Species primarily eats zooplankton and is prey of YOY bluefish and striped bass.
Blueback herring	*Alosa aestivalis*	Anadromous	Species' diet includes insect larvae and copepods It is prey of bluefish, weakfish, and striped bass.
Bluefish	*Pomatomus saltatrix*	Permanent or seasonal resident	Juveniles eat bay anchovy, Atlantic silverside, striped bass, blueback herring, Atlantic tomcod, and American shad. Species is prey of a variety of birds.

Gizzard shad	*Dorosoma cepadianum*	Freshwater	Juveniles eat daphnids, cladocerans, adult copepods, rotifers, algae, phytoplankton, and detritus; adults eat phyto- and zooplankton. Species is prey of striped bass, other bass species, and catfish.
Hogchoker	*Trinectes maculates*	Estuarine	Adults are generalists and eat annelids, arthropods, and tellinid siphons. Species is prey of striped bass.
Rainbow smelt	*Osmerus mordax*	Anadromous	Larval and juvenile smelt eat planktonic crustaceans; larger juveniles and adults feed on crustaceans, polychaetes, and fish. Adults eat anchovies and alewives. Species is prey of striped bass and bluefish.
Shortnose sturgeon	*Acipenser brevirostrum*	Federally endangered; permanent or seasonal resident	Juveniles feed on benthic insects and crustaceans.
Spottail shiner	*Notropis hudsonius*	Freshwater	Species eats aquatic insect larvae, zooplankton, benthic invertebrates, and the eggs and larvae of fish, including their own species. Species is prey of striped bass.
Striped bass	*Morone saxatilis*	Anadromous	Species eats menhaden. river herring, tomcod, and smelt. Larvae are prey of spottail shiner, white perch, striped bass, bluegill, and white catfish.
Weakfish	*Cynoscion regalis*	Permanent or seasonal resident	Small weakfish feed primarily on crustaceans, while larger weakfish feed primarily on anchovies, herrings, spot. Species is prey of bluefish, striped bass, and other weakfish.
White catfish	*Ameiurus catus*	Freshwater	Juveniles eat midge larvae. Adults are omnivores, feeding on anything from fish to insects to crustaceans.
White perch	*Morone americana*	Estuarine	Species eat eggs of other fish and larvae of walleye and striped bass. Prey of larger piscivorous fish and terrestrial aquatic vertebrates.
Blue Crab	*Callinectes sapidus*	Estuarine	Zoea eat phytoplankton, and dinoflagellates; adults opportunistic. Larval crabs are the prey of fish, shellfish, jellyfish; juvenile and adult blue crabs are prey of a wide variety of fish, birds, and mammals.

Table 2-5. Locations in the Hudson River Estuary (see Figure 2-10) Where the Presence of Aquatic RIS Life Stages Represented at Least 10 Percent of the Total Number Collected in Referenced Surveys or Studies (adapted from ASA 2007; river segment abbreviations from Figure 2-10)

<table>
<tr><th rowspan="2">Species</th><th rowspan="2">Lifestage</th><th colspan="13">River Segments</th></tr>
<tr><th>BT</th><th>YK</th><th>TZ</th><th>CH</th><th>IP</th><th>WP</th><th>CW</th><th>PK</th><th>HP</th><th>KG</th><th>SG</th><th>CS</th><th>AL</th></tr>
<tr><td rowspan="5">Alewife</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS[c]</td></tr>
<tr><td>YSL[d]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td></tr>
<tr><td>PYSL[e]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">LRS</td><td></td></tr>
<tr><td>YOY[f]</td><td></td><td></td><td colspan="2">BSS[a]</td><td></td><td></td><td>BSS</td><td></td><td></td><td></td><td colspan="2">BSS</td><td></td></tr>
<tr><td>Year +[g]</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Atlantic menhaden[h]</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td colspan="4">ASMFC 2006a</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">American shad</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">LRS</td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td>BSS</td><td colspan="3">LRS</td><td colspan="2">LRS/BSS</td><td>BSS</td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Atlantic sturgeon</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td colspan="3">FJS[b]: Only 12 fish caught 2005</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Atlantic tomcod</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td colspan="2">LRS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td colspan="2">LRS/FJS</td><td></td><td colspan="2">LRS/FJS</td><td>FJS</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td colspan="2">FJS</td><td></td><td colspan="2">FJS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 2-5 (continued)

<table>
<tr><th>Species</th><th>Lifestage</th><th>BT</th><th>YK</th><th>TZ</th><th>CH</th><th>IP</th><th>WP</th><th>CW</th><th>PK</th><th>HP</th><th>KG</th><th>SG</th><th>CS</th><th>AL</th></tr>
<tr><td rowspan="5">Bay anchovy</td><td>Eggs</td><td colspan="3">LRS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td colspan="4">LRS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td colspan="5">LRS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td colspan="4">LRS/BSS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td colspan="2">BSS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Blueback herring</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">LRS</td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">LRS/BSS</td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Bluefish</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td colspan="3">BSS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Gizzard shad</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">BSS</td><td></td><td colspan="2">BSS</td><td></td><td>BSS</td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">BSS</td><td></td><td colspan="2">BSS</td><td></td><td></td></tr>
</table>

Table 2-5 (continued)

<table>
<tr><th>Species</th><th>Lifestage</th><th>BT</th><th>YK</th><th>TZ</th><th>CH</th><th>IP</th><th>WP</th><th>CW</th><th>PK</th><th>HP</th><th>KG</th><th>SG</th><th>CS</th><th>AL</th></tr>
<tr><td rowspan="5">Hogchoker</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td>FJS</td><td></td><td colspan="4">FJS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td colspan="3">FJS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Rainbow smelt</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">LRS</td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">LRS</td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td colspan="7">LRS</td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td colspan="7">LRS/FJS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td colspan="4">FJS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Shortnose sturgeon</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td rowspan="2">ER Text</td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td colspan="13">FJS/LRS: Only 32 fish caught in 2005</td></tr>
<tr><td rowspan="5">Spottail shiner</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>BSS</td><td></td><td colspan="4">BSS</td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>BSS</td><td></td><td></td><td colspan="3">BSS</td></tr>
<tr><td rowspan="5">Striped bass</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td colspan="6">LRS</td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td colspan="5">LRS</td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td colspan="6">LRS</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td colspan="6">LRS/BSS</td><td></td><td></td><td></td><td>LRS</td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td colspan="2">BSS</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">BSS</td><td></td></tr>
</table>

Table 2-5 (continued)

<table>
<tr><th>Species</th><th>Lifestage</th><th>BT</th><th>YK</th><th>TZ</th><th>CH</th><th>IP</th><th>WP</th><th>CW</th><th>PK</th><th>HP</th><th>KG</th><th>SG</th><th>CS</th><th>AL</th></tr>
<tr><td rowspan="5">Weakfish</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td colspan="4">FJS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td colspan="2">FJS</td><td></td><td></td><td>FJS</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">White catfish</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>FJS</td><td></td><td></td><td colspan="3">FJS</td></tr>
<tr><td>Year +</td><td></td><td></td><td colspan="2">FJS</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">FJS</td></tr>
<tr><td rowspan="5">White perch</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="4">LRS</td></tr>
<tr><td>YSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="6">LRS</td></tr>
<tr><td>PYSL</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">LRS</td><td></td></tr>
<tr><td>YOY</td><td></td><td></td><td colspan="2">BSS</td><td colspan="5">LRS</td><td colspan="2">BSS</td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td colspan="2">BSS</td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">BSS</td><td></td></tr>
<tr><td rowspan="5">Blue crab[l]</td><td>Eggs</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Zoea</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Megalops</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Juvenile</td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Year +</td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

[a] BSS: Beach Seine Survey (1974–2005)
[b] FJS: Fall Juvenile Survey (also known as Fall Shoals Survey) (1979–2004)
[c] LRS: Long River Survey (1974–2004)
[d] YSL: yolk-sac larvae
[e] PYSL: post-yolk-sac larvae
[f] YOY: young of year
[g] Year +: yearling and older
[h] Obtained from ASMFC 2006a distribution
[l] Obtained from ASMFC 2006a distribution
Source: NYSDEC 2004b

Alewife

The alewife (*Alosa pseudoharengus*, family Clupeidae) is a pelagic, anadromous species found in riverine and estuarine habitats along the Atlantic coast from Newfoundland to South Carolina; landlocked populations have also been introduced in the Great Lakes and Finger Lakes. The species is historically one of the most commercially important fish species in Massachusetts and continues to be harvested as a source of fish meal, fish oil, and protein for animal food industries (Fay et al. 1983). The commercial fishing industry does not differentiate between the alewife and the blueback herring (*Alosa aestivalis*) and refers to the two species collectively as river herring. Commercial landings of river herrings peaked in the 1950s at approximately 34,000 MT (37,500 t) and then declined to less than 4000 MT (4400 t) in the 1970s (Haas-Castro 2006a). Between 1996 and 2005, landings of river herring ranged from 300 to 900 MT (330 to 990 t) annually, with 90 percent of landings in Maine, North Carolina, and Virginia (Haas-Castro 2006a). The river herring fishery is one of the oldest fisheries in the United States; however, no commercial fisheries for river herring exist in the Hudson River today. River herring are often taken as bycatch in the offshore mackerel fishery; within New York and New Jersey, river herring accounted for 0.3 percent of annual landings on the Atlantic coast (CHGEC 1999).

Spawning adults enter the Hudson River from the Atlantic Ocean in early spring and spawn once per year between late May and mid-July in shallow, freshwater tributaries with low current at temperatures between 11°C (52°F) and 27°C (81°F) (Everly and Boreman 1999; Fay et al. 1983). Females first spawn at 3 to 4 years of age and produce 60,000 to 100,000 eggs. Alewives spawn 3 to 4 weeks before blueback herring in areas where the two species occur sympatrically, and the peak spawning of each species occurs 2 to 3 weeks apart from one another (Fay et al. 1983). Within the Hudson River estuary, peak abundance of river herring eggs generally occurs within the Catskill region of the upper estuary during mid-May (CHGEC 1999). Incubation time varies inversely with water temperature and ranges from 2 to 15 days, and eggs are semidemersal and are easily carried by currents (Fay et al. 1983; CHGEC 1999). The yolk sac larvae (YSL) stage lasts approximately 2 to 5 days, and the post-yolk-sac larvae (PYSL) stage lasts until transformation to the juvenile stage at approximately 20 millimeters (mm) (0.78 in.). Full development occurs at approximately 45 mm (1.8 in.) at the age of about 1 month (Fay et al. 1983; CHGEC 1999).

Young-of-the-year (YOY) have been found in both lower and upper regions of the river (Table 2-5). Juveniles migrate to the ocean between July and November of their first year. At sexual maturity, alewives weigh 153 to 164 grams (g) (0.34 to 0.36 pounds (lb)) and can weigh 325 to 356 g (0.72 to 0.78 lb) by their seventh year; the average length for males is 29 cm and for females is 31 cm (Fay et al. 1983). Alewives in the Hudson River estuary have a life span of up to 9 years (Haas-Castro 2006a). Juveniles in the lower Hudson River have been reported to feed on chironomid larvae and amphipods, and the diet of adult alewives consists primarily of zooplankton, amphipods, mysids, copepods, small fish, and fish eggs. After spawning, alewives feed heavily on shrimp (Fay et al. 1983; CHGEC 1999). The species fulfills an important link in the estuarine food web between zooplankton and top piscivores. Juvenile and adult alewife is prey for gulls, terns, and other coastal birds, as well as bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and striped bass (*Morone saxatilis*) (CHGEC 1999).

The annual abundance in the Hudson River of YOY alewifes has been estimated to range from 110,000 to 690,000 individuals (CHGEC 1999). For each annual cohort, entrainment mortality for the combined abundance of alewife and blueback herring for all water withdrawal locations within the Hudson River varies widely, ranging from 8 to 41 percent for data taken between 1974 and 1997, while impingement mortality of the alewife is low, ranging from 1.1 to 1.9 percent for the same time period (CHGEC 1999). The Atlantic States Marine Fisheries Commission (ASMFC) implemented a Fisheries Management Plan for the American shad and river herring in 1985. Restoration efforts under the plan include habitat improvement, fish passage, stocking, and transfer programs; however, the abundance of river herring still remains well below historic estimates (Haas-Castro 2006a). River herring were present in both impingement and entrainment samples obtained from IP2 and IP3.

<u>Atlantic Menhaden</u>

The Atlantic menhaden (*Brevoortia tyrannus*, family Clupeidae) is a euryhaline species found in inland tidal waters along the Atlantic coast from Nova Scotia to Florida (MRC 2006). Menhaden is commercially harvested as a high-grade source of omega-3 fatty acid, which is used in pharmaceuticals and processed food production (ASMFC 2006a). Atlantic menhaden make up between 25 and 40 percent of the combined annual landings of menhaden species along the Atlantic coast and Gulf of Mexico (Rogers and Van Den Avyle 1989). The Atlantic menhaden was first commercially fished in the late 1600s and early 1700s for use in agricultural fertilizer, and the species was later harvested for oil beginning in the early 1800s (Rogers and Van Den Avyle 1989). Fish meal from menhaden also became a staple component in swine and ruminant feed beginning in the mid-1900s and began to be used in aquaculture feed in the 1990s (ASMFC 2006a).

Atlantic menhaden migrate seasonally and exhibit north-south and inshore-offshore movement in large schools composed of individuals of a similar size and age (Rogers and Van Den Avyle 1989). Migration patterns are linked to spawning habits, and the species spawns year-round throughout the majority of its range, with spawning peaks in the spring and fall in mid-Atlantic and northern Atlantic regions (MRC 2006). Menhaden reach sexual maturity at lengths of 18 to 23 cm (7.1 to 9.1 in.), and female fecundity ranges from 38,000 eggs for a small female to 362,000 eggs for a large female (ASMFC 2006a; MRC 2006). Eggs are pelagic and hatch offshore in 2.5 to 2.9 days at an average temperature of 15.5°C (59.9°F) (ASMFC 2006a; Rogers and Van Den Avyle 1989). Larvae absorb the yolk sac within approximately 4 days of hatching and begin to feed on zooplankters (Rogers and Van Den Avyle 1989).

The survival of larvae is a function of temperature and salinity, with the highest survival rates occurring in laboratory experiments at temperatures greater than 4°C (39°F) and salinities of 10 to 20 ppt (ASMFC 2006a). Larvae migrate shoreward into estuaries at 1 to 3 months of age at a size of 14 to 34 mm (0.55 to 1.3 in.) (ASMFC 2006a). Metamorphosis to the juvenile stage occurs at approximately 38 mm (1.5 in.), and menhaden begin to filter feed on phytoplankton, zooplankton, copepods, and detritus (MRC 2006). Juveniles move into shallow portions of estuaries and are generally more abundant in areas of lower salinity (less than 5 ppt) and waters above the brackish-freshwater boundary in rivers. Juveniles leave estuaries in dense schools between August and November at lengths of 55 to 140 mm (2.2 to 5.5 in.) and migrate southward along the North Carolina coast as far south as Florida in late fall and early winter (Rogers and Van Den Avyle 1989). During the following spring and summer, menhaden move northward, redistributing in schools consisting of similarly sized individuals (ASMFC 2006a).

Most menhaden reach maturity at 2 years of age, at which point approximately 90 percent of individuals are capable of spawning (Rogers and Van Den Avyle 1989). Menhaden lose their teeth as juveniles, and adults are strictly filter feeders, feeding on planktonic organisms (ASMFC 2006a). Atlantic menhaden can live 8 to 10 years; however, fish over 4 years of age are uncommon in commercial catches. Maximum adult length is 500 mm (19.7 in.) and maximum weight is 1500 g (3.3 lb) (Rogers and Van Den Avyle 1989). Menhaden are prey for a number of piscivorous fish, including bluefish (*P. saltatrix*), striped bass (*M. saxatilis*), bluefin tuna (*Thunnus thynnus*), as well as birds and marine mammals because of their abundance in nearshore and estuarine waters (ASMFC 2006a; Rogers and Van Den Avyle 1989).

Atlantic menhaden were not a focus of the Hudson River monitoring programs; therefore, historical records for the Hudson River population trends are unavailable. However, based on tagging studies, the Atlantic menhaden population appears to be composed of a single population that undergoes extensive seasonal migration (ASMFC 2006a). Menhaden are primarily harvested via reduction purse-seine fishing, and Virginia and North Carolina are the only States that currently permit this type of fishing for this species (ASMFC 2006a). Menhaden landings peaked during the late 1950s at an annual average of over 600,000 t (544,000 MT) and then declined during the 1960s from 576,000 t (523,000 MT) in 1961 to 162,000 t (147,000 MT) in 1969. Landings rose in the 1970s as the stock rebuilt, maintained moderate levels during the 1980s, and declined again in the 1990s. Landings have varied in the 2000s with average annual landings of 184,900 t (168,000 MT) from 2000 to 2004, and 146,900 t (133,000 MT) landed in 2005. Landings from the reduction purse-seine fishery accounted for 79 percent of total landings along the Atlantic coast in 2005 (ASMFC 2006a). Atlantic menhaden are also harvested for bait in many Atlantic coast States; however, no data are available for these landings as they are taken via cast net, pound net, gill net, and as bycatch. Atlantic menhaden were generally not present in entrainment samples from IP2 and IP3, but were present in impingement samples.

American Shad

The American shad (*Alosa sapidissima*, family Clupeidae) is the largest of the anadromous herring species found in the Hudson River estuary and ranges from Newfoundland to northern Florida. The species is most abundant between Connecticut and North Carolina. The stock was introduced along the Pacific coast in the Sacramento and Columbia Rivers in 1871, and the population is now established from Cook Inlet, Alaska, to southern California (Facey and Van Den Avyle 1986). American shad has been commercially harvested via gillnets for meat and roe since the late 17th century (Haas-Castro 2006b). Before World War II, American shad was the most valuable fish along the east coast (Facey and Van Den Avyle 1986).

American shad spend most of their life at sea and only return to their natal rivers at sexual maturity (at the age of about 5 years) to spawn. Adult American shad have an average length of 30 in. (76.2 cm), weigh up to 12 lb (5.4 kg), and have a life span in the Hudson River of about 11 years (CHGEC 1999). Shad eggs have a high mortality rate, and fecundity of females changes with latitude, decreasing from south to north. Females in southern rivers produce 300,000 to 400,000 eggs, and females in northern rivers produce an average of 125,000 eggs (Haas-Castro 2006b). Spawning occurs at night in shallow waters of moderate current in sand, gravel, or mud substrates (Facey and Van Den Avyle 1986). The species can repeat annual spawning up to five times within their lifetime in northeastern rivers; however, most shad from southeastern rivers die after spawning (Facey and Van Den Avyle 1986; CHGEC 1999). Egg abundance in the Hudson River peaks in May, and once hatched, YSL transform into PYSL within 4 days to 1 week in waters at a temperature of 17°C (63°F) (Everly and Boreman 1999; CHGEC 1999). Larvae inhabit riffle pools of moderate depth near spawning grounds and develop into juveniles 4 to 5 weeks after hatching when they are approximately 25 mm (1 in.) in length (Everly and Boreman 1999; Facey and Van Den Avyle 1986). American shad eggs, YSL, PYSL, and YOY are generally found between Kingston and Albany (Table 2-5), probably in response to food availability (Limburg 1996). Juveniles travel downriver in schools between June and July (Everly and Boreman 1999), utilize the middle estuary by September, and move to the lower estuary by late October (Limburg 1996). Adults spend the summer months in the northwestern Atlantic waters off the Gulf of Maine, the Bay of Fundy, and the coast of Nova Scotia. In the fall months, individuals migrate southward as far as North Carolina (CHGEC 1999).

Shad stop eating before running and spawning and resume feeding after spawning during their downriver migration back to the Atlantic Ocean (Everly and Boreman 1999). Larvae feed on *Bosmina* spp., cyclopoid copepodites, and chironomid larvae. Juveniles are opportunistic feeders and consume free-swimming organisms at the surface as well as insects (CHGEC 1999). The principal food source of the adult American shad is zooplankton, though the species also consumes small crustaceans, copepods, mysids, small fish, and fish eggs (Facey and Van Den Avyle 1986). The American eel (*Anguilla rostrata*) and catfish (*Ictalurus* spp.) prey upon American shad eggs, and bluefish (*Pomatomus saltatrix*) prey upon larvae (CHGEC 1999). Once juveniles migrate to the Atlantic Ocean, likely predators include sharks, tuna, and porpoises; adult shad are not thought to have many predators (Facey and Van Den Avyle 1986).

The estimated population of American shad in the Hudson River has declined from 2.3 million in 1980 to 404,000 in 1996 (ASMFC 1998). The decline of the species in the Hudson and Connecticut Rivers in the past century is attributed to overfishing, degradation of riverine habitat, and dam construction (Haas-Castro 2006b). ASMFC implemented a Fisheries Management Plan for the American shad and river herring in 1985. Restoration efforts under the plan include habitat improvement, fish passage, stocking, and transfer programs; however, abundance of American shad remains well below historic estimates (Haas-Castro 2006b). Low DO conditions can affect the migration patterns of American shad and limit spawning. Improvements in sewage treatment facilities along the Hudson River in the late 1960s have eliminated the low DO conditions that were problematic in waters south of Albany and have allowed adult shad to spawn farther upriver (CHGEC 1999). According to CHGEC (1999), entrainment mortality has caused a 23.8 percent annual decrease in abundance of juvenile American shad, and impingement may reduce the population by an additional 1 percent annually. The majority of entrainment mortality is believed to occur in the Albany region as a result of the Albany Steam Station and Empire State Plaza (CHGEC 1999). American shad were present in both impingement and entrainment samples obtained from IP2 and IP3.

<u>Atlantic Tomcod</u>

The demersal, anadromous Atlantic tomcod (*Microgadus tomcod*, family Gadidae) is found in northwest Atlantic estuarine habitats, with a range extending from southern Labrador and northern Newfoundland to Virginia (Stewart and Auster 1987). The species is nonmigratory and inhabits brackish waters, including estuarine habitats, salt marshes, mud flats, eel grass beds, and bays. The species is short-lived, with an estimated mortality rate ranging from 81 to

98 percent by the age of 2 years (McLaren et al. 1988). Mean lifespan within the Hudson River is 3 years, though populations north of the Hudson River tend to be longer lived (Stewart and Auster 1987). Most tomcod within the Hudson River are thought to remain within the estuary for life; however, a small number of individuals have been marked and recaptured in the lower New York Bay, the East River, and western Long Island Sound (Klauda et al. 1988). The tomcod has not been a commercially important species in the northeast within the past century, and no catch statistics have been recorded since the 1950s, as the species is generally a target for winter sport fishing only along the New England coast (Stewart and Auster 1987). Tomcod are particularly vulnerable to impingement and entrainment because of their high concentration near the lower portion of the Hudson River estuary (Barnthouse and Van Winkle 1988; Boreman and Goodyear 1988) (Table 2-5).

Spawning occurs under ice between December and January in shallow stream mouths (Stewart and Auster 1987). In the Hudson River, tomcod aged 11 to 13 months contribute approximately 85 to 97 percent of annual egg production, and the majority of tomcod in the Hudson River spawn only once in their lifetime (McLaren et al. 1988). Females produce an average of 20,000 eggs, and incubation time correlates inversely with salinity and ranges from 24 to 63 days (Dew and Hecht 1994; Stewart and Auster 1987). Once hatched, larvae float to the surface and are swept by currents into estuaries, where they develop into juveniles. YSL are found throughout the lower half of the estuary, and PYSL are concentrated in the Yonkers and Tappan Zee regions of the estuary (CHGEC 1999) (Table 2-5). Adults are found at all levels of salinity, but larvae and juvenile densities are highest within the 4.5 to 6.7 ppt salinity range (Stewart and Auster 1987). The Hudson River represents the southernmost major spawning area of the species, and the tomcod is the only major species within the freshwater region of the Hudson River to hatch between February and March (Dew and Hecht 1994). Because the species hatches earlier than herring species within the Hudson and larvae and juveniles are able to tolerate low temperatures, tomcod experience little interspecific competition for food until the fall of their first year (McLaren et al. 1988). Tomcod are found at temperatures as low as -1.2°C (30°F) and have not been observed to inhabit waters at temperatures higher than 26°C (79°F) (Stewart and Auster 1987). The species has also been observed at a wide range of depths varying from the surface to 69 m (226 ft) (Froese and Pauly 2007a). Tomcod have three visible stages of first year growth within the Hudson River population. Juveniles show rapid growth during the spring, little to no growth during the summer, and rapid growth again in the fall, which is highly correlated with prevailing water temperatures (McLaren et al. 1988). Growth has been found to slow at temperatures above 19°C (66°F), and growth essentially ceases at temperatures above 22°C (72°F) (CHGEC 1999).

The diet of tomcod consists primarily of small crustaceans but also may include polychaete worms, mollusks, and small fish. Because tomcod have a lipid-rich liver and prey on many benthic organisms, they are especially sensitive to contaminants in highly polluted waterways, including PCBs and other chlorinated hydrocarbons (Levinton and Waldman 2006). Recent work by Wirgin and Chambers (2006) has reported evidence of induction of hepatic expression of cytochrome P4501A1 and messenger ribonucleic acid (mRNA) in Hudson River tomcod, suggesting a potential for deoxyribonucleic acid (DNA) damage, somatic mutations, and initiation of carcinogenesis consistent with chemical exposure. Within the Hudson River estuary, juvenile tomcod serve as alternate prey in the summer months for yearling striped bass (*M. saxatilis*) during years when juvenile striped bass's main prey, the bay anchovy (*A. mitchilli*), is scarce (Dew and Hecht 1976 cited in Stewart and Auster 1987). Juvenile tomcod are also the prey of large juvenile bluefish (*P. saltatrix*) (Juanes et al. 1993).

The Hudson River tomcod population exhibits wide fluctuations in annual abundance because the species is relatively short lived, and a yearly population is generally composed of only one age class (Levinton and Waldman 2006). The population of tomcod aged 11 to 13 months has been estimated to vary year-to-year between 2 to 5 million individuals, and numbers of tomcod aged 23 to 25 months may vary from 100,000 to 900,000 individuals. A combined abundance index suggests that a population decline has occurred since 1989 (CHGEC 1999). Recent information provided by Entergy (2006c) estimated the population of Atlantic tomcod spawning in the Hudson River during the winter of 2003–2004 to be 1.7 million fish, with 95 percent confidence limits of 1.0 and 2.9 million fish. This estimate, derived by a Petersen mark-recapture technique, is based on the number of tomcod caught and marked between RM 25 and 76 (RKM 40 to 122) in box traps between December 15, 2003, and February 1, 2004, and recaptured in trawls in the Battery region from January 5 through April 11, 2004. The estimated 2003–2004 Atlantic tomcod spawning population in the Hudson River is the ninth lowest observed among 20 recent years of Petersen estimates (Entergy 2006c). Atlantic tomcod were present in both impingement and entrainment samples obtained from IP2 and IP3.

<u>Bay Anchovy</u>

The bay anchovy (*Anchoa mitchilli,* family Engraulidae) occurs along the Atlantic coastline from Maine to the Gulf of Mexico and the Yucatan Peninsula (Morton 1989) and is a common shallow-water fish in the Hudson River estuary. No commercial fishery for the bay anchovy exists on the Hudson River, but it is preyed upon by other fish, such as the striped bass (*M. saxatilis*), which is recreationally important on the Hudson River. Unless otherwise noted, the information below is from Morton (1989).

Considered a warm water migrant, the bay anchovy uses the Hudson River estuary for spawning and as a nursery ground. Adults are found in a variety of habitats, including shallow to moderately deep offshore waters, nearshore waters off sandy beaches, open bays, and river mouths. Studies conducted in the Hudson River from 1974–2005 suggest that eggs, YSL, PYSL, YOY, and older individuals occur in greatest abundance from the Battery to IP2 and IP3 (Table 2-5, Figure 2-10). There is also evidence from recent work by Dunning et al. (2006a) that the peak standing crops of bay anchovy eggs and larvae in New York Harbor, the East River, and Long Island Sound are approximately eight times larger than the population estimates for the lower Hudson River, probably because of the larger water volumes in those areas and the salinity preference of the species. Spawning generally occurs at water temperatures between 9 and 31°C (48 and 88°F). The spawning period for the species is long, typically ranging from May through October. Spawning generally occurs in the late evening or at night, and the eggs are pelagic. Schultz et al. (2006) has reported that anchovies that spawn in the Hudson River are mostly 2 years old, whereas yearlings predominate in other locations, such as Chesapeake Bay. Eggs are usually concentrated in salinities of 8 to 15 ppt and, at temperatures around 27°C (81°F), hatch in 24 hours. At hatching, the YSL are about 1.8 to 2.0 mm (0.07 to 0.08 in.) long. Within 24 hours of hatching, YSL consume the yolk sac and become PYSL. Fins begin to develop during the PYSL stage. Larvae are transparent and become darker as they develop into juveniles. PYSL eat copepod larvae and other small zooplankton.

Larvae metamorphose to juveniles at about a length of 16 mm (0.63 in.). Juveniles and adults travel and hunt in large schools. Juveniles acquire adult characteristics at about 60 mm (2.4 in.) in length and gain a silvery lateral band. Adults have a relatively high tolerance to fluctuations in both river temperature and salinity, and there is evidence in the Hudson River that early-stage anchovies migrate up-estuary at a rate or 0.6 km/day (0.4 mi/day) and are capable of periodic vertical migration (Schultz et al. 2006). Adult and juvenile bay anchovy feed primarily on mysid shrimp, copepods, other small crustaceans, small mollusks, other plankton, and larval fish (Hartman et al. 2004). Important predators include birds, bluefish (*P. saltatrix*), weakfish (*C. regalis*), summer flounder (*Paralichthys dentatus*), and striped bass (*M. saxitilis*) (CHGEC 1999). The population trend in the Hudson River appears to show a population decline, although exact population counts are not available (Tipton 2003). Tipton (2003) also speculates that the reduction in bay anchovy may be linked to increased predation and overall populations of striped bass, bluefish, or other important commercial fish. Fishery statistics are not available for this species from National Marine Fisheries Service (NMFS) because of the lack of commercial and recreational fishing. The Mid-Atlantic Fishery Management Council has not identified bay anchovy as a managed species. Bay anchovy were present in impingement samples, and represented a sizable portion in entrainment samples obtained from IP2 and IP3 during 1981, and 1983-1987.

<u>Blueback Herring</u>

The blueback herring (*Alosa aestivalis*, family Clupeidae) is an anadromous species found in riverine and estuarine waters along the Atlantic coast ranging from Nova Scotia to St. Johns River, Florida. As noted in the life history of the alewife (*A. pseudoharengus*), commercial fisheries do not differentiate between the blueback herring (*A. aestivalis*) and alewife, and the two species are collectively referred to as river herring. River herring are harvested for fish meal, fish oil, and protein for animal food industries (Fay et al. 1983). Commercial landings of river herrings peaked in the 1950s at approximately 34,000 MT (37,000 t) and then declined to less than 4000 MT (4400 t) in the 1970s. Between 1996 and 2005, landings of river herring ranged from 300 to 900 MT (330 to 990 t) annually, with the majority of the landings in Maine, North Carolina, and Virginia (Haas-Castro 2006a). The river herring fishery is one of the oldest fisheries in the United States; however, no commercial fisheries for river herring exist in the Hudson River today. River herring are often taken as bycatch in the offshore mackerel fishery. Within New York and New Jersey, river herring accounted for 0.3 percent of annual landings on the Atlantic coast (CHGEC 1999).

Blueback herring spawn once per year between late May and mid-July in the main channels of estuaries or relatively deep freshwater with swift currents on sand or gravel substrate at temperatures between 14°C (57°F) and 27°C (81°F) (Everly and Boreman 1999; Fay et al. 1983). Female egg production varies greatly, ranging from 46,000 to 350,000 eggs per female (Fay et al. 1983), and incubation time is approximately 6 days (Bigelow and Schroeder 1953). Blueback herring spawn 3 to 4 weeks after alewives in areas where the two species occur sympatrically, and the peak spawning of each species occurs 2 to 3 weeks apart from one another (Fay et al. 1983). In the Hudson, blueback herring spawn most commonly within the Mohawk River and upper Hudson River (CHGEC 1999). The YSL stage exists 2 to 3 days before yolk-sac absorption, and the PYSL stage lasts until larvae reach approximately 20 mm (0.79 in.), with full development occurring at 45 mm (1.8 in.) (Fay et al. 1983). Eggs, YSL, PYSL, and YOY are generally found between Poughkeepsie and Albany (Table 2-5). Juvenile blueback herring assume adult characteristics within a month of hatching, at which point growth slows. Peak abundance of juveniles occurs during late June within the upper estuary (CHGEC 1999) (Table 2-5). Migration downriver to the Atlantic Ocean occurs in October, which is generally later than peak migration for both the American shad and the alewife within the Hudson River estuary (Fay et al. 1983). Some blueback herring do not migrate and tend to stay within the lower reaches of the estuary during their first 1 to 2 years (CHGEC 1999). Average length for males is 23 cm (9.1 in.) and for females is 26 cm (10 in.) (Collette and Klein-MacPhee 2002).

Adult blueback herring feed mainly on copepods but also eat amphipods, shrimp, fish eggs, crustacean eggs, insects, and insect eggs. The diet of blueback herring in the lower Hudson River consists primarily of chironomid larvae and copepods. As described for the alewife, blueback herring is an important link in the estuarine food web between zooplankton and top piscivores. The blueback herring is prey for gulls, terns, and other coastal birds, as well as for bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and striped bass (*Morone saxatilis*) (CHGEC 1999).

Annual abundance of blueback herring YOY in the Hudson River estuary has been estimated to range from 1.2 million to 50.1 million individuals from sampling conducted with a Tucker trawl since 1979 (CHGEC 1999). According to CHGEC (1999), entrainment mortality for the combined abundance of blueback herring and alewife for all water withdrawal locations within the Hudson River varies widely, ranging from 8 to 41 percent in data taken between 1974 and 1997, while impingement mortality of the two species was low, ranging from 0.2 to 0.7 percent for the same time period. Blueback herring were present in both impingement and entrainment samples obtained from IP2 and IP3.

<u>Bluefish</u>

The bluefish (*Pomatomus saltatrix*, family Pomatomidae) is a migratory, pelagic species that occurs in temperate and tropical waters worldwide on the continental shelf and in estuaries. Along the Atlantic coast, the bluefish ranges from Nova Scotia to the Gulf of Mexico (Pottern et al. 1989). Bluefish are a highly sought-after sport fish along the North Atlantic Coast, and State and Federal regulations on the commercial catch of the species began in the early 1970s (CHGEC 1999; Pottern et al. 1989). The majority of the Atlantic coast bluefish catch occurs between New York and Virginia, and recreational fishing has accounted for 80 to 90 percent of the total bluefish catch in the past, with a peak in 1981 and 1985 of over 43,000 MT (47,000 t). Landings have since decreased, reaching a low of 3300 MT (3600 t) in 1999; landings in 2005 totaled 3500 MT (3300 t) (Shepherd 2006a). The bluefish is also harvested commercially for human consumption, and during peak years in 1981 to 1983, average annual landings were 7.4 million kg (16.3 million lb), accounting for 0.5 percent of the total Atlantic coast commercial finfish and shellfish landings (Pottern et al. 1989).

North American bluefish populations range from New England to Cape Hatteras, North Carolina, in the summer, and migrate to Florida and the Gulf Stream during the winter. Fisheries data also indicate the existence of small nonmigratory populations in southern Florida waters and the Gulf of Mexico (Pottern et al. 1989). Bluefish are generally not found in waters colder than 14 to 16°C (57.2 to 60.8°F) and exhibit signs of stress at temperatures below 11.8°C (53.2°F) and above 30.4°C (86.7°F) (Collette and Klein-MacPhee 2002).

Generally, bluefish have two major spawnings per year. The first spawning occurs during the spring migration as bluefish move northward to the South Atlantic Bight between April and May; the second spawning occurs in the summer in offshore waters of the Middle Atlantic Bight between June and August. Two distinct cohorts of juvenile bluefish in the fall result from the two spawning events, which mix during the year creating a single genetic pool (Shepherd 2006a). Females can produce 600,000 to 1.4 million eggs (CHGEC 1999). Larvae hatch in 46 to 48 hours at temperatures of 18 to 22°C (64.4 to 71.6°F) (Collette and Klein-MacPhee 2002). Newly hatched larvae are pelagic and stay in offshore waters for the first 1 to 2 months of life before migrating shoreward to shallower waters (CHGEC 1999). Beach seine survey results indicate YOY bluefish are generally found between Yonkers and Croton-Haverstraw (Table 2-5). YSL typically consume the yolk sac by the time they reach 3 to 4 mm (0.12 to 0.16 in.) in length (Pottern et al. 1989). Bluefish larvae grow rapidly; spring-spawned juveniles reach lengths of 25 to 50 mm (0.99 to 2 in.) once they move to mid-Atlantic bays in the summer, grow to lengths of 175 to 200 mm (6.9 to 7.9 in.) by late September when migration begins, and reach lengths of about 260 mm (10.2 in.) by the following spring. Summer-spawned juveniles exhibit slower growth because they are unable to inhabit bays and estuaries until after their first migration, though summer-spawned juvenile growth rates exceed those of spring-spawned juveniles during the second year, at which point differences between the two stocks are less pronounced (Pottern et al. 1989). Adult bluefish can live up to 12 years and reach weights of 14 kg (31 lb) and lengths of 100 cm (39 in.) (Shepherd 2006a).

Bluefish are avid predators, and the Atlantic coast population is estimated to consume eight times its biomass in prey annually. Larvae feed on zooplankton and larvae of other pelagic-spawning fish (Pottern et al. 1989). In the Hudson River estuary, YOY feed on bay anchovy (*A. mitchilli*), Atlantic silverside (*M. menidia*), striped bass (*M. saxatilis*), blueback herring (*A. aestivalis*), Atlantic tomcod (*M. tomcod*), and American shad (*A. sapidissima*) (CHGEC 1999; Juanes et al. 1993). Adult bluefish diets are dominated by squids, clupeids, and butterfish. YOY bluefish are prey for birds including Atlantic puffin (*Fratercula arctica arctica*), Arctic tern (*Sterna paradioaea*), and roseate tern (*Sterna dougalli dougalli*) (Collette and Klein-MacPhee 2002). Sharks also prey on bluefish; species include the bigeye thresher (*Alopias superciliosus*), white shark (*Carcharodon carcharias*), shortfin mako (*Isurus oxyrinchus*), longfin mako (*I. paucus*), tiger shark (*Galeocerdo cuvier*), blue shark (*Prionace glauca*), sandbar shark (*Carcharhinus plumbeus*), smooth dogfish (*Mustelus canis*), spiny dogfish (*Squalus acanthias*), and angel shark (*Squatina* spp.) (Collette and Klein-MacPhee 2002).

The bluefish population data from the Hudson River estuary show a declining trend since the population peaked in 1981 and 1982 (CHGEC 1999). Bluefish populations along the east coast have historically fluctuated widely, though analysis by the National Marine Fisheries Service (NMFS) of data between 1974 and 1986 did not find evidence of a systematic decline of the species (CHGEC 1999). According to CHGEC (1999), bluefish have not been found in entrainment samples from power plants along the Hudson River, which include Roseton Units 1 and 2, IP2 and IP3, or Bowline Point Units 1 and 2 (CHGEC 1999). CHGEC (1999) also stated that juvenile bluefish may be impinged, but the numbers are estimated to be relatively small. Electronic data obtained from Entergy (Entergy 2007b) showed that bluefish eggs and larvae were infrequently observed in entrainment samples, but were common in impingement samples from IP2 and IP3 (NL-09-160).

Gizzard Shad

The gizzard shad (*Dorosoma cepedianum*, family Clupeidae) is a pelagic herring species that is found in the waters of the Atlantic and Gulf coastal plains streams as well as in freshwater lakes and reservoirs ranging from New York to Mexico (MDNR 2007a). Gizzard shad are found mainly in freshwater rivers, reservoirs, lakes, and swamps, and in slightly brackish waters of estuaries and bays (Froese and Pauly 2007b). The gizzard shad is a relatively recent immigrant to the Hudson River estuary, though it is now considered a permanent resident, and the species is continuing to expand its range throughout the northeastern United States (CHGEC 1999; Levinton and Waldman 2006). No commercial or sport fishery for gizzard shad exists on the Hudson River (CHGEC 1999). Larvae have been observed in the tidal waters of the Hudson River since 1989 (Levinton and Waldman 2006). A spawning population is believed to exist in the Mohawk River, but no spawning has been observed in the Hudson River (CHGEC 1999).

Adult gizzard shad grow to 23 to 36 cm (9 to 14 in.) in length with an average weight of 907 g (2 lb) and an average life span of 7 years in northern populations (CHGEC 1999; Morris 2001). Both males and females mature between 2 and 3 years of age, and females spawn between April and June in shallow waters between 10 and 21°C (50 and 70°F) (CHGEC 1999; MDNR 2007a). Fecundity is thought to be highly variable but does appear to increase with size of the female (CHGEC 1999). Females can produce between 50,000 and 379,000 eggs (MDNR 2007a). Eggs hatch in 1.5 to 7 days, depending on water temperature (CHGEC 1999). YSL transform into PYSL within 5 days of hatching and begin to feed on microzooplankton until they reach 2.5 cm (1 in.) in length. At this point, development of the digestive system supports a diet including plant material; juveniles eat a variety of daphnids, cladocerans, adult copepod, rotifers, algae, phytoplankton, and detritus (CHGEC 1999). Gizzard shad grow rapidly during the first 5 to 6 weeks of life, at which point growth slows; individuals reach a length of 10 to 25 cm (4 to 10 in.) by their first summer (CHGEC 1999). Adults are filter feeders, eating a variety of phytoplankton and zooplankton. Larvae are not an important prey species because of their size, but age 0 gizzard shad are consumed by a number of species including striped bass, largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), black crappie (*Pomoxis nigromaculates*), white bass (*Morone chrysops*), and spotted bass (*Micropterus punctulatus*) (CHGEC 1999). Predators of adult gizzard shad include catfish (order Siluriformes) and striped bass (*M. saxatilis*) (Morris 2001).

Abundance data are not available for the gizzard shad from the Hudson River sampling programs because of the low capture rate of the species in these programs (CHGEC 1999). Beach seine surveys from 1974 to 2005 suggest YOY and older gizzard shad occur primarily from Cornwall north to Albany (Table 2-5). Impingement data are available at three power stations along the Hudson River (Danskammer, Roseton Units 1 and 2, and the now-shuttered Lovett Generating Station) and indicate year-to-year fluctuations with a general trend of increasing impingement and peak adult impingement during the winter months. According to CHGEC (1999), entrainment of early life stages is thought to be low, and small gizzard shad are rare in utility ichthyoplankton surveys. Gizzard shad eggs and larvae were not observed in entrainment samples from IP2 and IP3 during evaluations in 1981 and 1983-1987, but were commonly observed in impingement samples.

Hogchoker

The hogchoker (*Trinectes maculatus*, family Soleidae) is a right-eyed flatfish species found along the Atlantic coast in bays and estuaries from Maine to Panama (Dovel et al. 1969). The hogchoker is common in the Hudson River estuary and surrounding bays and coastal waters, and abundance indices from the annual Fall Juvenile Survey (also known as the Fall Shoals Survey) channel sampling in the Hudson River from 1974 to 1997 indicate that the hogchoker population has remained relatively stable with a nonsignificant 1 percent increase per year (CHGEC 1999). Because of its small size (adults range from 6 to 15 cm (2.4 to 5.9 in.) with a maximum size of 20 cm (7.9 in.)), the hogchoker is not commercially harvested in any area within its geographic range (Collette and Klein-MacPhee 2002). CHGEC (1999) indicates that hogchoker larvae are found mainly within deeper channel waters and are not often captured during the Longitudinal River Survey; low numbers of juveniles are captured during the Beach Seine and Fall Juvenile Surveys, and yearlings and adults are generally not exposed to Hudson River generating stations because they remain in the waters below RM 34 (CHGEC 1999). However, the Fall Juvenile Survey information reviewed by the NRC staff suggests that YOY and older hogchokers have been collected from Tappan Zee to Poughkeepsie—an area that includes IP2 and IP3 (Table 2-5).

The majority of hogchokers in the Hudson River reach sexual maturity at the age of 2 years, though some faster growing males have been observed to spawn at age 1 year (Koski 1978). Spawning occurs in estuaries between May and October in the Hudson River estuary, which is a 5-week longer spawning period than that of the Chesapeake Bay population (Collette and Klein-MacPhee 2002; Koski 1978). Spawning occurs in waters 20 to 25°C (68 to 77°F) and a salinity of 10 to 16 ppt (Collette and Klein-MacPhee 2002). Eggs are observed in greatest numbers from the last week in May through July in lower estuary waters. Egg production is positively correlated with size, and females can produce between 11,000 and 54,000 eggs. Within the Hudson River, eggs are most common between RM 12 and 24 (RKM 19 and 39). Eggs hatch in 24 to 36 hours at temperatures between 23.3 and 24.5°C (73.9 and 76.1°F). YSL absorb the yolk sac within 48 hours of hatching, and eye migration occurs within 34 days of hatching or at lengths of 0.2 to 0.4 in. (0.51 to 0.02 cm) (Collette and Klein-MacPhee 2002; CHGEC 1999). Larvae have been observed to congregate upstream in waters with lower salinity than their hatching ground (Dovel et al. 1969). Within the Hudson River, YSL are most abundant between RM 24 and 33 (RKM 39 and 53), and PYSL are most abundant from RM 24 through RM 55 (RKM 39 and 89). Juveniles are found above RM 39 (RKM 63), while yearling and older individuals are found below RM 34 (RKM 55) (CHGEC 1999). Adult individuals inhabit nonvegetated waters with sandy or silty bottoms (Whiteside and Bonner 2007).

Adult hogchokers feed mainly on annelids, arthropods, and tellinid siphons (Derrick and Kennedy 1997). The species is a generalist and may also prey on midges, ostracods, aquatic insects, annelids, crustaceans, and foraminiferans (Whiteside and Bonner 2007). Larger striped bass (*M. saxatilis*) prey on yearling and older hogchokers within the Hudson River estuary, which may affect the abundance of those age groups (CHGEC 1999). The Northeast Fisheries Science Center also found the smooth dogfish (*Mustelus canis*) to be a predator of hogchoker (Roundtree 1999 as cited in Collette and Klein-MacPhee 2002). Hogchokers were observed in both impingement and entrainment samples from IP2 and IP3.

Rainbow Smelt

Rainbow smelt (*Osmerus mordax*, family Osmeridae) is an anadromous species once found along the Atlantic coast from Labrador to the Delaware River, although the southern end of the range is now north of the Hudson River. NOAA (2007) lists rainbow smelt as a Species of Concern. Unless otherwise noted, information below comes from Buckley (1989).

Adult rainbow smelt along the east coast move into saltwater in summer, where they are found in waters less than 1 mi (1.6 km) from shore and usually no deeper than 6 m (20 ft). In spring, spawning adults typically move up the estuaries before ice breaks up to spawn above the head of tide in water temperatures of 4.0 to 9.0°C (39 to 48°F). They have been found to run up into coastal streams to spawn at night and then return to the estuary during the day. Females, depending on size, produce about 7,000 to 75,000 eggs (summarized in NOAA 2007a), which are from 1.0 to 1.2 mm (about 0.04 in.) in diameter. Eggs are typically deposited over gravel, and egg survival appears to be influenced by water flow, substrate type, and egg density. Exposure to salt or brackish water can cause egg mortality, as can sudden increases in temperature, diseases, parasites, contaminant exposure, and predation by other fish species. Incubation times can be 8 to 29 days and decrease with increasing water temperature. Common mummichog (*Fundulus heteroclitus*) and fourspine stickleback (*Apeltes quadracus*) are reported to be major predators of smelt eggs.

YSL are 5 to 6 mm (0.20 to 0.24 in.) long at hatching. The yolk sac is absorbed by the time the larvae reach 7 mm (0.28 in.) and enter the PYSL stage. The larvae initially concentrate near the surface and drift downstream. As they grow, they seek deeper water and congregate near the bottom. Vertical migration begins, and they move to the surface to feed during the day and deeper at night. The vertical migration patterns may maintain their position in two-layered estuarine systems. Larval and small juvenile smelt eat copepods and other small planktonic crustaceans as well as fish. In turn, larval and juvenile smelt are probably eaten by most estuarine piscivores.

Smelt grow fairly rapidly and begin to school when they reach a length of 19 mm (0.75 in.). As the smelt grow, they move down estuaries into higher salinity and, as adults, migrate to sea. They are mature and participate in spawning runs at age 1. Adults grow to average approximately 25.4 cm (10 in.) in length. Larger juveniles and adults feed on euphausiids, amphipods, polychaetes, and fish such as anchovies (family Engraulidae) and alewives (*A. pseudoharengus*). Adults also eat other fish species, including common mummichog, cunner (*Tautogolabrus adspersus*), and Atlantic silversides (*Menidia menidia*). Bluefish (*P. saltatrix*), striped bass (*M. saxatilis*), harbor seals (*Phoca vitulina*), and other large piscivores eat adult smelt.

Once a prevalent fish in the Hudson River, an abrupt smelt population decline in the Hudson River was observed from 1994 to , and the species may now have no viable population within the Hudson River. The last tributary run of rainbow smelt was recorded in 1988, and the Hudson River Utilities' Long River Ichthyoplankton Survey show that PYSL essentially disappeared from the river after 1995 (Daniels et al. 2005). When present, the largest abundances of eggs and YSL occurred from Poughkeepsie to the Catskills, and the largest abundances of PYSL, YOY, and older individuals were distributed from approximately Yonkers to Hyde Park (Table 2-5, Figure 2-6). Rainbow smelt runs in the coastal streams of western Connecticut declined at about the same time as in the Hudson River (Daniels et al. 2005).

Smelt landings in waters south of New England have dramatically decreased, although the reasons for this are unknown. Daniels et al. (2005) note slowly increasing water temperatures in the Hudson River and suggest that the disappearance of rainbow smelt from the Hudson River may be a result of global warming. Rainbow smelt were observed in both impingement and entrainment samples obtained from IP2 and IP3.

<u>Spottail Shiner</u>

The spottail shiner (*Notropis hudsonius*, family Cyprinidae) is a freshwater species which occurs across much of Canada, south to the Missouri River drainage, and in Atlantic States from New Hampshire to Georgia, with habitat ranging from small streams to large rivers and lakes, including Lake Erie (Smith 1985a). One of the most abundant fishes in the Hudson River, spottail shiners are commonly 3.9 in. (100 mm) in length, which is large for shiner species (Smith 1985a). The maximum length is approximately 5.8 in. (147 mm) (Schmidt and Lake 2006; Smith 1985a; Marcy et al. 2005a).

Spottail shiners spawn from May to June or July (typically later for the northern populations) over sandy bottoms and stream mouths (Smith 1985a; Marcy et al. 2005a); water chestnut (*Trapa natans*) beds provide important spawning habitat (CHGEC 1999). Individuals older than 3 years are seldom found, but there is evidence of individuals living up to 4 or 5 years (Marcy et al. 2005a). Fecundity is a factor of age: the ovaries of younger females contain 1400 eggs, and ovaries of older females contain from 1300 to 2600 eggs; a correlation between fecundity and size does not appear to exist (Marcy et al. 2005a). In the Hudson River Estuary, beach seine survey data from 1974 to 2005 showed the largest abundances of YOY and Year 1+ individuals occurred from Poughkeepsie north to Albany (Table 2-5).

Spottail shiners are opportunistic feeders, typically eating insects, bivalve mollusks, and microcrustaceans throughout the water column (Marcy et al. 2005a). Aggregations of spottail shiners have been observed preying on eggs of alewives (*Alosa psedoharengus*) and mayflies (Marcy et al. 2005a). Striped bass (*M. saxatilis*) larvae are also prey for spottail shiners (McGovern and Olney 1988), as are spottail eggs and larvae (Smith 1985a). Spottail shiners are frequently used as bait (Smith 1985a), and they are an important prey species for some fish, including walleye (*Sander vitreus*), channel catfish (*I. punctatus*), northern pike (*Esox lucius*), and smallmouth bass (*Micropterus dolomieu*) (IDFG 1985). The Hudson River population of spottail shiners is known to be susceptible to impingement and entrainment at water intakes, and this could be affecting the survivorship of most life stages (CHGEC 1999). Eggs and larval forms of spottail shiner were infrequently observed in entrainment samples from IP2 and IP3, but were commonly impinged.

<u>Striped Bass</u>

The striped bass (*Morone saxatilis*, family Moronidae) is an anadromous species, with a range extending from St. Johns River, Florida, to St. Lawrence River, Canada (ASMFC 2006b). Individual stocks of striped bass spawn in rivers and estuaries from Maine to North Carolina. When adults leave the estuaries to go to the Atlantic, the stocks mix; striped bass return to their natal rivers and estuaries to spawn. The Atlantic coast striped bass fishery has been one of the most important commercial fisheries on the east coast for centuries and has been regulated since European settlement in North America (ASMFC 2006b). In 1982, overfishing depleted the striped bass population to fewer than 5 million fish. Since that time, the Atlantic coast population has been restored to 65 million in 2005 (ASMFC 2006b). Striped bass have been important in both commercial and recreational fisheries, and while the majority of the stock spawns in the Chesapeake Bay, the Hudson River contributes to the stock as well. Fabrizio (1987) reported that of the age 2–5 individuals sampled from the Rhode Island commercial trap-net fishery in November 1982, 54 percent were from the Chesapeake Bay stock and 46 percent were from the Hudson River stock. Wirgin et al. (1993) estimated that the Chesapeake Bay and Hudson River stocks combined contributed up to 87 percent of the mixed fishery stock on the Atlantic coast.

The striped bass is a long-lived species, reaching 30 years of age, and spends the majority of its life in coastal estuaries and the ocean. Females reach maturity between 6 and 9 years, and then produce between 0.5 million and 3 million eggs per year, which are released into riverine spawning areas (ASMFC 2006b). The males, reaching maturity between 2 and 3 years, fertilize the eggs as they drift downstream (ASMFC 2006b). The eggs hatch into larvae, which absorb their yolk and then feed on microscopic organisms. PYSL mature into juveniles in the nursery areas, such as river deltas and inland portions of coastal sounds and estuaries, where they remain for 2 to 4 years, before joining the coastal migratory population in the Atlantic (ASMFC 2006b). Recent field investigations by Dunning et al. (2006b) have suggested that dispersal of age 2+ striped bass out of the Hudson River may be influenced by cohort abundance. In the spring or summer, adults migrate northward from the mouth of their spawning rivers up the Atlantic coast, and in the fall or winter they return south, in time to spawn in their natal rivers (Berggren and Lieberman 1978; ASMFC 2006b). Work by Wingate and Secor (2007), using remote biotelemetry on a total of 12 fish, suggested that specific homing patterns are possible for this species, and these patterns may influence their susceptibility to localized natural and anthropogenic stressors. Based on long-term monitoring data, various life-stages associated with this species are found in the Hudson River from Tappan Zee to Albany (Table 2-5).

Several factors play a role in spawning, including water temperature, salinity, total dissolved solids concentration, and water velocity and flow. Peak spawning occurs in water temperatures of 15 to 20°C (59 to 68°F) but can occur between 10 and 23°C (50 and 73°F) (Shepherd 2006b). Striped bass reach 150 cm (59 in.) in length and 25 to 35 kg (55 to 77 lb) in weight (Shepherd 2006b). Adult striped bass are omnivores and prey on invertebrates and fish, especially clupeids, including menhaden (*B. tyrannus*) and river herring (*Alosa* spp.) (Shepherd 2006b). Diets vary by season and location, typically including whatever species are available (Bigelow and Schroeder 1953). YOY striped bass diet is made up of fish and mysid shrimp (Walter et al. 2003).

Compared to other anadromous species, striped bass appear to spend extended periods in the Hudson River, contributing to their PCB body burdens. In 1976, the Hudson River commercial fishery was closed because of PCB contamination, although shad fishermen continue to catch striped bass in their nets (CHGEC 1999). Commercial restrictions on harvesting the Atlantic coastal fishery, in part supported by the Atlantic Striped Bass Conservation Act of 1984 (16 U.S.C. 5151–5158), which allows coastal States to cooperatively regulate and manage the stock, have led to the declaration of full recovery of the population in 1995 (ASMFC 2006b). Abundance levels have continued to increase in the Atlantic population. Restrictions on both commercial and recreational fisheries have been relaxed because of the recovery of the population (ASMFC 2006b), but the fisheries continue to be limited to State waters (within 3 nautical miles of land), and New York State's commercial fishery remains completely closed. While commercial landings have remained lower than the levels seen in the early 1970s, recreational landings have increased, and in 2004 made up 72 percent of the total weight harvested from the Atlantic stock (Shepherd 2006b). Recreational fishing in the Hudson River during the spring generally occurs north of the Bear Mountain Bridge (RKM 75 (RM 46)) (Euston et al. 2006). Striped bass were commonly found in entrainment and impingement samples obtained from IP2 and IP3.

Weakfish

The weakfish (*Cynocsion regalis*, family Sciaenidae) is a demersal species found along the Atlantic coast ranging from Massachusetts Bay to southern Florida and is occasionally found as far north as Nova Scotia and as far south as the eastern Gulf of Mexico (Mercer 1989). The weakfish is one of the most abundant fish species along the Atlantic coast and is fished recreationally as well as commercially via gill-net, pound-net, haulseine, and trawl (Mercer 1989). ASMFC considers weakfish to be composed of one stock based on genetic analysis; however, more recent tagging studies have indicated that weakfish may return to their natal estuary to spawn (ASMFC 2006c). The stock as a whole is thought to be declining as evidenced by decreased landings in recent years. Landings peaked in 1981 and 1982 at 12,500 MT (13,800 t), declined from 1989 through 1993, peaked again in 1998 at over 5000 MT (5500 t), and then declined from 1999 through 2004, at which point a record low of less than 1000 MT (1100 t) was reported (ASMFC 2006c). Entrainment of eggs and larvae at power plants within the Hudson River is not common because weakfish spawn in waters with higher salinity, though movement of juveniles into the Hudson River estuary during late winter and early spring results in some entrainment of young juveniles and impingement of larger juveniles (CHGEC 1999).

Weakfish are found at a depth range of 10 to 26 m (33 to 85 ft) and temperatures between 17 and 27°C (63 and 81°F) (Froese and Pauly 2007c). Adults favor shallow coastal waters with sandy substrate and a salinity of 10 ppt or higher, though they are found in a variety of estuarine environments (CHGEC 1999). Adult weakfish vary greatly in size, ranging from 6 to 31 in. (15 to 79 cm) in length, with a maximum weight of 20 lb (9.1 kg), and can live up to 11 years (CHGEC 1999). Most weakfish mature at the age of 2 during the late summer months, and almost all weakfish are mature by the end of their third summer (CHGEC 1999). Size at maturity varies with latitude: in northern populations, females have been observed to mature at 256 mm (10.1 in.) and males at 251 mm (9.9 in.), while in North Carolina populations, females have been observed to spawn at 230 mm (9.1 in.) and males at 180 mm (7.1 in.) (Mercer 1989). Weakfish migrate southward in the fall to the coastal waters of North Carolina and Virginia and then move northward in the spring to spawn (ASMFC 2006c).

Spawning takes place along the northeastern coast of the Atlantic between the Chesapeake Bay and Montauk, Long Island, New York, in nearshore coastal and estuarine waters during the spring and summer (CHGEC 1999). Within the New York Bight, two spawning peaks occur in mid-May, consisting of larger individuals that migrate northward earlier, and in June, consisting of smaller individuals (Mercer 1989). Fecundity estimates vary widely, though fecundity can be generally correlated with size and geographic area (from 4593 eggs for a 203-mm (8-in.) female to 4,969,940 eggs for a 569-mm (22.4-in.) female and from 306,159 eggs for a northern female to 2,051,080 eggs for a similarly sized female in North Carolina) (Collette and Klein-MacPhee 2002). Eggs can tolerate a temperature range of 12 to 31.5°C (53.6 to 88.7°F) and a salinity range of 10 to 33 ppt (Collette and Klein-MacPhee 2002). Larvae hatch within 36 to 40 hours at temperatures of 20 to 21°C (68 to 69.8°F) (Mercer 1989). Larvae move into bays and estuaries after hatching; in the Hudson River estuary, larvae are rarely observed north of the George Washington Bridge because of the lower salinity of these waters (CHGEC 1999). Larvae feed primarily on cyclopoid copepods, as well as calanoid copepods, tintinnids, and polychaete larvae (Collette and Klein-MacPhee 2002). Weakfish juveniles grow rapidly during their first year and reach lengths of 7.6 to 15.2 cm (3 to 6 in.) by the end of the summer (CHGEC 1999). Juveniles are typically distributed from Long Island to North Carolina in late summer and fall in waters of slightly higher salinity, sand or sand-grass substrates, and depths of 9 to 26 m (30 to 85 ft) (Mercer 1989). Juveniles are considered adults at approximately 30 mm (1.2 in.) (Collette and Klein-MacPhee 2002).

Adult weakfish feed on a variety of organisms, and their diet varies with locality and availability of food sources. Smaller weakfish (less than 20 cm (7.9 in.)) feed primarily on crustaceans, while larger weakfish feed primarily on anchovies, herrings, spot, and other fish (CHGEC 1999; Mercer 1989). Adult weakfish of all sizes also prey on decapod shrimps, squids, mollusks, and annelid worms (CHGEC 1999; Mercer 1989). Bluefish (*P. saltatrix*), striped bass (*M. saxatilis*), and older weakfish prey on younger weakfish, while weakfish of larger size are preyed on by dusky sharks (*Carcharhinus obscurus*), spiny dogfish (*Squalus acanthias*), smooth dogfish (*Mustelus canis*), clearnose skate (*Raja eglanteria*), angel sharks (*Squatina* spp.), goosefish (family Lophiidae), and summer flounder (*Paralichthys dentatus*) (Collette and Klein-MacPhee 2002).

YOY and older weakfish are generally found from Yonkers to West Point (Table 2-5). Weakfish abundance fluctuated from 1979 to 1990, and abundance was relatively low between 1990 and 1997; overall, abundance declined 6 percent between 1979 and 1997 (CHGEC 1999). The weakfish stock as a whole declined suddenly in 1999 and approached even lower levels by 2003, which ASMFC determined to be the result of higher natural mortality rates rather than the result of fishing mortality (ASMFC 2007b). A leading hypothesis suggests that insufficient prey species and increased predation by striped bass may contribute significantly to rising natural mortality rates in the weakfish population (ASMFC 2007b). Weakfish were commonly found in both impingement and entrainment samples obtained from IP2 and IP3.

<u>White Catfish</u>

The white catfish (*Ictalurus catus*, family Ictaluridae) is a demersal species found in estuarine and freshwater habitats along the Atlantic coast from the lower Hudson River to Florida, though it has been introduced in other areas, including Ohio and California (Smith 1985b). The natural distribution of the species is thought to be in coastal streams from the Chesapeake Bay to Texas; limited recreational fishing for this species occurs in the Hudson River (CHGEC 1999). White catfish are the least common species of catfish in New York waters (NYSDEC 2008a). The New York State Department of Health has issued a fish advisory for the species because of the potential for elevated levels of PCBs (NYSDOH 2007). Additionally, the New Jersey Department of Environmental Protection (NJDEP) has issued a health advisory for the white catfish downstream of the New York-New Jersey border, which includes portions of the Hudson River and Upper New York Bay (NJDEP and NJDHSS 2006).

The white catfish is of intermediate size compared with other species in the family; adults grow to lengths of 8.3 to 24 in. (21 to 62 cm) and reach weights of 0.6 to 2.2 lb (0.25 to 1.0 kg) (Marcy et al. 2005b). The species has been reported to live 11 or more years as evidenced by individuals observed in South Carolina (Marcy et al. 2005b). White catfish prefer fresh or brackish water and, in the upper Hudson River, are most commonly found in channel borders, shoals, and vegetated backwaters (Marcy et al. 2005b). Though the white catfish is more salt tolerant than most catfish species, it is not typically found in waters with salinities above 8 ppt (CHGEC 1999; NJDEP 2005). Fall Juvenile Survey data from 1979 to 2004 suggests that YOY and older individuals were generally found from the Saugerties to Albany segments of the Hudson River (Figure 2-10, Table 2-5).

White catfish are sexually mature between 3 to 4 years of age at the size of 7 to 8 in. (18 to 20 cm). Adults move upstream for spawning between late June and early July when Hudson River water temperatures reach approximately 70°F (21°C) (CHGEC 1999). Before spawning, both males and females construct nests on sand or gravel bars, and males protect the nest once females lay eggs. Females that are 11 to 12 in. (28 to 30 cm) can lay 3200 to 3500 eggs. Eggs hatch in 6 to 7 days at temperatures between 75 to 85°F (24 to 29°C) (CHGEC 1999; Smith 1985b). Males continue to protect young until the juveniles form large schools and disperse from the nest (MDNR 2007b). YOY migrate downstream to deeper waters in September and October, and generally, yearling and older white catfish move out of the upper Hudson River estuary once the water temperatures drop below 59°F (15°C) to overwinter in the lower estuary. (Smith 1985b, CHGEC 1999).

White catfish have an especially varied diet. Adults collected from the North Newport River in Georgia were found to consume over 50 different species of prey (Marcy et al. 2005b). Juveniles and smaller adults feed primarily on midge larvae and macroinvertebrates, while larger adults have a more diverse diet, which may consist of midge larvae, crustaceans, algae, fish eggs, and a number of fish species, including herring (*Clupea* spp.), menhaden (*Brevoortia* spp.), gizzard shad (*Dorosoma cepedianum*), and bluegills (*Lepomis macrochirus*) (CHGEC 1999; Smith 1985b). Amphipods are widely consumed by adult catfish and make up a large percentage (up to 80 percent) of the volume of food eaten (CHGEC 1999).

The white catfish population is considered stable throughout the majority of its range, though the Hudson River population appears to have been in decline since 1975 (CHGEC 1999). The decline may partially be a result of food-limited growth and survival of larvae and YOY as a result of resource depletion by PYSL and YOY striped bass (*Morone saxatilis*) (CHGEC 1999). According to CHGEC (1999), early life stages of this species are generally not at risk of entrainment because spawning and early development occurs upstream near nests, which adult white catfish guard. CHGEC (1999) also states that juvenile and adult white catfish are infrequently impinged; the species has been recorded to consist of 0.42 percent of total fish impinged at IP2 and IP3. White catfish were not commonly observed in entrainment samples but were common in impingement samples obtained from IP2 and IP3.

<u>White Perch</u>

White perch (*Morone americana*) is endemic to the North American eastern coastal areas and range from Nova Scotia to South Carolina. It is not actually a perch, but a member of the temperate bass family Percichthyidae, along with striped bass (*M. saxatilis*). White perch are year-round residents in the Hudson River between New York City and the Troy Dam near Albany. They have never been a recreationally or commercially important resource for the Hudson River, and commercial fishing was closed in 1976 because of PCB contamination, but they are well represented in impingement collections of Hudson River power plants. In other parts of its range, white perch is intensively fished (Klauda et al. 1988).

Spawning habitats vary and can be clear or turbid, fast or slow, in water less than 7 m (23 ft) deep (Stanley and Danie 1983). In the Hudson River, most spawning occurs in the upper reaches (RKM 138 to 198 (RM 86 to 123)) in shallow embayments and tidal creeks, and adults move offshore and downriver after spawning (Klauda et al. 1988). Spawning in the Hudson River begins in late April when water temperatures reach 10 to 12°C (50 to 54°F) and can continue until late May or early June when temperatures reach 16 to 20°C (61 to 68°F) (Klauda et al. 1988). Fecundity depends on age and size of the females and ranges from about 5,000 to over 300,000 eggs (Stanley and Danie 1983). The eggs are adhesive and sink and may stick to the substrate or each other.

Hatching takes place between 1 and 6 days following fertilization, and the incubation period is inversely related to water temperature but relatively unaffected by salinity and silt levels (Collette and Klein-MacPhee 2002; Stanley and Danie 1983). Newly hatched YSL are about 2 mm (0.08 in.) long, and after 5 to 6 days, the yolk sac is absorbed (Collette and Klein-MacPhee 2002). The YSL generally remain in the same area where they hatched for 4 to 13 days (Stanley and Danie 1983). PYSL eat zooplankton and grow rapidly. Juveniles eat larger zooplankton. In the spring as water temperature rises, adults, which can reach maximum lengths of 495 mm (19.5 in.), begin their spawning migration and start to move upstream into shallower, fresher waters and into tidal streams.

Juveniles tend to stay in inshore areas of the estuary and in creeks until they are about a year old and 20 to 30 cm (8 to 12 in.) in length and then tend to move downstream to brackish areas (Stanley and Danie 1983). Although they may move offshore during the day, they tend to return to shoal areas at night. Most males and females mature at 2 years. After spawning, they return to deeper waters. In summer, large schools of white perch tend to move slowly without direction, and they tend not to travel very far. (Stanley and Danie 1983)

White perch are opportunistic feeders and have a broad range of prey. Young adults in freshwater environments feed on aquatic insects, crustaceans, and other smaller fishes (Stanley and Danie 1983). In brackish and estuarine environments, the white perch feed on fish eggs, the larvae of walleye (*Sander vitreus*) and striped bass, and other smaller adult fish (Chesapeake Bay Program 2006). Young adult white perch also consume amphipods, snails, crayfish, crabs, shrimp, and squid where available. White perch larger than 22 cm (9 in.) feed almost exclusively on other fish. White perch are consumed by many larger predatory fish species. White perch were commonly observed in both entrainment and impingement samples obtained from IP2 and IP3.

<u>Blue Crab</u>

Blue crab (*Callinectes sapidus*, family Portunidae) is an important commercial and recreational resource throughout much of its range, which in the western Atlantic is from Nova Scotia through the Gulf of Mexico to northern Argentina. The life history of blue crab in the Hudson River estuary is largely based on the Delaware and Chesapeake Bays, where the most relevant information in the United States has been gathered. Unless otherwise noted, information below is from Perry and McIlwain (1986).

Spawning and mating in blue crabs occur at different times. Mating takes place when female crabs are in the soft condition after their terminal, or last, molt. Males then carry the soft-shelled females until their shell hardens. Females store the sperm, which is used to fertilize the eggs for repeated spawnings. After the shell hardens, the females move downstream to the mouths of estuaries to spawn. Females extrude fertilized eggs and attach them on the underside of their bodies as a bright orange “sponge” consisting of up to 2 million eggs. The eggs become darker as they mature, and the sponge is almost black at the time of hatching. The eggs hatch and release the first zoea stage after about 2 weeks.

Larval crabs go through seven zoeal stages (and sometimes eight) in 31 to 49 days, depending on temperature and salinity. The zoeae are planktonic and live in the ocean near shore. Zoeae eat small zooplankton, such as rotifers. The last zoeal stage metamorphoses with its molt to a megalops larva, which persists from 6 to 20 days. Megalops larvae have more crab-like features than zoeae and are initially planktonic but gradually become more benthic. Megalops larvae inhabit the lower estuary and nearshore areas (ASMFC 2004) and have been found as far as 40 mi (64 km) offshore. Winds, tides, and storms transport the larvae back in towards shore (Kenny 2002). Among others, jellyfish are predators on crab larvae.

The megalops larvae molt and metamorphose into the first crab stage, which has all the features of a blue crab, and, like all crustaceans, grows by molting. The early crab stages, which are 10 to 20 mm (0.4 to 0.8 in.) carapace width in size, migrate to fresher water. Although benthic, blue crabs are good swimmers. They feed less and cease molting as winter nears and bury themselves in the mud in winter. Because the Hudson River is at the northern end of the blue crab’s range, severe winters may affect over-winter survival (Kenney 2002).

In the Chesapeake Bay, blue crabs mature in 18 to 20 molts, at which time females undergo a final, or terminal, molt, and males continue to grow and molt (Kenney 2002). In the Hudson River, most females make the terminal molt before they reach a carapace width of about 125 mm (4.92 in.) (Kenney 2002). Adult males prefer the low salinity areas of upper estuaries, while females, after mating, move to and remain in the higher salinity areas of the lower estuary. Blue crabs can live about 3 or 4 years, although most probably do not live past the age of 2. Adult blue crabs are benthic predators that will lie in wait to catch small fish. They also eat other crabs and crustaceans, mollusks, dead organisms, zebra mussels, aquatic plants, and organic debris. They will also eat other blue crabs. Young and adult blue crabs are prey for many predators, including a variety of birds, including herons and diving ducks; humans; raccoons; and fish, including various members of the sciaenid (drum) family, American eel, and striped bass. Cannibalism is thought to be a major source of mortality. Environmental factors thought to affect juvenile and adult blue crab populations include drought, winter mortality, hypoxia, hurricanes, and the effects of human development (ASMFC 2004).

New York has a relatively small blue crab fishery, which reported a large decrease in landings in 1997; since then, the harvest has been about a million pounds a year (ASMFC 2004). Blue crab fishing in the Hudson River Estuary occurs mostly in the summer and fall (Kenney 2002). Egg-bearing females are returned to the river to help protect spawning stock (Kenney 2002). Blue crab have been impinged on the screens of IP2 and IP3.

2.2.5.5 Special Status Species and Habitats

<u>Atlantic Sturgeon</u>

The Atlantic sturgeon (*Acipenser oxyrhynchus*, family Acipenseridae) is an anadromous species, with a range extending from St. Johns River, Florida, to Labrador, Canada. Considered the “cash crop” of Jamestown before tobacco, the Atlantic sturgeon has been harvested for its flesh and caviar, as well as its skin and swim bladder. A long-lived, slowly maturing species, the Atlantic sturgeon can reach 60 years of age (ASMFC 2007c; Gilbert

1989). Maturity is reached at 7 to 30 years for females, and 5 to 24 for males, with fish in the southern range maturing earlier than those inhabiting the northern range (ASMFC 2007c). Fecundity is correlated with age and size, ranging from 400,000 to 8 million eggs per female (NMFS 2007). Individuals reach lengths of about 79 in. (200 cm), while the largest recorded sturgeon was 15 ft (4.5 m) and 811 lb (368 kg) (ASMFC 2007c).

In the spring, adult Atlantic sturgeons migrate to freshwater to spawn, with males arriving a few weeks before the females. In the Hudson River, the males' migration occurs when water temperatures reach 5.6 to 6.1°C (42 to 43°F); the females appear when water temperatures warm to 12.2 to 12.8°C (54 to 55°F). Spawning occurs a few weeks later (Gilbert 1989). Eggs are deposited on hard surfaces on the river bottom, and hatch after 4 to 6 days (Shepherd 2006c). Individuals do not spawn annually—spawning intervals range from 1 to 5 years for males and 2 to 5 years for females (NMFS 2007). Females typically leave the estuary 4 to 6 weeks after spawning, but the males can remain in the estuary until the fall. Larvae feed from their yolk sac for 9 to 10 days, and then the PYSL begin feeding on the river bottom (Gilbert 1989). In the fall, the juveniles move downstream from freshwater to the estuaries, where they remain for 3 to 5 years, and then migrate to the ocean as adults (Shepherd 2006c). Individuals return to their natal river for spawning, and so the species is divided into five distinct population segments (ASSRT 2007). Juveniles and adults are bottom feeders, subsisting on mussels, worms, shrimp, and small fish (Gilbert 1989; ASMFC 2007c).

Before 1900, landings of Atlantic sturgeon reached 3500 MT (3860 t) per year. This number dropped in the 20th century, and from 1950 to 1990, landings ranged from 45 to 115 MT (50 to 127 t) per year (Shepherd 2006c). ASMFC placed a moratorium on harvesting wild Atlantic sturgeon for the entire coast in 1997, in an attempt to allow the population to recover. In 1999, the Federal Government banned the possession and harvest of sturgeon in the Exclusive Economic Zone (Shepherd 2006c; ASMFC 2007c). Using a Petersen mark–recapture population estimator, Peterson et al. (2000) estimated that the Hudson River population of age 1 Atlantic sturgeon had declined about 80 percent between 1977 and 1985. The authors suggested that the then-current recruitment could be too low to sustain the population. As of October 2006, NMFS has listed Atlantic sturgeon as a candidate species for listing under the Endangered Species Act (71 *Federal Register* (FR) 61022). Threats such as bycatch, water quality, and dredging continue to affect Atlantic sturgeon (ASMFC 2007c). In the Hudson River, the Federal Dam (the southernmost obstruction in the river) is upstream of the northern extent of the Atlantic sturgeon spawning habitat and therefore is not a limiting factor (ASSRT 2007).

Average levels of PCBs in Hudson River sturgeon tissue exceeded FDA guidelines for human consumption in the 1970s and 1980s; since then, levels of PCBs have dropped below FDA guidelines (ASSRT 2007). Although the State placed a moratorium on harvesting Atlantic sturgeon in 1996 when it became apparent that the Hudson River stock was overfished, the American shad gill net fishery continues to take subadult sturgeon as bycatch. The Review Team for Atlantic Sturgeon concluded in 2007 (ASSRT 2007) that the Hudson River subpopulation has a moderate risk (less than 50 percent) of becoming endangered in the next 20 years as a result of the threat of commercial bycatch. Despite this, the Hudson River supports the largest subpopulation of spawning adults and juveniles, and some long-term surveys indicate that the abundance has been stable since 1995 or is even increasing (ASSRT 2007). Recent work by Sweka et al. (2007) has suggested that a substantial population of juvenile Atlantic sturgeon are present in Haverstraw Bay and that future population monitoring should focus on this area to obtain the greatest statistical power for assessing population trends. Eggs and larval forms of Atlantic sturgeon were not observed in entrainment samples collected from IP2 and IP3 in 1981 and 1983-1987, but sturgeon were present in impingement samples.

<u>Shortnose Sturgeon</u>

The shortnose sturgeon (*Acipenser brevirostrum*, family Acipenseridae) is amphidromous, with a range extending from St. Johns River, Florida, to St. John River, Canada. Unlike anadromous species, shortnose sturgeons spend the majority of their lives in freshwater, moving to saltwater periodically, without relation to spawning (Collette and Klein-MacPhee 2002). From colonial times, shortnose sturgeons have rarely been the target of commercial fisheries but have frequently been taken as incidental bycatch in Atlantic sturgeon and shad gillnet fisheries (Shepherd 2006c; Dadswell et al. 1984). The shortnose sturgeon was listed on March 11, 1967, as endangered under the Endangered Species Act of 1973, as amended. In 1998, a recovery plan for the shortnose sturgeon was finalized by NMFS (NMFS 1998). The threats to the species include dams, water pollution, and destruction or degradation of habitat (Shepherd 2006c).

Shortnose sturgeon can grow up to 143 cm (56 in.) in total length, and can weigh up to 23 kg (51 lb). Females are known to live up to 67 years, while males typically do not live beyond 30 years (Dadswell et al. 1984). As young adults, the sex ratio is 1:1; however, among fish larger than 90 cm (35 in.), measured from nose to the fork of the tail, the ratio of females to males increases to 4:1. Throughout the range of the shortnose sturgeon, males and females mature at 45 to 55 cm (18 to 22 in.) fork length, but the age at which this length is achieved varies by geography. At the southern extent of the sturgeon's range, males reach maturity at age 2, and females reach maturity at 6 years or younger; in Canada, males can reach maturity as late as age 11, and females at age 13 (Dadswell et al. 1984; OPR undated). One to two years after reaching maturity, males begin to spawn at 2-year intervals, while females may not spawn for the first time until 5 years after maturing, and thereafter spawn at 3- to 5-year intervals (Dadswell et al. 1984; OPR undated). Shortnose sturgeon migrate into freshwater to spawn during late winter or early summer. Eggs adhere to the hard surfaces on the river bottom before hatching after 4 to 6 days. Larvae consume their yolk sac and begin feeding in 8 to 12 days, as they migrate downstream away from the spawning site (Kynard 1997; Collette and Klein-MacPhee 2002). The juveniles, who feed on benthic insects and crustaceans, do not migrate to the estuaries until the following winter, where they remain for 3 to 5 years. As adults, they migrate to the nearshore marine environment, where their diet consists of mollusks and large crustaceans (Shepherd 2006c; OPR undated).

In the Hudson River, shortnose sturgeon use the lower Hudson and are dispersed throughout the river estuary from late spring to early fall and then congregate to winter near Sturgeon Point (RKM 139 (RM 86)). They then spawn in the spring, just downstream of the Federal Dam at Troy. The population of shortnose sturgeons in the Hudson River has increased 400 percent since the 1970s, according to Cornell University researchers (Bain et al. 2007). Recent work by Woodland and Secor (2007) estimates a fourfold increase in sturgeon abundance over the past three decades, but reports that the population growth slowed in the late 1990s, as evidenced by the nearly constant recruitment pattern at depressed levels relative to the 1986–1992 year classes. Although the Hudson River appears to support the largest population of shortnose sturgeons, Bain et al. (2007) report that other populations along the Atlantic coast are also increasing, and some appear to be nearing safe levels, suggesting that the overall population could recover if full protection and management continues. NMFS (2009) recently suggested to NRC Staff that the shortnose sturgeon population estimates for the Hudson River of 60,000 fish presented in Bain et al. (2007) are likely overestimates, and that 30,000 is a more appropriate estimate. Eggs and larval forms of shortnose sturgeon were not observed in entrainment samples from IP2 and IP3 in 1981 and 1983-1987, but sturgeon were present in impingement samples.

2.2.5.6 Other Potentially Affected Aquatic Resources

Phytoplankton and Zooplankton

Phytoplankton and zooplankton communities often form the basis of the food web in rivers and estuaries. The phytoplankton in the Hudson River generally fall into three major categories—diatoms, green algae, and blue-green algae. Diatoms are abundant through most of the year, but reach peak densities when water temperatures are low and watershed runoff and river flows are high. Green algae are present in highest abundances during the summer, when river flows are low and water temperatures are relatively high. Blue-green algae are generally present in late summer and early fall (CHGEC 1999).

Zooplankton populations in the Hudson River are divided into two major categories—holoplankton, which spend their entire live cycle as plankton, and meroplankton, which include the eggs and larvae of fish and shellfish that spend only a part of their life cycle in the planktonic community. Holoplankton in the brackish areas of the Hudson River from approximately IP2 and IP3 downstream (RM 40 (RKM 64)) are generally dominated by marine species; holoplankton from Poughkeepsie north (RM 68 (RKM 109)) are generally dominated by freshwater forms (Figure 2-10). Zooplankton sampling from Haverstraw Bay to Albany from April to December 1987–1989 identified five numerically dominant taxa—the cyclopoid copepod, *Diacyclops bicuspidatus thomasi*; the cladoceran, *Bosmina longirostris*; and the rotifers *Keratella* spp., *Polyarthra* spp., and *Trichocera* spp. (CHGEC 1999). Work by Lonsdale et al. (1996) suggests that larger (greater than 64 microns (0.0025 in.)) zooplankton species that include both mesozooplankton and micrometazoa have a minimal role in controlling total phytoplankton biomass in the lower Hudson River estuary. Grazing pressure sufficient to contribute to the decline of the phytoplankton standing crop occurred only during the month of October.

Phytoplankton communities in the freshwater portion of the Hudson River are susceptible to predation by the zebra mussel, *Dreissena polymorpha*. Work by Roditi et al. (1996) suggests that the mussels are able to remove Hudson River phytoplankton effectively in the presence of sediment and can do so at rapid rates. The authors indicate that, based on their measurements and unpublished estimates of the size of the zebra mussel population, the mussels present in the upper stretches of the river can filter a volume equivalent to the entire freshwater portion of the Hudson River every 2 days. Strayer suggests that they filter a volume of water equal to all of the water in the estuarine Hudson every 1–4 days during the summer (2007). Significant declines in zooplankton biomass were also reported after the introduction of the mussel (Pace et al. 1998). Work by Strayer et al. (2004) suggests that the long-term impacts of zebra mussel removal of phytoplankton and zooplankton have profoundly affected the food web in the Hudson River, resulting in a shift of open-water species to downriver locations away from the mussels and a shift of littoral species upriver. The resulting changes affected a variety of commercially and recreationally important species, including American shad and black bass, illustrating the importance of zooplankton and phytoplankton in food webs associated with the freshwater portion of the Hudson River (Strayer et al. 2004).

Aquatic Macrophyte Communities

Aquatic macrophyte communities provide food and shelter to a variety of fish and invertebrate communities and are an important component of the Hudson River ecososystem. Macrophyte communities are generally divided into three broad groups that include emergent macrophytes, floating-leaved macrophytes, and submerged macrophytes (also known as SAV). Emergent macrophytes in the Hudson River generally occur near the shoreline to a water depth of about 5 ft (1.5 m) and have leaves that rise out of the water. Floating leaved macrophytes are attached to the bottom and have floating leaves and long, flexible stems. Submerged macrophytes are found beneath the water surface at a depth related to the clarity of the water (CHGEC 1999). The composition and distribution of aquatic macrophyte communities vary along the river and are controlled by physical characteristics and season. Work by Findlay et al. (2006) shows that the densities of macroinvertebrates in SAV beds were more than three times as high as densities on unvegetated sediments, suggesting that SAV beds may be the richest feeding grounds in the Hudson River estuary for fish. Further, the authors also noted that many species of macroinvertebrates that are common in aquatic macrophyte beds are rare or absent from unvegetated sites.

SAV beds in the Hudson are represented by two predominant species—the native submerged eel grass, *Vallisneria americana* and the introduced water chestnut, *Trapa natans* (Findlay et al. 2006). CHGEC (1999) identified 18 species of submergent aquatic vegetation between Kingston and Nyack, including nine species of *Potamogeton* (pondweed), and *Elodea* sp. (common pondweeds used in aquaria), and a variety of other species. Historical and recent work has shown that SAV occupies major portions of some reaches of the Hudson River, when present, and can cover as much as 25 percent of the river bottom (Findlay et al. 2006). New York State has been studying the SAV in the Hudson River estuary from the Troy Dam south to Yonkers since 1995. Using true color aerial photography, researchers from Cornell University and the New York Sea Grant Extension inventoried the spatial extent of the SAV and water chestnut beds from 1995 to 1997 and in 2002. They determined that vegetated area constitutes roughly 8 percent of total river surface area with eel grass three times as abundant as water chestnut. Plant coverage over the entire study area from the Troy Dam to Yonkers was about 6 percent of the river bottom area for eel grass and 2 percent for water chestnut, although the distribution of both plants varies greatly among reaches of the tidal freshwater Hudson River (Nieder et al. 2004). According to NYSDEC (2007a), there has been a 9-percent decline in all SAV and a 7-percent gain in water chestnut.

Coastal Marshes, Wetlands, and Riparian Zones

Coastal marshes, tidal wetlands, and associated riparian zones are found along the lower Hudson River. Vegetation in these areas includes emergent grasses, sedges, and other plants adapted to nearshore conditions that often experience changes in runoff, salinity, and temperature. FWS has identified the area extending from the Battery north to Stony Point at the northern end of Haverstraw Bay as Lower Hudson River Estuary Complex #21 (FWS 2008a). Within this complex there are many significant wetland habitats, including a regionally significant nursery and wintering habitat for a variety of anadromous, estuarine, and marine fish, as well as a migratory area for birds and fish that feed on abundant prey items.

Recognizing the importance of coastal wetlands, tidal marshes, and riparian zones, NOAA, partnering with NYSDEC, identified four locations along the lower Hudson River estuary for inclusion in the National Estuarine Research Reserve System in 1982 (NOAA 2008a). The areas, from north to south, are Stockport Flats, Tivoli Bay, Iona Island, and Piermont Marsh; they collectively represent over 4800 acres (1900 ha) of protected habitat.

Stockport Flats is the northernmost site in the Hudson River Reserve and is located on the east shore of the river in Columbia County near the city of Hudson. This site is a narrow, 5-mi-long landform that includes Nutten Hook, Gay's Point, Stockport Middle Ground Island, the Hudson River Islands State Park, a portion of the upland bluff south of Stockport Creek, and dredge spoils and tidal wetlands between Stockport Creek and Priming Hook. The dominant features of Stockport Flats include freshwater tidal wetlands that contain subtidal shallows, intertidal mudflats, intertidal shores, tidal marshes, and floodplain swamps (NOAA 2008a).

Tivoli Bay extends for 2 mi along the east shore of the Hudson River between the villages of Tivoli and Barrytown, in the Dutchess County town of Red Hook. The site includes two large coves on the east shore—Tivoli North Bay, a large intertidal marsh, and Tivoli South Bay, a large, shallow cove with mudflats. The site also includes an extensive upland buffer area bordering North Tivoli Bay. Habitats at this site include freshwater intertidal marshes, open waters, riparian areas, shallow subtidal areas, mudflats, tidal swamps, and mixed forest uplands (NOAA 2008a).

Iona Island is located near the Town of Stony Point in Rockland County, 6 mi south of West Point. This bedrock island is located in the vicinity of the Hudson Highlands and is bordered to the west and the southwest by Salisbury and Ring Meadows. In the early 20th century, filling activities connected Round Island to the south end of Iona Island. There is approximately 1 mi of marsh and shallow water habitat between Iona Island and the west shore of the Hudson River, and the area includes brackish intertidal mudflats, brackish tidal marsh, freshwater tidal marsh, and deciduous forested uplands.

Piermont Marsh lies at the southern edge of the village of Piermont, 4 mi south of Nyack. The marsh is located on the west shore of the Tappan Zee region near the town of Orangetown in Rockland County. The site includes 2 mi of shoreline south of the mile-long Erie Pier and the mouth of Sparkill Creek. Habitats at this location include brackish tidal marshes, shallows, and intertidal mud flats.

2.2.5.7 Nuisance Species

<u>Zebra Mussel</u>

In the early 1990s, the nonnative zebra mussel, *Dreissena polymorpha,* made its first appearance in the freshwater portions of the Hudson River estuary. Beginning in early fall 1992, zebra mussels have been dominant in the freshwater tidal Hudson, constituting more than half of heterotrophic biomass, and filtering a volume of water equal to all of the water in the estuary every 1-4 days during the summer (Strayer 2007). The mussel's range extends from Poughkeepsie to the Troy Dam, with the highest densities occurring between Saugerites and Albany (CHGEC 1999; Strayer et al. 2004; Caraco et al. 1997). The presence of the mussels resulted in a decrease in phytoplankton biomass of 80 percent (Caraco et al. 1997) and a decrease of zooplankton abundance of 70 percent (Pace et al. 1998). Water chemistry was also altered, as phosphate and nitrate concentrations increased and DO concentrations decreased after the mussels were established (CHGEC 1999; Caraco et al. 2000). Caraco et al. (2000) indicated that these effects fundamentally changed food web relationships in the river and may have had a significant impact on many fish species.

Work by Strayer et al. (2004) found that open-water species such as *Alosa* spp. (shad and herring) exhibited a decreased abundance in response to Zebra mussel introduction, while the abundance of littoral species such as centrarchids (sunfish) increased. The median decrease in abundance of open-water species was 28 percent, and the median increase in abundance of littoral species was 97 percent. The authors also noted that populations of open-water species shifted downriver, away from the zebra mussel population, while littoral species shifted upriver.

Growth rates of open-water and littoral species were also affected by the mussels. Strayer and Smith (1996) found impacts to unionid bivalve mussels (*Elliptio complanata, Anodonta implicata, Leptodea ochracea*) such as decreasing densities and incidences of infestations. After the arrival of the zebra mussel, the authors reported that densities of these three unionid clam species fell by 56 percent, recruitment of YOY unionids fell by 90 percent, and the biological condition of unionids fell by 20–50 percent, with *E. complanata* less severely affected than the other two. Strayer and Smith (1996) suggest that the impacts to these species may be associated with both competition for food and biofouling by zebra mussels.

The work of Strayer, Caraco, Pace, and others has raised important questions and issues concerning the nature of impacts to fish communities from exotic or introduced species, the management of fish populations affected by these species, and the need to carefully consider all potential environmental stressors present when assessing the reasons for fish or invertebrate population declines. Changes in abundance and distribution in the freshwater portion of the Hudson River estuary involved many recreationally and commercially important species, including striped bass (*M. saxatilis)*, American shad (*A. sapidissima*), redbreast sunfish, and black bass (*Micropterus* spp*.)*. The changes Strayer et al. (2004) documented since 1992 include overall decreases in abundance, redistribution of species up- or downriver in relation to the mussels and fundamental changes to food webs because of the physical presence of the mussels and their filtration activity.

Recent work by Strayer and Malcom (2006) suggests that there are still significant gaps in understanding about the biology and life cycle of the zebra mussel in the Hudson River. The researchers used a combination of long-term data and simulation modeling. The authors evaluated mussel population size, adult growth, and body condition and found considerable interannual variation in these factors that was not strongly correlated with phytoplankton population. The data suggested a 2- to 4-year population cycle that was driven by large interannual variations in recruitment. Strayer and Malcolm's (2006) work indicates that a complete understanding of the potential effects of this species on aquatic food webs, and thus recreationally, commercially, or ecologically important fish and invertebrate species and communities requires a better understanding of the factors affecting the zebra mussel life cycle in the Hudson River than currently exists.

<u>Water Chestnut</u>

The water chestnut was first observed in North America in 1859 near Concord, Massachusetts (FWS 2004). Currently, the plant is found in Maryland, Massachusetts, New York, and