Attachment C

DOI Modified Prescription for Fishways

United States Department of the Interior

FISH AND WILDLIFE SERVICE
300 Westgate Center Drive
Hadley, MA 01035-9589

JUN - 7 2016

In Reply Refer To:
FWS/R5/ES-ERR/063194

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

RE: Conowingo Hydroelectric Project, Federal Energy Regulatory Commission (FERC No. P- 405) Modified Prescription for Fishways

Dear Secretary Bose:

This correspondence contains the U.S. Department of the Interior's (Department) Modified Prescription for Fishways Pursuant to Section 18 of the Federal Power Act (Modified Prescription) for the Federal Energy Regulatory Commission Project No. 405 Conowingo Hydroelectric Project. This Modified Prescription is being filed in compliance with the Department's regulations at 43 CFR Part 45. All hearing requests and alternatives submitted to the Department have been withdrawn within the specified deadlines. Pursuant to the Department's regulations and the U.S. Fish and Wildlife Service's delegation of authority, we are now electronically filing our Modified Prescription for the above referenced Project.

Sincerely,

Wendi Weber
Regional Director

cc: Service List

ATTACHMENT A

BEFORE THE
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

Exelon Corporation, Applicant	)	Conowingo Hydroelectric Project
	)	FERC No. 405

UNITED STATES DEPARTMENT OF THE INTERIOR DECISION DOCUMENT AND MODIFIED PRESCRIPTION FOR FISHWAYS PURSUANT TO SECTION 18 OF THE FEDERAL POWER ACT

Submitted this 8th day of June, 2016
by:

Wendi Weber
Regional Director
U.S. Fish and Wildlife Service
United States Department of the Interior

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UNITED STATES DEPARTMENT OF THE INTERIOR

DECISION DOCUMENT

MODIFIED PRESCRIPTION FOR FISHWAYS

PURSUANT TO SECTION 18 OF THE FEDERAL POWER ACT

1. Introduction

The United States Department of the Interior (Department) through the U.S. Fish and Wildlife Service (Service) hereby submits its Modified Prescription for Fishways for the Conowingo Hydroelectric Project (Project, Conowingo, and Conowingo Project), FERC P-405, pursuant to Section 18 of the Federal Power Act (FPA). The Department is filing this Modified Prescription with the Federal Energy Regulatory Commission (Commission or FERC) with those portions of its supporting administrative record not already filed with the Commission under 43 C.F.R. part 45.

2. Administrative Process,

This Modified Prescription is the product of a process that began formally with the Department's response to the Commission's Ready for Environmental Analysis (REA) Notice on January 31, proposed to reserve her authority to prescribe fishways during the term of the license, presented several possible alternatives, and announced that if the Department subsequently amended that proposal to include measures in addition to the reservation of authority, the Service would provide the right to a trial-type hearing and accept proposals for alternatives at that time. The Department also made recommendations to the Commission under FPA Section 10(j), including a recommendation that the Commission include fishway terms consistent with the Department's Alternative G. On August 7, 2015, the Department withdrew that 10(j) recommendation, filed an Amended Preliminary Prescription proposing to require the construction, operation, and maintenance of fishways under Section 18 of the Federal Power Act, and providing time and opportunity for public comment and requests for trial-type hearing or formal presentation of alternatives under the 2005 Energy Policy Act and the Department's implementing regulations at 43 C.F.R. part 45. In response to that filing, on September 11, 2015, the license applicant, Exelon Generation Company, filed a request for Trial-Type Hearing and a proposed Alternative. American Rivers, the Chesapeake Bay Conservancy, and The Conservation Fund subsequently intervened in the trial-type hearing process. This Modified Prescription for Fishways reflects the terms of a settlement agreement reached with the license applicant, Exelon Corporation, filed with the Commission on May 13, 2016, and is the conclusion of the Department's decision-making process.

3. Project Works

The Conowingo Hydroelectric Project (Figure 1) is located in Maryland on the Susquehanna River at river mile (RM) 10 with a total upstream drainage area of 27,500 square miles. Conowingo Dam is located in Maryland connecting Cecil and Harford Counties, as is the lowermost 6 miles of the Project impoundment (Conowingo Pond). The upper 8 miles of Conowingo Pond are located in Pennsylvania, within York and Lancaster Counties. Construction of the Project was completed in 1928, and consists of a main dam, a spillway, Conowingo Pond, an intake and powerhouse, two fish lifts constructed in 1972 (West Fish Lift) and 1991 (East Fish Lift), and other appurtenant facilities (Exelon 2012a, pp. A-2; E-79).

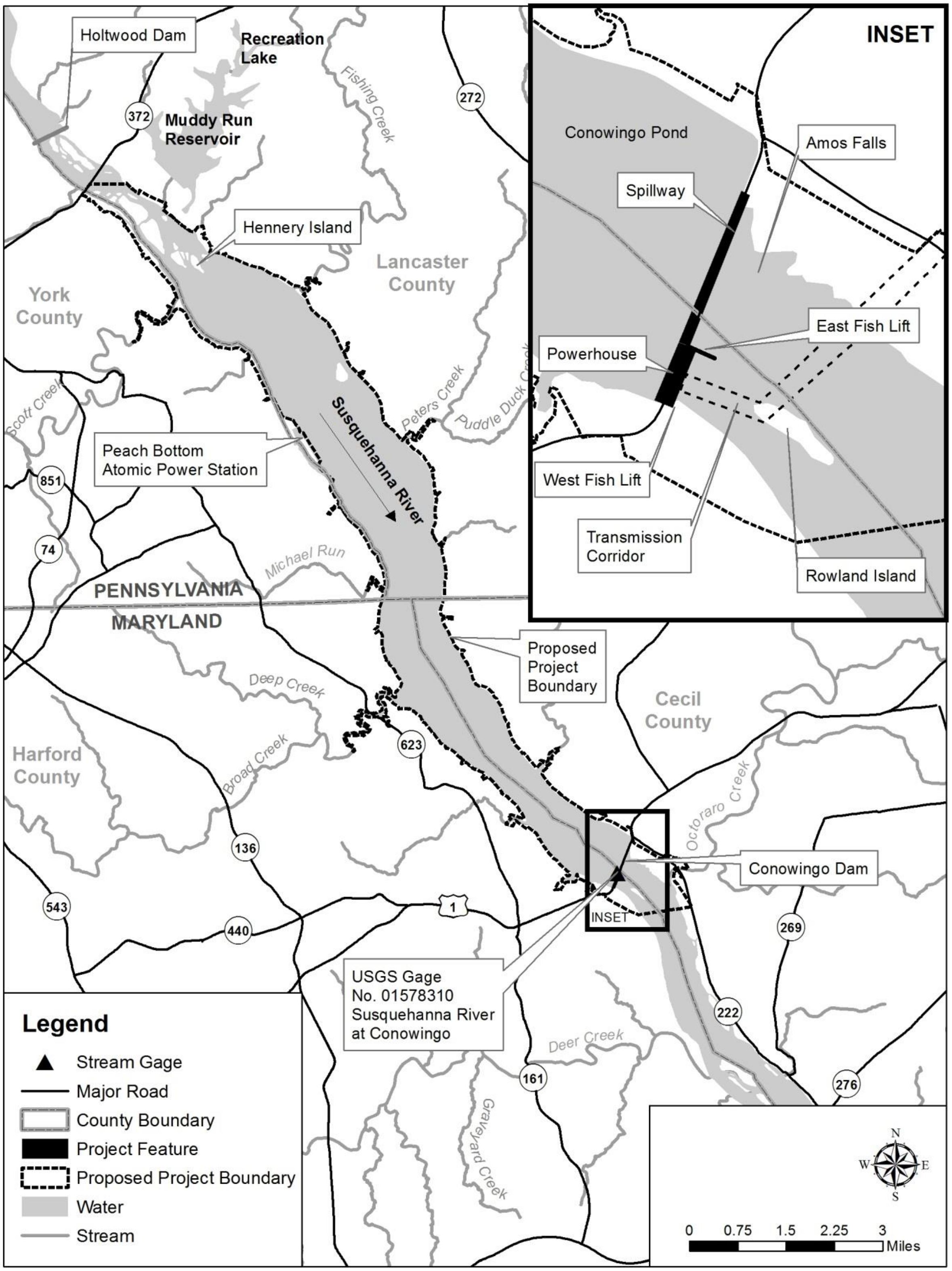

Figure 1. Conowingo Dam Project Area (FERC 2015, p. 37).

The Conowingo Dam is a concrete gravity dam with a maximum height of approximately 94 feet and a total length of 4,648 feet. The dam consists of four distinct sections from east to west: a 1,190-foot long non-overflow gravity section with an elevation of 115.7 feet; an ogee-shaped spillway, the major portion of which is 2,250 feet long with a crest elevation of 86.7 feet and the minor portion of which is 135 feet long with a crest elevation of 99.2 feet; an intake-powerhouse section which is 946 feet long; and a 127-foot long abutment section. The tailrace and spillway sections of the dam are separated by a dividing wall extending 300 feet downstream of the powerhouse. The dam and powerhouse also support US Highway Route 1, which passes over the top of Conowingo Dam. During the original construction, the entire dam was erected upon a solid rock formation of granite and diorite (Exelon 2012a, p. A-2).

In 1978, to increase the dam's capacity and upgrade the structure to meet stability requirements, the dam was anchored into the bedrock foundation by a post-tensioned anchorage system consisting of stranded wire tendons installed in holes drilled through the structure and continuing into the foundation rock. A total of 537 tendons were installed across the non-overflow, spillway and powerhouse intake monoliths (Exelon 2012a, p. A-2).

Flow over the Conowingo Dam ogee spillway sections is controlled by 50 stony-type crest gates with crest elevations of 86.7 feet and two regulating gates with crest elevations of 99.2 feet. Each of the crest gates is 22.5 feet high by 38 feet wide and has a collective discharge capacity of approximately 16,000 cfs at a reservoir elevation of 109.2 feet (Exelon 2012a, p. A-2).

The intakes for each turbine are individually protected by seven trash racks; five are made entirely of steel (clear spacing of 5.375 inches) and two are steel-framed with wood racks (clear spacing of 4.75 inches; Table 1). The top two racks are constructed of wood due to frazzle ice accumulations on the steel sections. The racks were previously cleaned by a stationary crane. However, a multi-purpose gantry crane was installed in 2007 and is now used as a trash rake (Exelon 2012a, p. A-4).

Table 1. Turbine intake structure characteristics at Conowingo Hydroelectric Project (Exelon 2012a, p. A-7).

Site Characteristic		Units 1-11 (Francis and Kaplan Units)	2 House Units
Intake Elevations	Top (ft.)	69.2	41.5
	Bottom (ft.)	11.2	25.7
Unit Intake Width (ft.)		23 per bay, 2 bays per unit	23
Unit Intake Area (sq. ft.)		1334 per bay, 2 bays per unit	361 1 bay for both units
Trash Rack Bars	Thickness (in)	0.625	0.5
	Height (in)	24	24
	Clear Spacing (in)	5.375	1.5

The first seven turbine/generating units (1-7) are completely enclosed within the powerhouse, while the last four units (8-11) are an outdoor type of construction thereby eliminating a superstructure in this area (Table 2). For Units 1-7, a 27-foot diameter butterfly valve is installed at the entrance to the scroll case. These valves are operated by oil pressure cylinders which are opened from a central oil pressure system, but are rarely used. Dewatering is performed by placement of headgates and stoplogs. The main power station superstructure enclosing Units 1-7 includes the generator room and the electrical bay. The electrical bay is located between the generator room and the powerhouse headworks and consists of the 13.8-kilovolt (kV) bus and switching equipment. Compartments for step-up transformers are located on the roof of the electrical bay, together with the station service control room and the main control room, from which windows afford a direct view of the generator room. For Units 8-11, there are no valves within the intake; unit dewatering is performed by placement of headgates and stoplogs. Generator circuit breakers and electrical equipment are located in a two-story structure between the generator area and the headworks. The main step-up transformers are located on the roof of this structure (Exelon 2012a, p. A-4). Total hydroelectric station hydraulic discharge capacity for the Project is 86,000 cfs (Exelon 2012a, p. B-7).

Table 2. Turbine characteristics at the Conowingo Hydroelectric Project (Exelon 2012a, p. A-9).

Unit	Type	Rated Head (ft.)	Runner Speed (rpm)	Rated Output (hp)	Approx. Rated Discharge (cfs)
1	Francis	89	81.8	64,500	6,749
2	Francis	89	81.8	54,000	6,320
3	Francis	89	81.8	64,500	6,749
4	Francis	89	81.8	64,500	6,749
5	Francis	89	81.8	54,000	6,320
6	Francis	89	81.8	64,500	6,749
7	Francis	89	81.8	64,500	6,749
8	Mixed-Flow Kaplan	86	120	85,000	9,352
9	Mixed-Flow Kaplan	86	120	85,000	9,727
10	Mixed-Flow Kaplan	86	120	85,000	9,727
11	Mixed-Flow Kaplan	86	120	85,000	9,727
House #1	Francis	89	360	1,900	247
House #2	Francis	89	360	1,900	247

4. Resource Description

4.1 Susquehanna River

The Susquehanna River forms in upstate New York and west-central Pennsylvania and runs 444 miles from its headwaters in New York to the river mouth at Havre de Grace, Maryland (Figure 2). The Susquehanna River is the largest river that resides wholly within the United States that drains into the Atlantic Ocean, having a drainage area of over 27,500 square miles. It is the largest tributary to the Chesapeake Bay, providing 50 percent of the Bay’s freshwater (SRBC 2013a, entire).

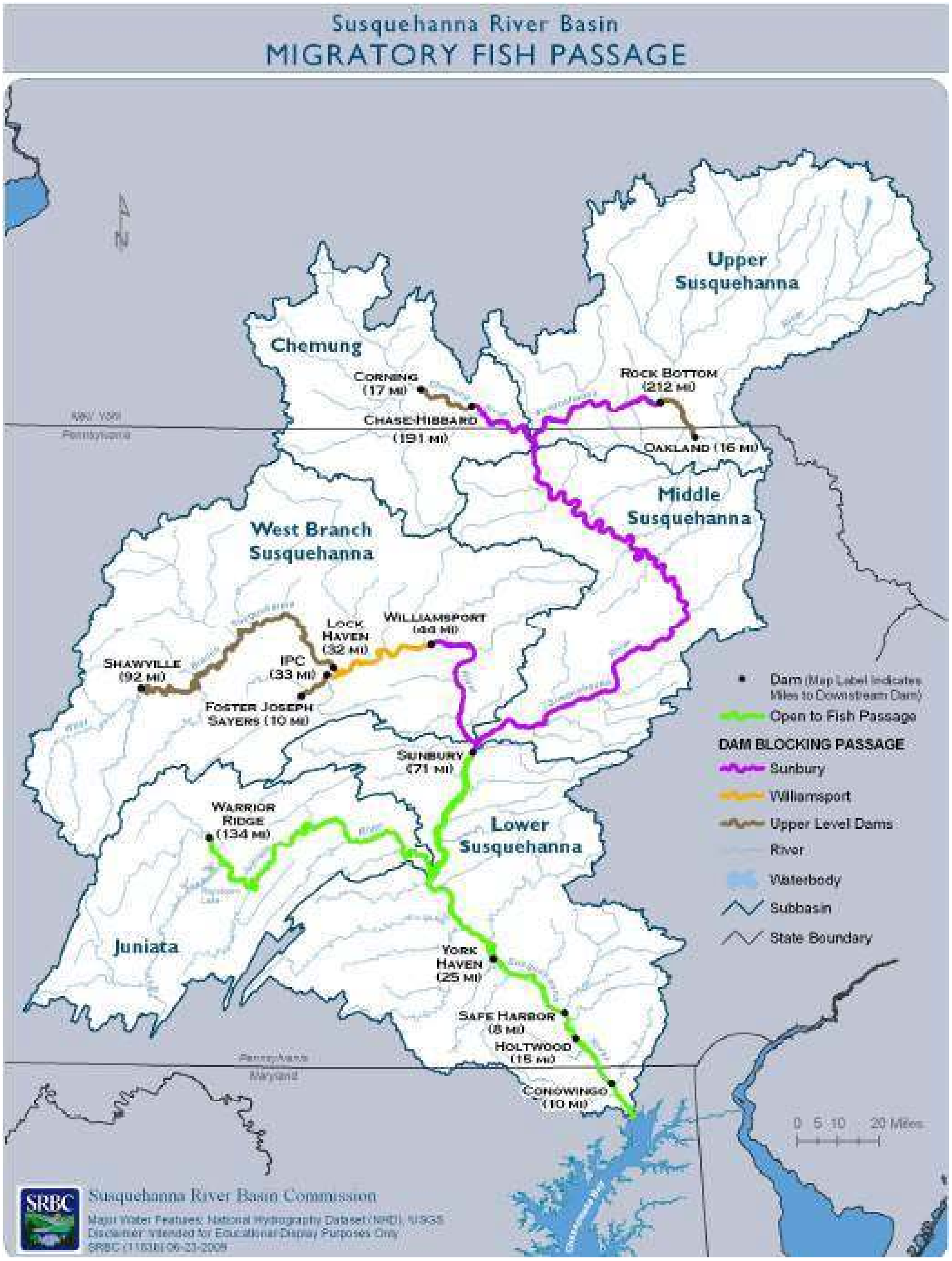

Figure 2. The Susquehanna River Basin, including locations of lower mainstem hydroelectric dams (SRAFRC 2010, p. 66).

4.1.1 History of Dam Construction on the Susquehanna River

Initial dam construction on the mainstem and large tributaries of the Susquehanna River began in the 1830s to feed the Susquehanna Canal system. Dams were located at Duncan's Island and

Columbia on the mainstem, as well as at Nanticoke on the North Branch and North Island on the Juniata River. The canal dams completely blocked migratory fish in some years, but allowed passage in others, particularly when the dams were damaged by ice flows. In 1866, fishways were required to be constructed at the dams, but ultimately were ineffective. By the end of the century, the canal system was abandoned, and breaks in the Columbia Dam on the lower mainstem re-opened a large portion of the river to migratory fish, with numbers rebounding until the early 1900s (SRAFRC 2010, p. 11).

At the turn of the 20th century, the lower mainstem of the Susquehanna River began to be developed to facilitate energy production. The size of this watershed and consistently large volume of water made the lower Susquehanna River an attractive reach for waterpower development, and for fossil and nuclear power plants that require large volumes of water for cooling. The generation capacity of all power projects on the lower Susquehanna River is over 8,000 MW (Table 3), including five hydroelectric, two atomic (nuclear), and one fossil (coal) generation plant (Figure 2).

Table 3. Energy development on the lower Susquehanna River in order of construction.

Project	**Capacity in 2013 (MW)**	**Year Building Started**	**Present ownership interest (100 percent unless stated otherwise)**
York Haven Hydro Project	19.6[a]	1901[a]	Cube Hydro Partners, LLC
Holtwood Hydro Project	234[b]	1905	Talen Energy
Conowingo Hydro Project	573[c]	1926[c]	Exelon
Safe Harbor Hydro Project	417.5[d]	1930[d]	Brookfield Renewable Energy Group
Brunner Island Power Plant	1490[e]	~1958[f]	Talen Energy
Muddy Run Pump Storage	1070[g]	1964[g]	Exelon
Three Mile Island Nuclear Plant	852[h]	1968[h]	Exelon – Unit 1
Peach Bottom Atomic Power Sta.	2490[i]	~1966	Exelon (50 percent) Public Service Enterprise Group Power (50 percent)
Wildcat Point (Proposed)	1000[j]	2014[k]	Old Dominion Electric Cooperative
Total Megawatts	8146.1		

a YHPC 2012. Exhibit A. p. 1.
b *https://www.pplenergyplus.com/large-business/products-and-services/renewable-energy/hydro* (accessed May 18, 2015)
c Exelon 2012a, pp. B-4, C-2.
d http://www.shwpc.com/facts_figures.html (accessed May 18, 2015)
e *http://www.pplweb.com/ppl-generation/ppl-brunner-island/ppl-brunnerisland-plant-fact-sheet.aspx* (accessed January 12, 2014)
f Construction start estimated; commercial operation began in 1961 according to reference at "e"

g Exelon 2012b, pp. A-5, C-2.
h *http://www.exeloncorp.com/assets/energy/powerplants/docs/TMI/fact_tmi.pdf* (accessed May 19, 2015)
i *http://www.exeloncorp.com/assets/energy/powerplants/docs/Peach_Bottom/Fact_PeachBottom.pdf (*accessed May 19, 2015)
j *http://www.odec.com/generation-transmission/future-generation* (accessed May 19, 2015)
k *http://wildcatpoint.com/news* (accessed May 19, 2015)

Construction of the lower mainstem hydroelectric dams began in 1901with the York Haven Dam at river mile (RM) 55. The York Haven Dam is a relatively low dam (9 – 18 feet high), which is operated as a run-of-river facility (FERC 2015, p. 32). The York Haven Hydroelectric Project is owned by Cube Hydro Partners, LLC, and is regulated by the FERC (FERC Project # 1888). The York Haven Hydroelectric Project was issued a 40-year license by FERC in December 2015.

The Holtwood Dam at RM 25 was the first of the high dams on the river, completed in 1910 and standing 55 feet high. During original construction, the Project included a fish ladder and a sluiceway to facilitate fish passage, but they were ineffective in passing American shad (SRAFRC 2010, p. 12). The Holtwood Hydroelectric Project is owned by PPL-Holtwood and is regulated by the FERC (FERC Project # 1881). The Holtwood Hydroelectric Project recently underwent redevelopment to increase generating capacity starting in 2010, and will be up for relicensing with FERC in 2030.

The Conowingo Dam at RM 10 was completed in 1928 and had no fish passage facilities included with initial construction (SRAFRC 2010, p. 12). Additional details on the Conowingo Dam are provided in Section 3.

The Safe Harbor Dam at RM 33 was completed in 1931. That dam is 75 feet high and did not have fish passage facilities installed during the original construction (SRAFRC 2010, p. 12). The Safe Harbor Hydroelectric Project is owned by Brookfield Renewable Energy Group and is regulated by the FERC (FERC Project #1025). The Safe Harbor Hydroelectric Project will be up for relicensing with FERC in 2030.

Muddy Run Pumped Storage Project (MRPSP) at RM 22 was constructed in 1966. This is a pumped storage facility on the eastern bank of Conowingo Pond that has the capacity to withdraw water up to 28,000 cfs from the Susquehanna River into a 198-acre power reservoir (pond) (Exelon 2012b, pp. A-6, A-7). The Project can discharge 32,000 cfs (Exelon 2012b, p. A-6). The MRPSP is owned by Exelon Corporation and is regulated by FERC (FERC Project # 2355). The MRPSP was issued a 40-year license by FERC in December 2015.

4.2 Migratory Fish of the Susquehanna River Basin

Historically, the Susquehanna River was accessible via the Chesapeake Bay to several species of sea-run migratory fish from the Mid-Atlantic coast. Migratory fish generally can be classified as either "anadromous" or "catadromous." Adult anadromous fish live in the ocean and migrate to freshwater rivers to spawn. Juvenile anadromous fish stay in freshwater habitats for several months or more before they return to the ocean and grow to maturity. Catadromy is the reverse of anadromy. Catadromous fish spend a large portion of their life in freshwater systems and migrate to the ocean to spawn. Juvenile catadromous fish migrate from the ocean to estuarine and freshwater systems to grow to maturity. Of the sea-run migratory fish present in the Susquehanna River, striped bass (*Morone saxatilis*), Atlantic sturgeon (*Acipenser oxyrinchus*), shortnose sturgeon (*A. brevirostrum*), sea lamprey (*Petromyzon marinus*), American shad (*Alosa sapidissima*), hickory shad (*A. mediocris*), alewife (*A. pseudoharengus*), and blueback herring (*A. aestivalis*) are anadromous and the American eel (*Anguilla rostrata*) is catadromous (SRAFRC 2010, p. 5; Li et al. 2014, p. 614).

Although the lower Susquehanna River continues to support several species of sea-run migratory fish, this document focuses on the American shad, river herring (collective term for alewife and blueback herring) and American eel, all of which historically used a substantial portion of the watershed for spawning and nursery habitat (SRAFRC 2010, pp. 7-10). Before the construction of the mainstem dams, these species ascended the Susquehanna River several hundred miles upstream into the West and North Branches (SRAFRC 2010, p. 7). Construction of canal dams on the Susquehanna River in the mid-1800s restricted access to historic spawning grounds for American shad and river herring, but the construction of the four large, hydroelectric dams on the lower mainstem river in the early 1900s eliminated access to nearly all of the spawning habitat and nursery habitat in the Susquehanna River (Dittman et al. 2009, p. 17; SRAFRC 2010, p. 12).

4.2.1 American Shad and River Herring

American shad and river herring are schooling fish that spend the majority of their life in the ocean but ascend their natal Atlantic coast freshwater rivers to spawn in the spring (Fay et al., 1983, p. 5; MacKenzie et al. 1985, pp. 5-6). Juveniles remain in freshwater rivers until fall before migrating back to sea, where they will remain until reaching maturity (Fay et al., 1983, p. 9; MacKenzie et al. 1985, p. 5). American shad typically take 3 to 6 years to mature and river herring take 3 years, with repeat spawning occurring in both species (Fay et al., 1983, p. 5; MacKenzie et al. 1985, pp. 4-5).

Anadromous species such as American shad and river herring are important links in the food chains for freshwater and ocean ecosystems. In freshwater, adults bring nutrients from the marine environment into the freshwater reaches of Atlantic coast tributaries (Garman and Macko 1998, p. 277). In addition, juvenile American shad and river herring can be important seasonal prey items for riverine predatory fish, such as largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) (Yako et al. 1998, p. 77; Hanson and Curry 2005, p. 361). As part of the Atlantic coastal food chain, juvenile and adult American shad and river herring consume zooplankton and serve as prey for popular commercial and recreational fish, such as striped bass, fish-eating birds and aquatic mammals (ASMFC 2009, p. 14).

American shad and river herring historically supported substantial river fisheries along the Atlantic coast and played an important role in the history and economy of the Susquehanna River (SRAFRC 2010, pp. 6–9). Their annual spring runs supported one of the oldest fisheries in the United States with spawning areas for American shad occurring as far inland as Binghamton, New York, 318 miles from the river mouth (SRAFRC 2010, p. 7).

Native Americans along the Susquehanna River relied on fish as a substantial component of their diet and caught American shad in large quantities long before European colonists arrived in North America. In the latter half of the 18th century, colonists from Connecticut settled in the Wyoming Valley (Scranton/Wilkes-Barre area) and established commercial and subsistence fisheries for American shad. American shad were a dietary staple and an integral part of the local economy. The fisheries in the North Branch (Susquehanna River upstream of its confluence with the West Branch at Northumberland, Pennsylvania) were economically valuable and abundant. Historical seine hauls near Northumberland would regularly catch at least 300 shad, some hauls taking 3,000 to 5,000. Nearly 10,000 shad were taken in a single haul at the Fish Island site. The annual commercial value of the North Branch shad fisheries in 1881 was estimated at $12,000[1] with an estimated catch of 150,000 fish. Commercial fisheries were also reported from the West Branch Susquehanna River and from the Juniata River. In addition, many American shad seine fisheries occurred on the lower Susquehanna in Pennsylvania and Maryland during the early decades of the 1800s (SRAFRC 2010, pp. 7-8). Fisheries continued in the river through the early 1900s with Pennsylvania reporting landings from 200,000 – 400,000 pounds annually. After 1910, these landings declined by two-thirds, concurrent with the initial construction of the mainstem dams and use of pound nets to intercept fish in the upper Chesapeake Bay (SRAFRC 2010, pp. 8, 12).

Less is known about historical abundance and use of the Susquehanna River by river herring, but historical accounts indicate they were abundant. While river herring may have spawned far upriver (i.e. Binghamton, New York), the river herring fishery on the Susquehanna River was largely confined to the lower river. Indications of large river herring runs may be found in Pennsylvania State Fishery Reports from around 1900. The reports indicate that many thousands of river herring were harvested, and that the fishery in the Susquehanna River far surpassed the fishery in the Delaware River (SRAFRC 2010, p. 8).

4.2.2 American Eel

American eels along the Atlantic coast of North America are panmictic, meaning that the entire coastal population spawns in one location in the ocean and young are distributed randomly along coastal currents until they reach estuaries and coastal rivers (i.e. they do not necessarily return to the river of their parent's origin; ASMFC 2012a, p. 6). Once young American eels reach the coast, they begin upstream migrations of varying distances. Some American eels will remain in estuaries until they reach maturity, which may occur as early as 3 to 5 years of age. Other young American eels will migrate upstream into freshwater rivers, some traveling hundreds of miles

[1] Referenced in 1881 dollars, would be equivalent to $290,000 in 2014 dollars (http://www.westegg.com/inflation/ last accessed June 1, 2015). Throughout the following discussion, dollar figures are given in the number of dollars spent in the years mentioned, not adjusted to 2014 dollars.

upstream and taking several years to complete the migration. Age at maturity in freshwater areas is highly variable, but it is not uncommon for American eels to be 15 years or older before reaching maturity in far upstream reaches of coastal rivers (ASMFC 2012a, p. 11). American eels in freshwater areas tend to be larger than their estuarine counterparts. In addition, far upstream freshwater reaches of rivers produce only female eels, which are much larger and more fecund than those found in estuaries (ASMFC 2012a, pp. 10, 14). Once American eels reach maturity, they begin their downstream migrations in rivers and estuaries. Maturity typically occurs during late summer through winter, although spring migration has been documented (ASMFC 2012a, p. 132; Eyler 2014, p. 38). American eels spawn in the Sargasso Sea in late winter and early spring and once spawning is completed, the adults die.

American eels play a valuable role in the freshwater river ecosystem, comprising more than 35 percent of the fish biomass in some freshwater streams (Odgen 1970, p. 54). As young eels, they migrate upstream in rivers in large schools and serve as a food source for predatory fish and birds. As American eels grow, especially in freshwater reaches, they begin feeding on aquatic insects, crayfish, and small fish (ASMFC 2012a, pp. 14-15). American eels are also an important host species for successful freshwater mussel reproduction (Lellis et al. 2013, p. 75) and the loss of American eels from freshwater habitats has been linked to reduced mussel populations in Susquehanna River tributaries (Minkkinen et al. 2014, entire). Freshwater mussels, as filter feeders, have the potential to reduce suspended solids and dissolved nutrients from a river system (Vaughn 2010, p. 28; Atkinson et al. 2013, entire).

American eels were once abundant throughout the Susquehanna River, historically reaching the headwaters of the Susquehanna River and tributaries (Dittman et al. 2009, pp. 15-17; SRAFRC 2010, p. 9). Native Americans historically fished and consumed American eels from watersheds as far upstream as Otsego Lake in Cooperstown, New York (Dittman et al. 2009, p. 15). A commercial fishery centered on American eels also occurred in the Susquehanna River basin during the late 1800s and early 1900s (SRAFRC 2010, p. 9). Landings of American eel from the Susquehanna River averaged 150,000 pounds per year from 1909–1912 (SRAFRC 2010, p. 10). Construction of the mainstem dams in the early 1900s precluded juvenile eels from accessing the majority of the Susquehanna River basin and eventually eliminated the in-river fishery upstream of Conowingo Dam (Dittman et al. 2009, p. 19; SRAFRC 2010, p. 12).

4.2.3 Impacts of Dams on Fish Migrations

Migratory fish have evolved to require specific conditions in river systems and the relatively recent alteration to many river systems by the construction of dams and other impacts has negatively affected migratory fish populations. Dams can impact both upstream and downstream fish migration in river systems (Limburg and Waldman 2009, pp 961). Dams not only block or impede fish migration, but also alter the hydrology and aquatic habitat in the river. Upstream of dams, where water flow is slowed, lake-like conditions, rather than riverine ones, prevail. Water flow downstream of dams, particularly at peaking hydroelectric projects, can be significantly altered (Limburg and Waldman 2009, p. 961) with drastic changes in water depth and velocity occurring over short time periods. Depending on the severity and location of blockages and changes to hydrology, migratory fish populations can be severely reduced or extirpated due to dam impacts (Limburg and Waldman 2009, p. 960).

4.2.3.1 Environmental Factors Associated with Fish Migrations

Migratory fish respond to environmental stimuli (e.g., light, temperature, day length, visual cues, sound, flow) to determine when and to what extent to migrate upstream or downstream (Loesch 1987, p. 90; MacKenzie et al. 1985, p. 5; Eyler 2014, p. 63). Primary cues for upstream migration of American shad, river herring, and American eels are freshwater flow and water temperature (Leggett and Whitney 1972, p. 659; Welsh and Liller 2013, p. 483; Ristroph et al. 2015, p. 1). When appropriate conditions exist, fish swim upstream against the current to reach spawning and juvenile rearing habitat (Walburg and Nichols 1967, p. 4; Welsh and Liller 2013, p. 483). In addition to environmental stimuli, the physiological condition of fish (e.g., sexual maturation) elicits a response to begin the spawning migration (Northcote 1998, p.5). For anadromous fish, the spawning migration is a result of fish seeking freshwater spawning habitat typically within their natal watershed (Walburg and Nichols 1967, p. 4; Loesch 1987, p. 89). For catadromous fish, the spawning migration culminates in the maturing fish, which entered a stream as juveniles to live and grow, leaving the freshwater watershed to spawn in the ocean (ASMFC 2012a, p. 10).

4.2.3.2 Impacts to Upstream Migration

American shad and river herring migrate upstream as adults and American eels migrate upstream as juveniles. The different species of fish have different swimming capabilities, with juvenile American eels having slower relative swimming speeds when compared to the adult American shad and river herring (Bell 1991, pp. 6.3–6.4). High water velocities, created by both natural flood flows and project related discharge may prevent fish from successfully migrating upstream to and past fishways in a timely manner (Haro et al. 2004, p. 1590). Conversely, both naturally occurring and project induced slow water velocities may not elicit an upstream migratory response (Bailey et al. 2004, p. 306), resulting in fish staying in downstream areas that may not be suitable or sufficiently sized spawning or nursery habitat.

4.2.3.3 Impacts to Downstream Migration

For downstream migration, fish respond to river flow and migrate past dams via different routes, including over dam spillways, down bypass channels, and through hydroelectric turbines (Kynard and O'Leary 1993, p. 785; Castro-Santos and Haro 2003, p. 994; Jansen et al. 2007, p. 1442). At hydroelectric dams, large volumes of water can direct out-migrating fish into potential hazards while they attempt to pass the project. Fish may be injured or killed via entrainment through a turbine, discharge through a gate with no adequate plunge pool, impingement on screens and racks, and trauma due to changes in barometric pressure (barotrauma). Mortality caused by passing downstream through turbines at hydroelectric projects can vary greatly depending on species, size, and life stage (adult or juvenile) of fish (e.g., 12 percent mortality for American shad, Heisey et al. 2008, pp. 7-8; 100 percent mortality for American eel, Carr and Whoriskey 2008, p. 393), as well as on turbine design, including turbine flow, tip speed, rotational speed, number of blades/buckets, blade spacing, and runner diameter (Franke et al. 1997; Section 4, p. 6). Also, barotrauma, such as the expansion and rupture of a fish's swim bladder, can cause mortality even if the fish is not injured by a strike from turbine blades (Brown et al. 2014, entire).

4.3 Migratory Fish Restoration Efforts on the Susquehanna River

4.3.1 Early Efforts by State and Federal Resource Agencies

Fish passage efforts in the Susquehanna River began as early as 1866, when the Pennsylvania Legislature passed an act requiring fish passage facilities to be constructed at dams. The fishways constructed in the latter part of the 1800s were largely ineffective in passing migratory fish, but enough fish passed by way of temporary dam breaches caused by ice damage to create optimism for the success of fish passage measures (SRAFRC 2010, p. 11).

The Holtwood Dam, the first of the high dams constructed on the river, had a primitive fish passage device that failed to pass American shad. When Conowingo Dam was being built in the mid-1920s, U. S. Commissioner of Fisheries O'Malley advised the Federal Power Commission (FPC) that “none of the fishways now constructed would be useful in assisting eels or fishes to pass over a dam 100 feet high” and “it is very doubtful that shad would ascend a fishway of any description or any height” (Joint State Government Commission 1949; pg. 42). Thus, with completion of the Conowingo Project in 1928, the Susquehanna River was closed to runs of migratory fishes (St. Pierre 2002, p. 1).

Technology in fishway design improved, and by the 1940s successful passage of American shad was demonstrated at Bonneville Dam on the Columbia River. With the urging of sportsmen, the Pennsylvania Fish Commission (PFC) and the Joint State Government Commission requested that the 1947 Session of the General Assembly of Pennsylvania ask the Congress of the United States to fund studies regarding the biological and engineering feasibility of constructing fish passage facilities at Susquehanna River dams. In response to a Congressional request on this matter, the Service offered several recommendations to Pennsylvania. These included development of an interstate agreement with Maryland to regulate the fisheries, stocking of tagged adult American shad upstream of dams, and assessment of mortality of adult and juvenile American shad passing through turbines (St. Pierre 2002, p. 1).

Pursuant to a bill passed by the 81st Congress, the Service initiated a 6-year study of American shad fisheries of the Atlantic coast in March, 1950. In 1951, the Pennsylvania Legislature passed Bill No. 68 which authorized the PFC to make a comprehensive study of the migratory habits of

American shad, including the stocking and tagging of American shad upstream and downstream of Safe Harbor Dam. The Service was asked to cooperate and provided a project leader to oversee the effort (St. Pierre 2002, p. 2).

Results of this 1952 study led to a more detailed Susquehanna Fishery Study in 1957-1960, sponsored by Philadelphia Electric Company (PECO). The purpose of this $75,000 effort was to determine the desirability and feasibility of passing American shad and other migratory fishes at Conowingo Dam. The Advisory Committee guiding this study was represented by Maryland Department of Research and Education, PFC, and PECO, and technical support was provided by fishery experts from the U. S. and Canada. Based on results from this study, the Advisory Committee concluded that fish passage at Conowingo Dam would not be expected to substantially increase the numbers of American shad or other migratory fish in the Susquehanna River, assuming fish passage was not provided at the remaining upstream mainstem dams (Whitney et al., 1961, p. 2; St. Pierre 2002, p. 2).

Simultaneous with the Susquehanna Fishery Study, a “grass roots” coalition in Pennsylvania was pressuring the U. S. Commissioner of Fisheries and the Secretary of the Interior to petition the FPC to require fish passage at Susquehanna River dams. Though the state PFC and organized sportsmen groups were supportive, this effort was largely sustained by Basse Beck, a newspaperman with the Sunbury Daily Item and spokesman for the Susquehanna Economic Development Association. In response to Beck's insistence, and with support and advice from the Service, the PFC hired consultants to conduct engineering and biological studies of proposed fish passage at dams on the Susquehanna River (St. Pierre 2002, p. 2).

The consultants concluded that development of fish passage facilities at Susquehanna River dams was feasible, and that if properly designed and built, they would pass American shad and American eels which approached the dams. However, the authors recommended that prior to construction of major facilities, a step-wise restoration program should be undertaken. This would include an evaluation of “the present and future suitability of the river to support runs of migratory fishes” and, “trapping of adult fish at Conowingo Dam and transporting them by tank truck to the area upstream of dams for propagation" (Bell and Holmes 1962, pg. 5; St. Pierre 2002, p. 2).

In October, 1962, the PFC again petitioned the Secretary of the Interior to ask the FPC to require fish passage at Conowingo Dam. In view of recommendations in the PFC report, however, the Commissioner of the Fish and Wildlife Service directed the drafting of a study proposal to resolve the question of suitability of the river to support American shad (St. Pierre 2002, p. 3).

On February 8, 1963, representatives of the Service, PFC, and the Maryland Board of Natural Resources initiated development of a 3-year study, funded by the utility companies and conducted by a team led by Service biologist Frank Carlson. The New York Department of Environmental Conservation (NYSDEC) was also a partner in this effort. Oversight and policy decisions were provided by the four-member Administrative Committee for Susquehanna Shad Studies and each agency contributed staff to a Technical Committee assigned to work directly with Carlson (St. Pierre 2002, p. 3).

The suitability study was conducted between 1963 and 1966 at a cost of about $196,000. Based on study findings, the Administrative Committee concluded that about 350 miles of the mainstem Susquehanna River and major tributaries provided suitable habitat for American shad spawning and juvenile development. However, the Administrative Committee also recognized that "there is not sufficient information to permit decision as to whether or not adult shad with a strong urge to migrate upstream are available, whether or not the designed fishways would in fact attract fish, or whether or not adults would move efficiently upstream through the reservoirs" (Administrative Committee 1968, p. 3; St. Pierre 2002, p. 3).

In an effort to move ahead in responding to concerns expressed by the Administrative Committee, representatives from Pennsylvania, Maryland, and New York met with the Service in Washington, D. C. on May 6, 1969. A cooperative state-federal partnership was established with objectives of restocking the upper basin with American shad eggs and encouraging PECO to build a trap and lift at Conowingo Dam. This group named itself the Susquehanna Shad

Advisory Committee (SSAC) and established a technical subcommittee to provide scientific guidance (St. Pierre 2002, p. 4).

Throughout 1969 and early 1970, the SSAC met eight times with utility representatives. On September 29, 1970, a 5-year settlement agreement was reached with the utility companies whereby upstream licensees agreed to fund a program to collect and stock up to 50 million American shad eggs each year, and PECO agreed to build an experimental fish collecting device at the west side of Conowingo Dam. This device was largely designed by Service engineers and built by Arundel Corporation. Initially budgeted at $500,000, by the time the completed facility became operational in spring, 1972, it had actually cost over $1,000,000 (Settlement Agreement 1970, p. 3; St. Pierre 2002, p. 4).

The Conowingo trap was an effective device, collecting an average of over 1 million fish per year. During the period 1972–1976, in addition to collecting over 650 American shad, the facility captured nearly 875,000 blueback herring, 177,000 alewives, 1,300 hickory shad, and 380,000 American eels (Robbins 1972, pp. 9-10; Foote and Robbins 1973, pp. 7, 15, 19; Buchanan and Robbins 1974, pp 6, 12, 16; Buchanan 1975, pp. 13-14; Kotkas & McGhan 1976, pp. 7, 18). Numbers of this magnitude for these species have rarely been equaled since. American shad culture studies were conducted by the PFC, Service, and Maryland Department of Natural Resources (MDNR) during 1974–1976. It was determined that intensive culture and release of larval American shad would greatly enhance probability of future adult returns, as opposed to continued egg plants. A dedicated American shad hatchery was built with utility funding on PFC property (Van Dyke) along the Juniata River near Thompsontown, Pennsylvania in 1976 (St. Pierre 2002, p. 4).

Also in 1976, SSAC reorganized by adding voting representation from the National Marine Fisheries Service (NMFS) and the hydroelectric project owners (one vote for PECO and one for the three upstream licensees). This seven-member group was renamed Susquehanna River Anadromous Fish Restoration Committee (SRAFRC) in recognition that all migratory fish were targets of restoration in the program. The 5-year agreement from 1970 was annually extended during 1976 through 1980 (Settlement Agreement 1970, p. 3; St. Pierre 2002, p. 5).

Long-term operating licenses for the Susquehanna River hydroelectric projects were scheduled for renewal in different years, complicating resource agency efforts to condition individual licenses to include provisions for fish passage. The Department successfully petitioned the Federal Energy Regulatory Commission (FERC - formerly Federal Power Commission) to combine relicensing for the four projects. Pending receipt of comments from interested agencies on the subject of American shad restoration and fish passage, FERC issued and renewed one-year licenses to each project during 1976–1979 (St. Pierre 2002, p. 5).

In 1979, the Service established a Susquehanna River coordinator position in Harrisburg, Pennsylvania and a Strategic Plan for Restoration of Diadromous Fishes to the Susquehanna River was developed and adopted by state and federal resource agencies. Components of this plan were also included in the Susquehanna River Basin Commission's (SRBC) Comprehensive Plan for management of the basin (St. Pierre 2002, p. 5).

4.3.2 FERC Licensing Process in the 1980s and 1990s

Ultimately, no agreement over fishways was reached and FERC issued long-term licenses for the Projects in August 1980. Issues related to American shad restoration, fish passage, and flow requirements were set aside for hearing. Seven organizations intervened, including the Department, PFC, MDNR, SRBC, Pennsylvania Department of Environmental Protection (PADEP), Pennsylvania Federation of Sportsmen's Clubs, and the Upper Chesapeake Watershed Association. The Department provided a lead counsel role (St. Pierre 2002, p. 5).

Following a year of discovery and preparation of testimony, hearings were conducted before a FERC hearing officer in Washington D.C. between October, 1981 and February, 1982. This first phase hearing (Docket EL80-38) was restricted to American shad restoration requirements with flow issues being deferred. Over 10,000 pages of testimony and hearing record were developed. Parties were again urged to negotiate a settlement rather than rely on the hearing officer and FERC to dictate restoration conditions (St. Pierre 2002, pp. 5-6).

As part of their license renewal, owners of the Safe Harbor Project sought to expand the powerhouse by adding five large new units. The PFC and SRBC threatened to delay such expansion through legal actions since the American shad restoration questions remained unresolved. To avoid such delays, Safe Harbor Water Power Corporation (owned by Baltimore Gas and Electric and Pennsylvania Power and Light) settled the matter in an agreement which provided $750,000 for SRAFRC-approved restoration activities during 1981–1985 (Settlement Agreement 1981, p. 4; St. Pierre 2002, p. 6).

With FERC failing to take any action on the hearing record and funding from the 1981 settlement with Safe Harbor being exhausted within 4 years, negotiations continued between interveners and three upstream licensees. Finally, in December, 1984 a long-term settlement was reached (Table 4; Settlement Agreement 1984). This agreement provided, among other things, $3,700,000 over the 10-year period 1985–1994 to fund SRAFRC-approved studies related to American shad restoration. Licensees also agreed to resolve outstanding issues related to design and construction of fish passage facilities at Holtwood, Safe Harbor, and York Haven projects once PECO agreed to construct passage facilities at Conowingo Dam. SRAFRC was expanded to include representatives from each of the upstream licensees and the SRBC, and NMFS assumed a liaison role to the committee. FERC approved this settlement in April, 1985 (St. Pierre 2002, p. 6).

Separate settlement talks continued sporadically with PECO. To show commitment to the restoration effort, PECO continued to fund trap and transport operations at the Conowingo fish lift throughout the early 1980s. In addition to the fish passage issue, resource agency interveners pressed FERC for establishment of continuous minimum flows from the Conowingo Project to avoid fish kills and to improve habitat conditions downstream of the dam (St. Pierre 2002, p. 6).

Table 4. Settlement agreements addressing fish passage issues at the Susquehanna River lower mainstem hydropower projects.

Year	Parties	Projects	Primary Topics
1970	• Pennsylvania Power & Light Company • Philadelphia Electric Power Company • The Susquehanna Power Company • Metropolitan Edison Company • Safe Harbor Water Power Corporation • U.S. Fish & Wildlife Service • Pennsylvania Fish Commission • Maryland Department of Natural Resources • New York Department of Environmental Conservation	• Conowingo • Holtwood • Safe Harbor • York Haven	• PP&L to construct an experimental fish trapping device to be operated for 5 years at Conowingo Dam (operating by 1971) • Trap and transport operations to be conducted by PEPCO and SPCO • PP&L, SHWPC, and MetEd will collect and stock 50 million fertilized American shad eggs into the Susquehanna River for 5 years
1981	• Pennsylvania Power & Light Company • Safe Harbor Water Power Corporation • Pennsylvania Fish Commission • Susquehanna River Basin Commission	• Holtwood • Safe Harbor	• Requires minimum flow releases, lake level elevations, and water quality to be maintained at the Safe Harbor hydroelectric project • Licensees to pay $750,000 to SRAFRC for fish restoration activities • Licensees will construct fish passage facilities at the Safe Harbor and Holtwood hydroelectric projects at a future date
1984	• Pennsylvania Power & Light Company • Safe Harbor Water Power Corporation • York Haven Power Company • U.S. Fish & Wildlife Service • Pennsylvania Fish Commission • Susquehanna River Basin Commission • Maryland Department of Natural Resources • Pennsylvania Department of Environmental Resources • Upper Chesapeake Watershed Association • Pennsylvania Federation of Sportsmen's Clubs	• Holtwood • Safe Harbor • York Haven	• Resolves issues with fish passage for 1980 re-licensing for Holtwood, Safe Harbor and York Haven hydroelectric projects • Upstream licensees will contribute a total of $3.7 million from 1985 to 1995 toward studies and restoration efforts (including trap and truck and hatchery efforts) to determine if anadromous fish can be restored to the Susquehanna River

Table 4. Continued.

Year	Parties	Projects	Primary Topics
1988	• Philadelphia Electric Power Company • The Susquehanna Power Company • U.S. Fish & Wildlife Service • Pennsylvania Fish Commission • Susquehanna River Basin Commission • Maryland Department of Natural Resources • Pennsylvania Department of Environmental Resources • Upper Chesapeake Watershed Association • Pennsylvania Federation of Sportsmen's Clubs	• Conowingo	• Resolves issues with fish passage for 1980 re-licensing for the Conowingo hydroelectric project • Established seasonal minimum flows and dissolved oxygen criterion for the area downstream of Conowingo Dam • Conduct survival studies of juvenile American shad at Conowingo Dam • Installation of fish passage at Conowingo Dam capable of passing fish directly into Conowingo Pond • Continue to fund upstream trap and transport for American shad until the new upstream fish passage facility is operational • Establishment of the Susquehanna River Technical Committee to provide guidance for fish passage evaluation and modifications
1993	• Pennsylvania Power & Light Company • Safe Harbor Water Power Corporation • York Haven Power Company • U.S. Fish & Wildlife Service • Pennsylvania Fish & Boat Commission • Susquehanna River Basin Commission • Maryland Department of Natural Resources • Pennsylvania Department of Environmental Resources • Upper Chesapeake Watershed Association • Pennsylvania Federation of Sportsmen's Clubs	• Holtwood • Safe Harbor • York Haven	• Install spillway and powerhouse fish lifts at Holtwood Dam by 1997 • Install fish lift on west side of Safe Harbor Dam powerhouse by 1997 • Install a fish lift at the York Haven Dam powerhouse by 2000 • Establishment of Fish Passage Technical Advisory Committees at each project • Continue to fund egg collection and hatchery operations as well as upstream trap and transport of American shad from Conowingo Dam until installation of fish passage facilities is completed • Monitoring of upstream migration and downstream migration and survival at each project

Table 4. Continued.

Year	Parties	Projects	Primary Topics
1997	• York Haven Power Company • Pennsylvania Department of Environmental Protection • Pennsylvania Fish & Boat Commission • Maryland Department of Natural Resources • U.S. Fish & Wildlife Service • Susquehanna River Basin Commission	• York Haven	• Modification of the 1993 agreement for fish passage (change location and type of fishway) • Install fish ladder on the East Channel Dam by 2000 (capacity of 500,000 American shad equivalents annually) • Provide attraction flow to the fishway and minimize spill at the main dam during low flow periods to facilitate fish passage • Conduct studies to evaluate upstream American shad passage
2014	• York Haven Power Company, LLC • U.S. Fish & Wildlife Service • Pennsylvania Fish & Boat Commission • Maryland Department of Natural Resources • Susquehanna River Basin Commission	• York Haven	• Construction of nature-like fishway by 2021 • Operation of sluice gate for downstream passage of juvenile American shad • Studies to monitor upstream and downstream migration and survival of American shad • Contribute $75,000 toward downstream American eel study and monitor passage at York Haven Dam
2015	• Exelon Generation Co., LLC • U.S. Fish & Wildlife Service	• Muddy Run	• Contribute $75,000 toward downstream American eel study and monitor passage at the Muddy Run Pumped Storage Facility • Design American shad trap and truck facility at Conowingo Dam • Monitoring radio telemetered fish passing their facility as part of studies being conducted by other facilities

A FERC hearing was held in 1984 on the flow issue. The hearing officer was persuaded by the Licensee's plan for a multi-year biological assessment under different test flow regimes to determine what, if any, continuous release was needed. However, the full Commission reversed this decision in 1987 in favor of interveners, requiring an analysis technique designed and used by the Service called Instream Flow Incremental Methodology. FERC also required design and construction of an interim $4,000,000 trap and lift at the east end of the Conowingo powerhouse to supplement American shad collections at the existing west bank facility. A new committee called the Susquehanna River Technical Committee was established to oversee all flow and fish passage issues at Conowingo. Members included PECO, Service, PFC, MDNR, and SRBC with FERC serving as liaison (St. Pierre 2002, p. 7).

In light of this decision, PECO approached MDNR to work out a final solution on all issues related to continuous flows, water quality improvements in the Conowingo discharge and fish passage. A comprehensive settlement was reached with all interveners by the end of 1988 (Table 4; Settlement Agreement 1988). This included a minimum release schedule of up to 15,000 cfs during spring months, tapering to 5,000 cfs during summer and 3,500 cfs during winter months with a 3-year test of the need to continue winter releases. PECO also agreed to add turbine venting and, if needed, oxygen injection to meet Maryland's dissolved oxygen standard of 5 ppm in the Conowingo discharge (St. Pierre 2002, p. 7). Finally, rather than building another interim trapping device as suggested by FERC, PECO chose to construct a fish lift at the east end of the powerhouse capable of handling 750,000 American shad and 5 million river herring. This facility was designed to accommodate twice this capacity with future addition of a second lift hopper (Reid and Priest 1989, p. 2; MDNR 1988, p.1). The addition of the second hopper at the East Fish Lift (EFL) as well as a rebuild of the West Fish Lift (WFL) to make a lift structure was to be implemented once the capacity was reached at the EFL (Reid and Priest 1989, entire). With FERC approval of the settlement, the EFL was built in 1990 at a cost of $12,000,000 and began operation in April, 1991. This commitment for upstream fish passage at Conowingo triggered action in the upstream licensees' 1984 agreement whereby they were now required to initiate design of passage facilities for the upstream hydroelectric projects (St. Pierre 2002, p. 7).

The new EFL initially served as a collection facility for interim trap and transport operations until upstream fish passage facilities were constructed at the remaining mainstem dams. Annual costs associated with trap and transport of American shad and river herring from Conowingo Dam were covered by the three upstream hydroelectric dam owners/operators as a component of their 1984 agreement with the resource agencies (SRAFRC 2010, p. 15). Upstream licensees were responsible for trapping and transporting adult American shad to spawning waters upstream of York Haven until their fish passage facilities were operational.

On October 1, 1992, licensees of the three upstream hydroelectric projects met with intervener resource agencies and private groups and reached an Agreement in Principle to design, model-test, construct, and operate fish passage facilities at Holtwood, Safe Harbor, and York Haven dams. Target dates for commencement of operations were April 1, 1997 for Holtwood and Safe Harbor fish lifts. The York Haven passage facility (ultimately a vertical slot fish ladder) was to be operational within 3 years thereafter. A settlement agreement with these provisions was signed in Harrisburg on June 1, 1993 (Table 4; Settlement Agreement 1993, entire; St. Pierre 2002, p. 8).

In 1997, resource agencies and York Haven Power Company (YHPC) owner General Public Utilities-Genco reached a further agreement regarding fish passage at York Haven Dam. This agreement amended the 1993 settlement to allow for construction of a fish ladder with flow augmentation gates and an open weir at the hydroelectric project’s East Channel Dam, rather than the powerhouse fish lift originally agreed to in the 1993 settlement agreement (Table 4; Settlement Agreement 1997, entire)

Holtwood and Safe Harbor completed their fish lifts in time for the 1997 spring spawning run. Total cost for this construction was $38,000,000. In spring 2000, York Haven completed their $9,000,000 fish ladder at the East Channel (Red Hill) dam at Three Mile Island. These actions provided limited migratory fish access to about 200 miles of the Susquehanna River up to Sunbury, Pennsylvania and the entire Juniata River to the Warrior Ridge and Raystown dams (St. Pierre 2002, p. 8).

SRAFRC and the utilities had devoted considerable resources during the 1980s and 1990s to address downstream passage concerns at the hydroelectric projects. Radio-telemetry was used extensively to monitor behavior and movements of adult and juvenile American shad at hydroelectric projects (St. Pierre 2002, p. 8). In addition to fish propagation research and studies directed at discrimination between hatchery and wild produced American shad, SRAFRC funded numerous special studies including adult American shad stress analysis and hormone-induced spawning, effects of net pen confinement prior to release, and influence of hydroelectric project operations on adult and juvenile migrations (St. Pierre 2002, p. 8).

4.3.2.1 American Shad Trap and Transport

Trap and transport efforts at Conowingo Dam began in 1972 with the first operation of the WFL. However, due to low catches over the first decade, the first American shad were not transported from the WFL to upstream of the York Haven Dam until 1982 (Table 5). During the early 1980s, catch of American shad at Conowingo Dam improved modestly from earlier years, increasing to a record 2,039 fish in 1982 before falling to 167 by 1984. In an effort to increase the number of spawning American shad in the river upstream of dams, SRAFRC initiated collection and transfer of pre-spawned adult fish from the Connecticut and Hudson Rivers. From 1981 through 1987, a total of about 25,000 live American shad were stocked into the North Branch upstream from the four lower Susquehanna River hydroelectric dams from these sources. From 1985 through 1990, American shad catches at the WFL increased steadily from 1,546 to 15,719 fish (Table 5).

In 1991, the EFL became operational and both lifts were utilized to collect adult American shad for upstream transport. American shad returns to Conowingo continued to increase with both fish lifts operating. Maryland's American shad population estimate for the upper Chesapeake Bay increased steadily from 8,000 in 1984 to 140,000 in 1991 and a corresponding record of 27,227 American shad were collected in the fish lifts in 1991. The number of American shad trapped in the lifts further improved to 32,330 fish by 1994 and almost doubled the next year to over 61,000 fish. A modern record 102,000 river herring were also trapped at Conowingo that year, and the upper Bay American shad population estimate reached 339,000 (St. Pierre 2002, p. 7).

During the trap and transport program from 1982 to 2000, over 230,000 adult American shad, collected at Conowingo Dam, were stocked upstream of the four lower Susquehanna River hydroelectric dams (SRAFRC 2010, p. 18). Transport activities continued through 2000 funded by the hydroelectric dam owners as directed in the 1984 and 1993 settlement agreements. The trap and transport program was terminated once the final fish passage facility at York Haven Dam was completed and upstream migratory access was provided via four fish passage facilities to historical Susquehanna River spawning habitat for American shad.

4.3.2.2 American Shad Hatchery Stocking Efforts

From 1971 through 1977, about 222 million shad eggs were collected and stocked in hatching boxes at numerous mainstem and tributary sites in the lower and mid-Susquehanna Basin (Table 5). Initial egg collections were from the Susquehanna Flats (downstream of Conowingo Dam), but after 1972, other sources from the East Coast and the West Coast rivers were also used. After 1977, direct egg stocking was discontinued and all available eggs were utilized for hatchery culture at the Van Dyke facility (SRAFRC 2010, p. 17).

From 1976 through 2000, nearly 163 million cultured American shad fry were stocked in the Susquehanna River upstream of the four lower hydroelectric dams. Most American shad eggs for the Susquehanna River restoration program during the 1980s came from the Columbia River (Oregon), and the Pamunkey River (Virginia). Throughout the 1990s, the primary sources of American shad eggs were the Hudson and Delaware Rivers (SRAFRC 2010, pp. 17-18). Hatchery production during 1984–2000 averaged 8.4 million shad fry annually (Table 5). Based on microstructure and chemical marks on otoliths, it was shown that hatchery fish comprised 70–85 percent of adult shad returns to Conowingo during 1989–1996 (St. Pierre 2002, pp. 7–8).

Although the trap and transport efforts ended in 2000 with the opening of the fish ladder at York Haven Dam, stocking of hatchery-reared American shad fry has occurred annually in the Susquehanna River to the present date.

Table 5. Summary of American shad egg, fry, and adult stocking activities in the Susquehanna River upstream of dams, 1971–2000 (SRAFRC 2010, Table 1).

Year	Eggs Planted (millions)	Hatchery Fry Stocked (millions)	WFL/EFL Adult Catch	Adults Transported Upstream
1971	8.4	-	-	-
1972	7.1	-	182	116
1973	58.6	-	65	-
1974	50	-	121	-
1975	33.2	-	87	-
1976	54	0.78	82	-
1977	11	1.04	165	-
1978	-	2.13	54	-
1979	-	0.66	50	-
1980	-	3.53	139	-
1981	-	2.05	328	-
1982	-	5.06	2,039	800
1983	-	4.15	413	64
1984	-	12.03	167	0
1985	-	6.34	1,546	967
1986	-	9.97	5,195	4,172
1987	-	5.26	7,667	7,202
1988	-	6.53	5,146	4,736
1989	-	13.53	8,218	6,469
1990	-	5.71	15,719	15,075
1991	-	7.27	27,227	24,662
1992	-	3.06	25,721	15,674
1993	-	6.62	13,546	11,717
1994	-	6.56	32,330	28,681
1995	-	10	61,650	56,370
1996	-	7.47	37,512	33,825
1997	-	8.04	103,945	10,528
1998	-	11.76	46,481	4,593
1999	-	13.50	79,370	5,508
2000	-	9.79	163,330	1,351
Totals	**222.30**	**162.84**	**638,495**	**232,394**

4.3.3 Status of Current Restoration Efforts and Fish Passage at Lower Mainstem Hydroelectric Facilities

4.3.3.1 Fish Passage at York Haven Dam

The fish ladder constructed on the York Haven Project's East Channel Dam in 2000 was designed to pass 0.5 million American shad (Settlement Agreement 1997, pp. 2-3). The fish ladder was constructed according to the Service's design specifications and has had some success in passing American shad, although observed passage efficiency at that Project has been generally low (14 percent of the American shad passing Safe Harbor Dam from 2000–2014; USFWS 2015a, p 2.). One potential reason for low fish passage at York Haven Dam is that some spawning habitat is available for American shad downstream of the York Haven Dam and upstream of Safe Harbor Dam. Fish that are successfully spawning downstream of York Haven Dam may have no biological motivation to pass upstream (Kleinschmidt 2006, p. 9). The low passage efficiency may also be the result of fish having difficulty finding the entrance of the fish passage facility. A radio-telemetry study on American shad conducted in 2005 indicated that relatively few American shad approached the York Haven Dam at the location of the current fish passage facility in the east channel (Kleinschmidt 2006, p. 10).

To remedy the fish passage issues with the current fish ladder at York Haven Dam, a nature-like fishway will be completed in 2021 on the main dam (Table 4; Settlement Agreement 2014, p. 16). The Project owner will also be required to meet the upstream passage efficiency criterion for adult American shad of 75 percent that pass the downstream project (Safe Harbor) and downstream survival criteria of 85 percent for American eel, 80 percent for adult American shad and river herring, and 95 percent for juvenile American shad and river herring. The Project owner will be conducting upstream passage efficiency studies for American shad, and downstream survival studies for American shad, river herring, and American eel at their project in the coming years (Settlement Agreement 2014, pp. 18–33).

4.3.3.2 Fish Passage at Safe Harbor Dam

A fish lift was installed in 1997 and designed to pass 3.75 million alosines (Settlement Agreement 1993, p. 12). The Safe Harbor Project fish lift is designed and currently operating in accordance with the design criteria within the 1993 settlement. The Safe Harbor Project is similar in size and generating capacity to the Conowingo Dam and has demonstrated high upstream fish passage efficiency with its fish lift compared to other projects on the Susquehanna River, passing a cumulative total of over 288,000 American shad as well as many other species (Normandeau Associates 2014a, p. 3). The long-term average efficiency (1997–2014) for American shad passing the Safe Harbor Dam is 76 percent of those fish that were passed at the Holtwood Dam with a daily passage rate of 31 percent per day (USFWS 2015b, pp. 6–7).

4.3.3.3 Fish Passage at Holtwood Dam

The Holtwood Dam Project currently operates two fish lifts for upstream passage of migratory fish. The fish lifts were originally installed at the Holtwood Dam in 1997 and designed to pass 2.7 million shad and 10 million river herring (USFWS 2009, p. 3). Since their construction, the fish lifts have not achieved the attraction flow specified in the original fishway design and the Project has a malfunctioning entrance gate on the spillway side. The entrance to Gate C was damaged shortly after installation and has been inoperable since that time. Due to failure of the sacrificial flashboards that often occurs during the annual spring freshet there is considerable discharge to the spillway that attracts fish to the area of the inoperable fishway entrance and many fish fail to pass. In addition, when full attraction flow was supplied to the fishway entrances via flow through the exit flume, eddy currents were created in the exit flume that blocked fish exiting the fish passage facility (USFWS 2009, p. 15; USFWS 2014a, entire). Starting in 2010, the Project owner began redeveloping the Holtwood Project, including additional generating capacity as well as improvements to the existing fish passage facilities and operations. As part of the Prescription for Fishways, the Department required the Project owner to implement fish passage improvements including modifications to the existing fish lift. In addition, the Project owner was required to re-route discharge, conduct channel modifications, increase attraction flow, and install a spill control system to enhance the zone of passage up to the fishway entrances (USFWS 2009, p. 26). As part of the Water Quality Certification for the project, the PADEP also required the Holtwood Project to meet upstream passage efficiency criteria for American shad. The Project must pass 75 percent of American shad that pass the Conowingo Project and 50 percent of the American shad must pass the Holtwood Project in 5 days (PADEP 2009, p. 15).

Long-term fish passage efficiency at the Holtwood Project, as measured by the proportion of fish that successfully passed the downstream Conowingo Dam, has been low, averaging 32 percent from 1997–2014 (USFWS 2015a, p. 2). As of spring 2015, not all of the upgrades to the fishway had been completed; however, the Holtwood project reached 63 percent upstream passage efficiency for American shad during the 2015 season[2]. The project owner intends to complete the remaining construction to improve fish passage at the Holtwood Dam by 2016, and will be conducting studies to validate that passage efficiency standards are being met and identify any issues that need to be addressed to continue to improve efficiency (Holtwood 2014, p. 9).

4.3.3.4 Fish Passage at Muddy Run Pumped Storage Project

In addition to the lower mainstem dams, the Muddy Run Pumped Storage Project (MRPSP), also impacts migrations of anadromous fish. The Project is also operated by Exelon Generation Corp., the Licensee for the Conowingo Project. Although the MRPSP does not include a dam that spans the Susquehanna River, the Project withdraws and discharges water daily from the Conowingo Pond. The pumping capacity at MRPSP is large enough to cause local reversal of the river flow in the mainstem of the Susquehanna during periods of low inflow from upstream of the Project (USFWS 2013a, p. 11). The MRPSP has documented impacts of both causing delay and entraining migrating American shad and American eel into the storage pond associated with pumping and discharge operations during both upstream and downstream migration periods (USFWS 2013a entire; USFWS 2013b, entire). Under the new license issued by FERC in 2015, the Project owner will be required to conduct studies to ensure that the operation of the MRPSP is meeting the same upstream and downstream passage efficiency criteria for migratory fish as was established at the York Haven Dam (Settlement Agreement 2015, pp. 37-41).

4.3.3.5 Fish Passage at Conowingo Dam

As noted in Section 4.3.1, the experimental WFL began operation at Conowingo Dam in 1972. It was initially designed as a trapping facility and cannot pass migrating fish directly over the dam and into Conowingo Pond. The EFL at Conowingo Dam was originally designed to pass up to 1.5 million American shad and 10 million river herring based on the installation of two hoppers (buckets) at the lift (MDNR 1988, pp.1). However, a 1989 docket (EL80-38-003) filed

[2] Data from http://fishandboat.com/shad_susq.htm last accessed June 26, 2015.

with FERC signed by PECO and the parties of the 1988 settlement agreement, including the Service, stated that the EFL would initially be constructed with only one of the two hoppers from the original design with a resulting capacity of 0.75 million American shad (Reid and Priest 1989, p. 2). The addition of the second hopper at the EFL, as well as a rebuild of the WFL so that it could pass fish directly into Conowingo Pond, was to be implemented once the capacity was reached at the EFL (Reid and Priest 1989, entire). Neither the second hopper at the EFL nor the rebuild of the WLF have been implemented. The EFL passed more than 193,000 American shad in the peak year of 2001, but passage numbers have declined steadily since then, with the current lowest passage on record of 8,341 American shad in 2015[3]. Fish passage efficiency at the Conowingo Project has been relatively poor and the Project is limited by the capacity of the current EFL. For a thorough discussion of current fish passage at the Conowingo Dam, refer to Section 8 of this document.

4.3.3.6 SRAFRC Agency Efforts Supporting Migratory Fish Restoration

As part of each settlement agreement with the hydroelectric dam owners/operators for fish passage installation (Conowingo in 1988; Holtwood and Safe Harbor in 1993; and York Haven in 1997), separate fish passage technical advisory committees were developed. These advisory committees are comprised of resource agency members of the Pennsylvania Fish and Boat Commission (PFBC), MDNR and the Service, and the affected hydroelectric dam owners/operators (Settlement Agreement 1988, p. 12; Settlement Agreement 1993, p. 5). These committees meet annually, or as needed, to discuss and agree on operational matters needed to provide safe, timely, and effective upstream and downstream fish passage at the dams.

With the development of the advisory committees, the dam owners/operators ceased participation in the SRAFRC. Because of the change in membership of the SRAFRC (no longer including industry representatives), the name of the interagency restoration group changed again in 1995, dropping the word “Committee” in favor of “Cooperative” thus retaining the acronym SRAFRC. An organizational charter was developed and signed by six resource agencies, including NMFS and SRBC (SRAFRC 1995, entire). The charter defined the roles of the Policy and Technical committees and the Service program coordinator. The charter was renewed in

[3] Data from http://fishandboat.com/shad_susq.htm last accessed June 26, 2015.

2014 where NMFS was removed as a signatory to the SRAFRC, with the current membership consisting of the Service, PFBC, MDNR, NYSDEC, and SRBC. The Policy and Technical committees continue to meet annually or more frequently as needed (SRAFRC 2014, entire). SRAFRC continues to be an active supporter of American shad and other migratory fish restoration in the Susquehanna River.

American shad hatchery stocking efforts continue to occur in the Susquehanna Basin, and have been conducted using resource agency (primarily PFBC) funds since 2001 (SRAFRC 2013a, p. 142). The stocking program consists of egg collection of spawning fish primarily from the Potomac River since 2006 (SRAFRC 2013a, p. 168). Eggs are also collected from tank spawning at the WFL (SRAFRC 2013a, p. 168). Exelon provides an operator for the WFL operations but PFBC and MDNR currently fund the egg collection and biological sampling at that location (SRAFRC 2013a, p. 32). PFBC rears the American shad at the Van Dyke hatchery and then releases them to locations in the Susquehanna River Basin during the summer (SRAFRC 2013a, p. 162). An average of 5 million American shad fry have been stocked in the Susquehanna River annually from 2001 to 2012 (SRAFRC 2013a, p. 172). PFBC assesses the success of both hatchery stocking and natural production of American shad in the river upstream of York Haven Dam (SRAFRC 2013a, pp. 194-195). PFBC also evaluates adult American shad from the WFL to determine the percentage of returns that are hatchery versus wild origin to assess the success of the hatchery stocking program (SRAFRC 2013a, p. 215).

MDNR conducts sampling efforts downstream of Conowingo Dam to assess the population of adult and juvenile American shad and juvenile river herring. For the adult population assessment, American shad are captured and tagged in the tailrace of Conowingo Dam and the population size is determined using mark-recapture estimates (SRAFRC 2013a, pp. 272-296). Juvenile American shad and river herring assessments are conducted using seine surveys in the upper Chesapeake Bay and lower Susquehanna River (downstream of Conowingo Dam; Durell and Weedon 2011[4]).

[4] Durell, E.Q., and Weedon, C. 2011. Striped Bass Seine Survey Juvenile Index Web Page. http://dnr2.maryland.gov/fisheries/Pages/juvenile-index/index.aspx. Maryland Department of Natural Resources, Fisheries Service.

The PFBC, MDNR, and NYSDEC also work with other resource agencies, non-profit groups, and private individuals to improve access to upstream habitats through dam removals and providing fish passage within the Susquehanna River basin (Nicholas, no date, entire; NYSDEC, no date, entire). In addition, SRBC, PADEP, and other agencies are working to improve water quality and manage water usage throughout the basin (PADEP, no date, entire; SRBC 2013b, entire).

4.3.4 American Eel Restoration Efforts on the Susquehanna River

American eel restoration efforts in the Susquehanna River began as early as the 1930s. The PFBC conducted a trap and transport program that collected over 17 million juvenile eels downstream of Conowingo Dam and stocked them into the Susquehanna River Basin between 1936 and 1980 (SRAFRC 2010, p. 84). The WFL at Conowingo Dam collected a high of over 126,000 American eels in 1974 (Buchanan and Robins 1974, p. 5), but collections have declined dramatically in recent years, and fewer than 20 eels are captured annually in the EFL since it became operational in 1991 (SRAFRC 2013, p. 14; Normandeau Associates 2013, Table 1; Normandeau Associates 2014b, Table 1).

Fish lifts at the four lower mainstem dams were not designed to pass eels and have passed few American eels in recent years. However juvenile American eels are still abundant in the tailrace of Conowingo Dam. In 2008, the Service initiated an experimental trap and transport program at Conowingo Dam. This program has captured a cumulative total of more than 700,000 juvenile American eels from 2008 through 2014 and released them at various locations throughout the Susquehanna River Basin (SRAFRC 2013, p. 14; Minkkinen and Park 2014, p. 2). A portion of these American eels have been stocked in areas where freshwater mussels occur to promote successful reproduction of the eastern elliptio mussel (*Elliptio complanata*) (Minkkinen et al. 2014, entire).

As part of the Pennsylvania Water Quality Certification for the MRPSP, Exelon will provide $20,000 annually to the Service to support collection and stocking activities until a permanent collection facility is constructed on the west shore of Conowingo Dam (PADEP 2014, Appendix 1, p. 5). Exelon will also construct permanent American eel collection facilities on the eastern shore (by 2018) and western shore (by 2017) of the Susquehanna River downstream of Conowingo Dam. Exelon will trap and transport American eels to upstream areas as designated by PADEP (2014, Appendix 1, p. 16). Trap and transport, funded by Exelon, will continue through 2030, with the project being switched to volitional passage after that date (PADEP 2014, Appendix 1, p. 15).

4.4 Current Status and Management of Migratory Fish Populations

4.4.1 Management Authority for Migratory Fish Stocks in the Susquehanna River

4.4.1.1 Atlantic States Marine Fisheries Commission

The Atlantic States Marine Fisheries Commission (ASMFC) was formed by the 15 Atlantic coast states in 1942 in recognition that fish do not adhere to political boundaries. The ASMFC is a deliberative body, promoting cooperation and coordination among the member states as they implement their relative responsibilities under state law for protecting the public's interest in marine, estuarine, and anadromous fisheries within their respective jurisdictions. The ASMFC serves as a forum for the states to collectively address fisheries issues under the premise that as a group, using a cooperative approach, they can achieve more than they could as individuals. Fishery Management Plans (FMPs) are developed within the ASMFC under the authority of the Atlantic Coastal Fisheries Cooperative Management Act of 1993 (ACFCMA). States that do not comply with the requirements in the FMPs are subject to have their respective fisheries closed by the Secretary of Commerce (Section 5106 (c)).

The ASMFC's mission is to promote the better utilization of the marine, shell, and anadromous fishery resources of the Atlantic seaboard through the development of a joint program for the promotion and protection of such resources, and by the prevention of physical waste of the fisheries from any cause. The ASMFC's jurisdiction, through the member states, extends from the shoreline to 3 miles out, and all coastal states have their own laws and fisheries agencies to manage fisheries within 3 miles of their coasts. The ASMFC does not promote a particular state, jurisdiction, or a stakeholder sector.

4.4.1.2 Fishery Management Councils

Responsibility for compatible fisheries management action in the Exclusive Economic Zone

(EEZ), the sea area from 3 to 200 miles from shore, lies with the Secretary of Commerce and is conducted through Fishery Management Councils (FMCs). These FMCs were created when Congress passed Public Law 94-265, the Magnuson Fishery Conservation and Management Act of 1976 (also known as Magnuson-Stevens Act). The law created a system of regional fisheries management that was designed to allow regional, participatory governance by knowledgeable people with a stake in fishery management. Although the FMCs work primarily on off-shore fisheries, each federal FMC "...shall comment on and make recommendations to the Secretary and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority" (from Magnuson-Stevens Fishery Conservation and Management Act, Section 305, P.L. 104-297, (b) FISH HABITAT (3)(B)).

Two FMCs address issues related to American shad and river herring of the Susquehanna River; the Mid-Atlantic Fishery Management Council (MAFMC) and the New England Fishery Management Council (NEFMC). The regional FMCs develops fishery management plans and recommends management measures for the EEZ off the east coast of the United States. The councils recommend fishery management measures to the Secretary of Commerce through NMFS. The decisions made by the councils are not final until they are approved or partially approved by the Secretary of Commerce through NMFS.

Incidental catch of blueback herring, alewife, American shad, and hickory shad occur in the New England and Mid-Atlantic FMC fisheries. In the Mid-Atlantic FMC, an Amendment was passed to monitor river herring and American shad bycatch in the FMC's managed mackerel fishery (MAFMC 2014, entire). The New England FMC has established catch "caps" or limits by area for river herring and American shad as bycatch in the Atlantic herring fishery (NEFMC 2013, entire).

4.4.1.3 Susquehanna River Anadromous Fish Restoration Cooperative

The SRAFRC is an organization comprised of fishery agencies from the three basin states, the SRBC, and the federal government working together to restore self-sustaining migratory fishery resources and their habitats in the Susquehanna River Basin. This cooperative activity recognizes the need for a unified approach to planning, management, stock enhancement, and evaluation of inter-jurisdictional fishery resources and its purposes are: (1) to provide a forum for information exchange; (2) to plan and implement migratory fishery stock rebuilding programs; (3) to coordinate research activities aimed at collection of scientific data necessary to effect and assess the fishery restoration program; (4) to establish and maintain a comprehensive database and to report on progress; and, (5) to coordinate agencies involvement with construction, operation, and evaluation of passage facilities at dams in the Susquehanna River Basin.

The current Susquehanna River Anadromous Fish Restoration Cooperative Member Agencies include:

Maryland Department of Natural Resources
New York State Department of Environmental Conservation
Pennsylvania Fish and Boat Commission
Susquehanna River Basin Commission
United States Fish and Wildlife Service

The Service serves as the Chair for both the Policy Committee and Technical Committee. Although SRAFRC members cooperatively manage fisheries and restoration efforts within the Susquehanna River Basin, SRAFRC is not a regulating body and legal authority for management lies within the respective jurisdictions of the member agencies.

4.4.2 American Shad

The status of American shad along the Atlantic coast is summarized by the ASMFC in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2010, entire) and the most recent American Shad Stock Assessment (ASMFC 2007, Volume I, entire). Historically, American shad, hickory shad, alewife, and blueback herring (collectively termed alosines) were an extremely important fishery resource and supported many successful commercial fisheries along the Atlantic coast of the United States and Canada. Coast-wide landings of American shad at the turn of the 20th century were approximately 50 million pounds. However, by 1980 the landings decreased dramatically to 3.8 million pounds. Total landings of river herring varied from 40 to 65 million pounds from 1950 to 1970, then declined steadily thereafter to less than 12 million pounds by 1980 (ASMFC 2010, pp. 1–2). These dramatic declines in commercial landings suggested that a coordinated management action would be required to restore alosine stocks to their former levels of abundance. Therefore, in 1981 ASMFC members recommended the preparation of a cooperative Interstate Fishery Management Plan (FMP) for American shad and river herring. The initial FMP was completed in 1985 and recommended management measures that focused primarily on regulating fishing exploitation and enhancing stock restoration efforts (ASMFC 2010, p. 2).

Despite these efforts, alosine stocks continued to decline. In 1994, ASMFC determined that the original FMP was no longer adequate for protecting and restoring remaining American shad and river herring stocks. It concluded that the declines may have been the result of overharvest by in-river and ocean-intercept fisheries; excessive striped bass predation; biotic and abiotic environmental changes; and loss of essential spawning and nursery habitat due to water quality degradation and blockages of spawning reaches by dams and other impediments (ASMFC 2010, p. 2). A coast-wide assessment was completed in 1998 and Amendment 1 to the FMP was adopted in 1999, and additional addenda were added in 2000 and 2002. Amendment 1 and subsequent addenda focused on directed fishing mortality and established benchmarks in hopes of rebuilding the stocks (ASMFC 2010, p. 2). This approach defined ASMFC's American shad management until the adoption of Amendment 3 in 2010.

A stock assessment conducted in 2007 found that coast-wide American shad stocks were at all-time low levels and did not appear to be recovering to acceptable levels. Commercial landings declined to 574,306 pounds in 2005, a reduction of approximately 85 percent since 1980 (ASMFC 2007, Volume I, p. 49). The primary causes for continued stock declines were attributed to a combination of excessive total mortality, habitat loss and degradation, and migration and habitat access impediments including dams (ASMFC 2010, p. 3).

In response to the 2007 stock assessment, ASMFC adopted Amendment 3 to the FMP in 2010. Amendment 3 recommended the use of total mortality rates (rather than just fishing mortality rates) to assess the status of American shad populations and their potential for population growth (ASMFC 2010, pp.15). This was a change from management under Amendment 1 because it was recognized that besides fishing mortality, American shad stocks are subjected to several other sources of human-induced mortality including fish passage mortality at dams and water development projects (ASMFC 2010, p. 16).

For American shad, ASMFC selected total mortality rates that would preserve 30 percent of the biomass of the female spawning stock that would otherwise be available if there were no human-induced mortality. When total mortality rates exceed this threshold, states should take action to reduce total mortality. When reducing mortality, the priority would be to reduce mortality from inadequate passage at dams and/or bycatch (versus directed fishing efforts) since these losses are avoidable and do not benefit society (ASMFC 2010, p. 15).

Amendment 3 also required the states which continue to have commercial fisheries to file sustainability plans or their fisheries would be closed (ASMFC 2010, p. 31). A sustainability plan for the Susquehanna River has not been developed because no commercial fisheries exist in the river. Finally, Amendment 3 recommended states and jurisdictions develop habitat plans for American shad to reduce or mitigate the impact of dams and other obstructions, water quality, and contamination (ASMFC 2010, p. 42-45). Recommendations for fish passage included that states should work with the Service and the NMFS to: identify hydropower dams that impede fish migration and target them for appropriate recommendations during FERC relicensing; prioritize barriers in need of fish passage based on ecological criteria; develop new technologies to improve fish passage efficiency; design passage facilities that work under all water levels; and implement measures to pass fish via routes with the best survival (ASFMC 2010, p. 35-37). To fulfill the ASMFC recommendation for the development of a habitat restoration plan, state and federal partners within SRAFRC submitted a Susquehanna River Habitat Plan for American shad and river herring to the ASMFC (PFBC 2014, entire). This plan cites barriers to fish migration and poor water quality conditions as the most significant threats to American shad restoration to the Susquehanna River and requires the same passage efficiency criteria and restoration goals as the 2010 Migratory Fish Management and Restoration Plan for the Susquehanna River Basin.

4.4.2.1 Mid-Atlantic Region American Shad Status

Although there has been an overall coast-wide decline in American shad stocks, the 2007

ASMFC stock assessment found much variation in river population trends along the coast. However, there were regional trends with rivers in close geographic proximity showing similar trends in juvenile production (ASMFC 2007, Volume I, p. 153). When assessing the status of the Susquehanna River and attempting to give context to these trends, it is useful to compare it to other large rivers that are also located in the Mid-Atlantic region such as the Delaware River and the Potomac River.

4.4.2.1.1 The Susquehanna River American Shad

As described earlier, the Susquehanna River once supported large numbers of American shad, but stocks have been severely impacted by human activities, including construction of dams. Following efforts by resource agencies dating to the 1950s, the American shad stock improved slowly as a result of trap and transport efforts, fry stocking, and providing fish passage at the lower mainstem dams. American shad passage on the Susquehanna River increased from 1997 through 2001, with a peak of over 190,000 American shad passing Conowingo Dam and 16,000 passing York Haven Dam in 2001 (Figure 3). However, since 2001, adult numbers have decreased, due to a variety of potential contributing factors including: low numbers of spawning fish accessing quality upstream habitat as a result of poor fish passage efficiency and cessation of the trap and transport program; low hatchery production in recent years that reduced juvenile recruitment; ocean and Chesapeake Bay mortality; and increased predation (SRAFRC 2010, pp. 28-30). Only 8,341 American shad were counted at the EFL, with 43 of them ultimately passing York Haven Dam in 2015. 2015 was the lowest American shad passage season at Conowingo Dam since 1997 (Figure 3).

The decline over the past decade in adult American shad passing the Conowingo Dam fish lifts coincides with declines in the population observed downstream of the Conowingo Dam tailrace. MDNR conducted population estimates based on recapture of marked American shad and on results from a "surplus production" model in the tailrace area from 1986 to 2013. The adult population reached a peak from 1999 through 2007; however since 2009, the population of American shad downstream of Conowingo Dam has been as low as it had been before any fishway passage facilities were installed on the Susquehanna River (MDNR 2013, pp. 6–21). Also, catch-per-unit-effort (fish per boat hour) from the Conowingo Dam tailrace showed similar trends (MDNR 2013, pp. 6-21).

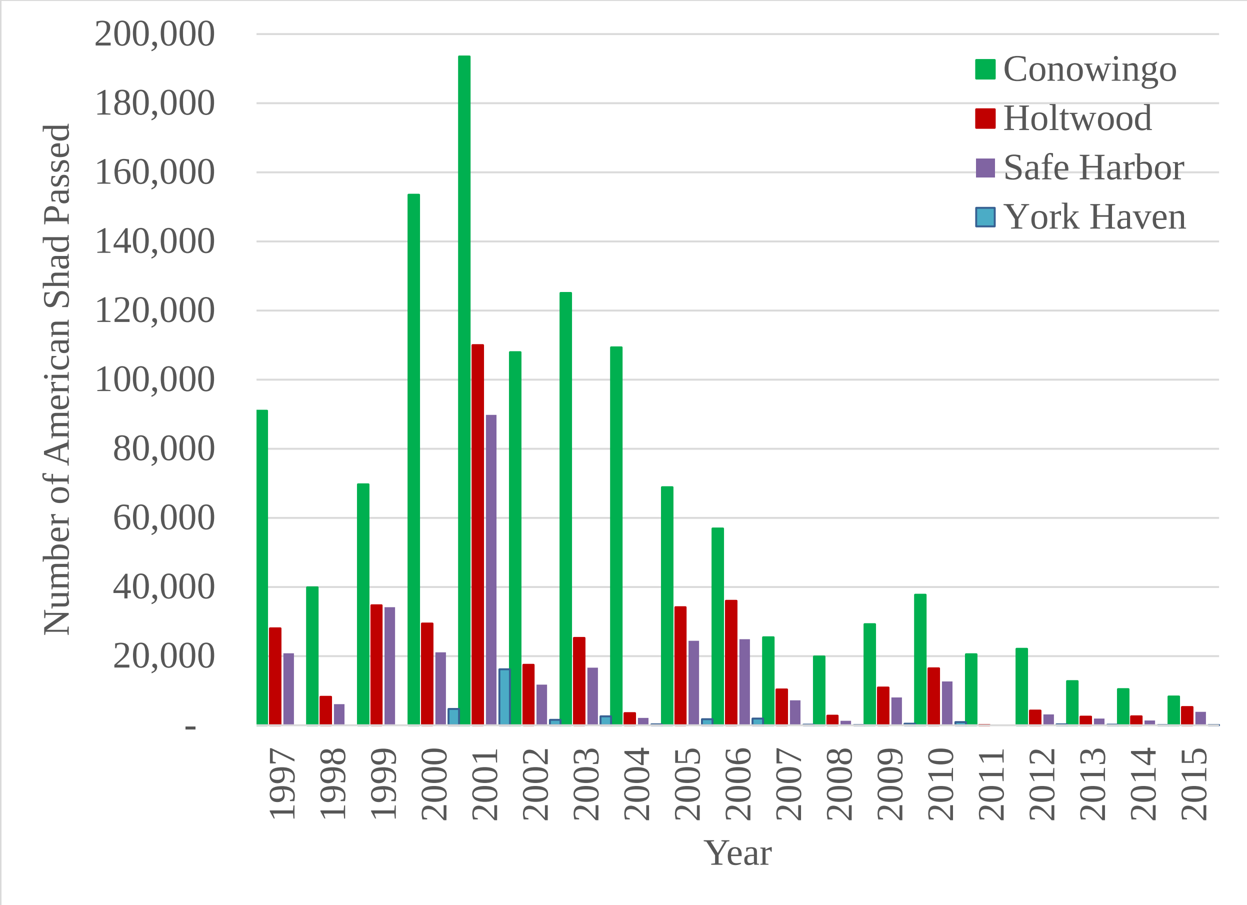

Figure 3. Number of American shad passed via fish passage facilities at the 4 lower mainstem dams on the Susquehanna River[5].

The American shad population in the Susquehanna River has been heavily supplemented by hatchery stocking efforts. In 2014, 45 percent of returning adult American shad was of hatchery origin, with the long-term average being 57 percent of hatchery origin (PFBC 2014, p. 9–10). The reduced hatchery releases in the past decade are likely contributing to declining population numbers downstream of Conowingo Dam compared to the late 1990s through early 2000s when much larger numbers of American shad fry were being released in the river (SRAFRC 2013a, p. 172).

The Susquehanna River has not supported a commercial fishery for American shad since the fishery was closed by MDNR in 1980 (ASMFC 2007, Volume I, p. 110). A small recreational

[5] Data from http://fishandboat.com/shad_susq.htm last accessed June 26, 2015.

catch-and-release fishery managed by MDNR still occurs in the tailrace of Conowingo Dam. The American shad fishery has been lost from the Pennsylvania and New York portions of the river for decades, which has resulted in the loss of economic and cultural benefits, and recreational opportunities, which were part of the historical shad fishery in those states.

4.4.2.1.2 The Delaware River American Shad

In the late 1890s, the Delaware River had the largest annual commercial American shad harvest of any river on the Atlantic coast, with estimates ranging up to 19 million pounds (approximately 5 million fish assuming 3.71 pounds per fish, see Table 8) in a given year (ASMFC 2007, Volume II, p. 302). The harvest began to decline rapidly in the early 1900s due to water pollution, overfishing, and dams on major tributaries of the Delaware River that blocked access to quality spawning habitat (ASMFC 2007, Volume II, p. 302). Despite more restrictive fishery regulations and a massive program of artificial propagation and stocking of shad fry in the late 1800s, the American shad fishery eventually collapsed under the combined pressures. By the 1940s, the Delaware River commercial American shad fisheries were mainly on the lower reaches of the river.

The Delaware River stock of American shad increased from the 1960s through the 1980s, likely as a result of improving water quality and the passage of the Clean Water Act in 1972, but it declined again in the1990s for unknown reasons and remains at low levels compared to the 1980s (ASMFC 2007, Volume II, p. 302). Two indices of abundance of American shad in the Delaware River are the Lewis haul seine fishery survey (conducted at RM 149) and the Smithfield Beach survey (conducted at RM 218). The catch-per-unit-effort (fish/haul) in the Lewis haul seine fishery in the lower Delaware River had a peak in 1989 with a 52.20 fish/haul, but declined in the 1990s and from 2000 to 2013, averaged 4.7 fish/haul per year. However, recent above average catches occurred in 2010 (12.31 fish/haul) and 2013 (11.61 fish/haul) (DRBFWMC 2014, p. 41). The 1996-2013 catch-per-unit-effort in the Smithfield Beach survey averaged 0.87 fish/foot hours of gillnet deployed, but also has been above this average in recent years (2010-2013) (DRBFWMC 2014, p. 44). These indices suggest a possible leveling off in the downward trend of the American shad population in the Delaware River, although populations are still at relatively low levels.

Conversely, the total number of American shad passed at the Conowingo Dam has generally been declining since 2001 (USFWS 2015a, p. 3). A major difference between the Delaware and Susquehanna Rivers is the presence of large mainstem dams on the Susquehanna River which are absent on the Delaware River. The dams on the Susquehanna River preclude fish from reaching quality spawning and rearing habitat, whereas in the Delaware River, American shad have unimpeded access to a large portion of their historical spawning and rearing habitat. The continued inaccessibility to spawning and rearing habitat in the Susquehanna River is a likely reason for the continued population decline on this river.

4.4.2.1.3 The Potomac River American Shad

Among Chesapeake Bay stocks of American shad, the Potomac River population shows the most promising signs of recovery. The gill net index, the pound net index, and the juvenile abundance index from the Potomac River used in the 2007 ASMFC stock assessment (ASMFC 2007, Volume III, Figure 11.15 and Tables 11.7 and 11.16) depict increasing trends in relative abundance. Age structure has broadened (ASMFC 2007, Volume III, p. 146) and the mean age has increased, which indicates increasing adult survival, increasing repeat spawners, and likely increasing total egg deposition. Estimates of total mortality declined from 2002 to 2005 and met management goals (ASMFC 2007, Volume III, p. 149) indicating that mortality levels should not preclude population growth.

The American shad population in Potomac River is increasing and we infer that the Susquehanna River population trend should be similar to the Potomac River since both are major Chesapeake Bay tributaries and fish migrating between their respective riverine and marine habitats would experience similar natural mortality. However, Potomac River American shad have access to suitable spawning and rearing habitat for 30 miles of undammed mainstem river with a fish ladder at Little Falls dam providing access to the final 10 miles of historic spawning habitat (ASMFC 2007, Volume III, p. 135). In the Susquehanna River, access to nearly all spawning habitat is substantially blocked by mainstem dams.

4.4.3 River Herring

The most recent coast-wide stock assessment for river herring was completed by ASMFC in 2012. The stock assessment concluded that the status of the coast-wide complex of river herring stocks on the Atlantic coast was depleted to near historic low abundance. A depleted status indicates that there was evidence for declines in abundance due to a number of factors (e.g. over fishing, bycatch in other fisheries, habitat degradation, migratory barriers), but the relative importance of these factors in reducing river herring stocks could not be determined (ASMFC 2012b Volume I, p. 58). There were contradictory trends in river herring abundance among individual stocks, with some increasing, some decreasing, and some fluctuating without trend, but fisheries-independent surveys that showed declines tended to be from areas south of Long Island (ASMFC 2012b Volume I, p. 55). Differences in abundance trends may be due to differences among rivers in fish passage efficiency or differences in management practices such as transport of adult fish into ponds upstream of dams as is commonly done in Maine rivers (ASMFC 2012b Volume I, p. 55).

On August 5, 2011, the NMFS received a petition from the Natural Resources Defense Council requesting the listing of river herring under the Endangered Species Act (ESA) as threatened throughout all or a significant portion of their range (NRDC 2011, entire). In response to this petition, the Status Review Team conducted another coast-wide assessment of river herring stocks along the Atlantic coast (NEFSC 2013, entire). Although listing under the ESA was determined not to be warranted, the conclusions of the Status Review Team indicated that many populations of both species are depleted and their abundance is well below historical levels (NEFSC 2013, p. 10). The range-wide abundance of alewife significantly increased from 1976 – 2012, but abundance of blueback herring neither significantly increased nor decreased over this time period (NEFSC 2013, p. 7). However, when examined on a regional basis, the Mid-Atlantic stock complex of alewife was stable while Mid-Atlantic stock complex of blueback herring was significantly decreasing, indicating the Mid-Atlantic is an area of concern for blueback herring conservation (NEFSC 2013, p. 9).

The ASMFC and NMFS have taken management actions to conserve river herring coast-wide. Under Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring

(River Herring Management), states which intend to have fisheries for river herring must have an approved Sustainable Fishery Management Plan (ASMFC 2009, pp 92 – 93); otherwise their fisheries would be closed by January 1, 2012. Currently, the sates of Maine, New Hampshire, New York, North Carolina, and South Carolina have approved plans (http://www.asmfc.org/species/shad-river-herring; accessed April 27, 2015). When NMFS announced listing under the ESA was not warranted, it also announced that it would be working with the ASMFC on a strategy to develop a long-term and dynamic conservation plan with the goal of addressing high priority data gaps for river herring (78 FR 48994 (8/12/13)).

4.4.3.1 Mid-Atlantic Region River Herring Status

There are a few indices of abundance from surveys conducted by resource agencies for river herring in the Mid-Atlantic region that have been used to assess population status and trends. These indices of abundance show much annual variation, but in general show declining populations.

The MDNR has been generating an index of juvenile river herring abundance from annual seine sampling within the Chesapeake Bay since 1954. Baywide juvenile indices for alewife were generally greatest during the 1960s, but then declined to their lowest levels in the 1980s. Since then, indices of abundance have increased but are highly variable without consistent trends since 1996 (ASMFC 2012c Volume II, Figure 13.8, p. 441). Likewise blueback herring juvenile indices were lowest in the 1980s, followed by an increase during mid 1990s but have also been highly variable without consistent trends since the late 1990s (ASMFC 2012c Volume II, Figure 13.12, pp.443).

The Washington D.C. Department of the Environment has conducted electrofishing surveys for adult spawning stock and beach seining for juvenile river herring in the Potomac River. Catch rates of adult river herring from electrofishing showed a steep decline for both alewife and blueback herring from the late 1990s to the early 2000s followed by a period of fluctuation at low levels through 2010 (ASMFC 2012c Volume II, p. 476). Catch rates of juvenile alewife from the beach seining survey also showed a dramatic decline from the early 1990s until 2010. However, juvenile blueback herring have showed a cyclical pattern with relatively high abundance in the late 1990s followed by a decrease by the mid-2000s and another increase in late 2000s (ASMFC 2012c Volume II, p. 476).

The Delaware Department of Natural Resources and Environmental Control conducts two trawl surveys in the Delaware Bay for fisheries assessment. The 30-foot bottom trawl is used to assess adult river herring and the 16-foot otter trawl is used to assess juvenile river herring. The 30-foot bottom trawl showed an increase in alewife abundance occurred from 1996–1998. After 1998, alewife relative abundance decreased and has remained at low levels since 2002. Blueback herring varied without trend throughout the 1990s prior to good year classes in 1999 and 2000, but then trended downward from 2001 to 2003 and has remained at depressed levels without trend since 2003 (ASMFC 2012c Volume II, pp 384). The annual abundance index from the 16-foot otter trawl showed young-of-the-year (YOY) alewife in the Delaware River and Bay varied without trend throughout the time series with peak years in 1996, 2000, 2003, and 2007. The age-1 alewife index declined since the highest value was reached in 1997. The YOY index for blueback herring increased slightly from 1990 through 2003, but substantial declines were noted since then (ASMFC 2012c Volume II, pp 386). These trends in abundance indices suggest the river herring population has declined in the Delaware Bay and Delaware River over the last decade.

4.4.3.2 Susquehanna River Herring

Declining trends in river herring populations observed throughout the Mid-Atlantic region have also been seen in the fish lifts at Conowingo Dam (Table 6). The numbers of river herring passing Conowingo Dam by the EFL have shown substantial annual variation, but in general, have greatly declined over the last decade. The highest number passing occurred in 2001 with 292,379, but since 2003 the number passing has dramatically declined and has remained less than 1,000 passing each year. In 2014, 25 blueback herring and 111 alewife passed Conowingo Dam (Normandeau Associates 2014b, p. 3). St. Pierre (1981, p. 36) estimated the run size in the 1890s at 10 to 40 million fish based on historical records of commercial catch of river herring at that time. Thus, contemporary numbers of river herring accessing habitat upstream of Conowingo Dam are a small fraction of what once occurred in the river.

Table 6. Counts of river herring passed at the Conowingo Dam East Fish Lift (1991-2014). Data were obtained from SRAFRC (2013a, p. 10) unless otherwise noted.

Year	Blueback Herring	Alewife	Total
1991	13,149	323	13,472
1992	261	3	264
1993	4,574	0	4,574
1994	248	5	253
1995	4,004	170	4,174
1996	261	3	264
1997	242,815	63	242,878
1998	700	6	706
1999	13,625	14	13,639
2000	14,963	2	14,965
2001	284,921	7,458	292,379
2002	2,037	74	2,111
2003	530	21	551
2004	101	89	190
2005	4	0	4
2006	0	0	0
2007	460	429	889
2008	1	4	5
2009	71	160	231
2010	4	1	5
2011	17	2	19
2012	25	27	52
2013[1]	7	0	7
2014[2]	25	111	136

[1]Data Source: Normandeau Associates (2013, p. 3)
[2]Data Source: Normandeau Associates (2014b, p. 3)

4.4.4 American Eel

Declines in American eel populations have been observed across their Atlantic coast range (Haro et al. 2000, entire) and can be attributed to a combination of causes such as historical overfishing, habitat loss, food web alterations, predation, turbine passage mortality, environmental changes, toxins and contaminants, and disease (ASMFC 2012a, p. 100). American eel are managed coast-wide by the ASMFC through an Interstate Fishery Management Plan which is followed by all Atlantic coast states (ASMFC 2000, entire and subsequent addenda). Addendum II to the Fishery Management Plan, issued by ASMFC in 2008, specifically requests provisions for upstream passage and downstream protection measures for American eel during FERC hydroelectric dam relicensing efforts as a management strategy to protect the coast-wide population of American eels (ASMFC 2008, p. 5). In 2012, ASMFC completed a coast-wide stock assessment for American eels and determined that the population of American eel is depleted and their abundance is well below historical levels (ASMFC 2012a, p. 15). The American Eel Management Board (state directors) addressed coast-wide population declines in October 2014, by establishing a quota for yellow (immature) eels and glass (juvenile) eels, and restricting licenses for the silver (mature) eel fishery (ASMFC 2014, entire). Currently there is no commercial harvest of American eels allowed in the Pennsylvania or New York portions of the Susquehanna River (ASMFC 2014, p. 13).

In 2004, the Service was petitioned to list American eel under the ESA, but ultimately determined that listing was not warranted (72 FR 4967 (2/2/07)). The Service determined that although the population of American eel had declined and had been extirpated from some areas, it was still widely distributed throughout its historic range and not in immediate threat of extinction (72 FR at 4995). In 2010, the Council for Endangered Species Act Reliability petitioned the Service to re-consider listing the American eel under the ESA based on new information (CESAR 2010, entire). The 2010 petition suggested that American eel was currently threatened with extinction due to the present or threatened destruction, modification, or curtailment of its habitat or range, overutilization for commercial and recreational purposes, disease and possibly predation, the inadequacy of existing regulatory mechanisms, as well as global warming, and anthropogenic factors related to electric generation by hydroelectric projects and the spread of swim bladder parasites from ship ballast water (CESAR 2010, p. 16). In 2015, the Service completed the status review and determined that listing was not warranted at this time and that the American eel remains widely distributed throughout its native range (80 FR 60834 (10/8/2015)).

4.4.4.1 Mid-Atlantic Region American Eel

American eel are relatively abundant in the Mid-Atlantic region and support a commercial fishery. From 2010 to 2013, 70 percent of the 1 million pound coast-wide annual commercial fishery harvest of American eel came from the Chesapeake Bay and tributaries (ASMFC 2014, p. 10, with no commercial harvest upstream of Conowingo Dam). The eel population in the Mid-Atlantic region is not evaluated separately from the coast-wide population. The coast-wide population was considered depleted in the 2012 ASMFC Stock Assessment. The 2012 ASMFC Stock Assessment used data available through 2010 and continued sampling since that time has shown no trend in juvenile recruitment (YOY) through 2013, indicating that the American eel population is not increasing or decreasing in abundance in since 2001 (ASMFC 2014, p. 8).

4.4.4.2 Susquehanna River American Eel

There is no current formal assessment for American eel abundance available for the Susquehanna River. Based on collections by the Service at Conowingo Dam since 2006, juvenile eels (elvers) continue to arrive at the dam in large numbers through the summer (Minkkinen and Park 2014, p. 9). Stocking efforts since 2008 have resulted in American eels being distributed throughout the watershed, with high densities observed at stocking location in studies conducted by resource agencies (Minkkinen and Park 2014, pp. 3, 11).

Service research studies on stocked American eels have found that they grow quickly and are maturing at relatively young ages. American eels are successfully maturing and migrating out of the Susquehanna River, with the first collections of adult eels occurring in 2013 (Minkkinen et al. 2014, entire). Downstream migrating adult American eels were collected in the fall months from the strainers located at Peach Bottom Atomic Power Station (on Conowingo Pond) and at Safe Harbor Dam.

The Service has identified previously stocked American eels with the parasitic stage of juvenile freshwater mussels attached to the eels' gills being found in Susquehanna River tributaries (Minkkinen et al. 2012, p 8). In the Susquehanna River, the American eel is the most effective fish host for successful reproduction of the freshwater elliptio mussel (Lellis et al. 2013, p 75). Preliminary results of field studies indicate that juvenile mussels were much more abundant after American eel stocking than before stocking (Minkkinen et al. 2014, entire). A greater abundance of American eels is expected to result in a greater abundance of mussels, which in turn, may improve water quality in the Susquehanna River and Chesapeake Bay.

5. Comprehensive Plans and Objectives

To address the decline of migratory fish in the Susquehanna River, SRAFRC developed the 2010

Migratory Fish Management and Restoration Plan (2010 SRAFRC Plan) for diadromous fish species in the Susquehanna River (SRAFRC 2010, entire). The 2010 SRAFRC Plan established restoration goals for migratory fish in the Susquehanna River. The restoration goals are based on the completion of a series of management actions, including development of fish passage efficiency criteria for the lower mainstem hydroelectric dams (SRAFRC 2010, pp. 35-55). The 2010 SRAFRC Plan was peer reviewed by a panel of experts, released in draft form for public comment, and all comments were addressed in an appendix to the plan (SRAFRC 2010, pp. 105-124). An addendum to the 2010 SRAFRC Plan was developed and approved by the SRAFRC Policy Committee in 2013. The 2013 addendum specifically addresses American eel restoration to the Susquehanna River basin (SRAFRC 2013, entire).

Following final approval by the SRAFRC Policy Committee, the 2010 SRAFRC Plan was filed with FERC and approved as a comprehensive plan. Pursuant to FPA Section 10(a)(2)(A)(16 U.S.C. 803(a)(2)(A)), and FERC Order No. 481-A, FERC determined that the 2010 SRAFRC Plan and the 2013 SRAFRC Plan satisfied the three statutory criteria to be recognized as comprehensive plans: that the plan is comprehensive for one or more beneficial uses of a waterway; the plan relies on specific standards, data, and methodologies; and the plan is filed with the Commission.

5.1 Published Plans

A number of published state, federal, and regional fishery plans contain management goals that pertain to the Susquehanna River. These comprehensive plans are recognized by the Federal Energy Regulatory Commission's Licensing Process:

Atlantic States Marine Fisheries Commission. 1998. Amendment 1 to the Interstate Fishery Management Plan for Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*). Fishery Management Report No. 31. July 1998. 43pp.

Atlantic States Marine Fisheries Commission. 1998. Interstate fishery management plan for Atlantic striped bass. Fishery Management Report No. 34. January 1998.

Atlantic States Marine Fisheries Commission. 1999. Amendment 1 to the Interstate Fishery Management Plan for shad and river herring. Fishery Management Report No. 35. April 1999. 77pp.

Atlantic States Marine Fisheries Commission. 2000. Interstate fishery management plan for American Eel. Fishery Management Report No. 36 of the Atlantic States Marine Fisheries Commission. 79pp.

Atlantic States Marine Fisheries Commission. 2000. Technical Addendum 1 to Amendment 1 of the Interstate Fishery Management Plan for shad and river herring. February 9, 2000. 6pp.

Atlantic States Marine Fisheries Commission. 2009. Amendment 2 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. May 2009.

Atlantic States Marine Fisheries Commission. 2010. Amendment 3 to the Interstate Fishery Management Plan for shad and river herring, Arlington, Virginia. February 2010.

Chesapeake Bay Program. 2000. Migratory Fish Restoration and Passage on the Susquehanna River. January 2000.

Chesapeake Bay Program. 2004. Restoring Fish Passages throughout the Chesapeake Bay Watershed. February 2004.

Chesapeake Bay Program. 2004. Shad and the Chesapeake Bay. February 2004.

Chesapeake Bay Program. 2005. Fish Passage Goals. January 2005.

National Marine Fisheries Service. 1998. Final Recovery Plan for the Shortnose Sturgeon (*Acipenser brevirostrum*). Prepared by the Shortnose Sturgeon Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland. December 1998. 104pp.

National Park Service. 1982. The nationwide rivers inventory. Department of the Interior, Washington, D.C. January 1982.

Policy Committee of the Susquehanna River Anadromous Fish Restoration Committee (SRAFRC). 2002. Alosid management and restoration plan for the Susquehanna River Basin.

Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). 2010. Migratory fish management and restoration plan for the Susquehanna River Basin. 124pp.

Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC). 2013. Susquehanna River Basin American eel restoration plan: addendum to the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) 2010 migratory fish management and restoration plan for the Susquehanna River Basin. 18pp.

Susquehanna River Basin Commission. 1987. Comprehensive plan for management and development of the water resources of the Susquehanna River Basin. Harrisburg, Pennsylvania. June 1987. 153pp. and appendices.

5.2 Restoration Objectives

5.2.1 American Shad and River Herring

The Service supports goals and objectives in the 2010 SRAFRC Plan as a framework to restore important migratory fish resources to the Susquehanna River Basin.

The goal of the 2010 SRAFRC Plan relating to American shad and river herring is:

> *Restore self-sustaining, robust, and productive stocks of migratory fish capable of producing sustainable fisheries, to the Susquehanna River Basin throughout their historic ranges in Maryland, Pennsylvania, and New York. The goals are 2 million American shad and 5 million river herring spawning upstream of the York Haven Dam.*

The steps to achieve this goal are partitioned into five objectives, each with a series of tasks. The tasks include a brief description along with timelines, costs, potential sources of funding and an assessment of task status. Brief overviews of the five objectives are:

A. Restore access to historic habitats for juvenile and adult migratory fish. This objective calls for development of passage plans and performance measures to achieve specified minimum passage efficiency for American shad, American eel, and other migratory fish species at major basin dams.

B. Maintain or improve existing migratory fish habitat. This objective focuses on essential habitat issues by inventorying blockages and assessing the impact of fish passage impediments through active involvement of SRAFRC in watershed project reviews while supporting monitoring and improving water quality.

C. Enhance migratory fish spawning stock biomass and maximize juvenile recruitment. This objective includes a variety of tasks designed to directly or indirectly improve migratory fish stocks in the Susquehanna River. Tasks focus on improving current techniques for artificial augmentation of American shad stocks, developing new techniques for augmenting river herring and American eel populations, restoring non-alosine migratory fish, improving upstream and downstream migration, improving spawning and rearing habitat, and improving regulatory framework restricting harvest of migratory fish.

D. Evaluate the migratory fish restoration effort and adjust programs or processes as needed. This objective stresses the importance of data dissemination and analysis. Tasks will include collecting baseline data essential to monitor restoration progress while researching and experimenting with technologies to improve survival, reproduction and spawning biomass.

E. Ensure cooperation among all restoration partners while generating support for the restoration of migratory fish among the general public and potential funding sources. This objective stresses the importance of a watershed approach to restoration and emphasizes the need to include coastal states and ocean waters.

The SRAFRC, through its Policy and Technical Committees, member agencies and partners, will rely on this plan as the foundation of its restoration activities while also recognizing that changes in fish stocks, threats, and management techniques will require flexibility and adaptation (SRAFRC 2010, p. 6).

To restore access to historical habitat for juvenile and adult migratory fish in the Susquehanna River (objective A), the SRAFRC has established upstream and downstream passage efficiency criteria for the lower mainstem dams on the river. The upstream criteria for American shad are 75 percent of the fish passing the next downstream dam or 85 percent of the fish that enter a hydroelectric project's tailwaters (SRAFRC 2010, p. 35). For Conowingo Dam, the criterion of 85 percent of the American shad that enter the project's tailwaters is applicable because there are no other dams downstream of Conowingo Dam from which to measure the 75 percent standard. Although SRAFRC established population restoration objectives for river herring in the 2010 SRAFRC Plan, they did not establish an upstream passage efficiency criterion for river herring. For downstream passage, the 2010 SRAFRC Plan calls for 80 percent survival for adult, and 95 percent survival for juvenile American shad and river herring (SRAFRC 2010, p. 36-37).

The Service typically expects that all fish attempting to pass a dam will be allowed to pass when it issues fishway passage prescriptions. Nonetheless, in the case of the Susquehanna River dams on the lower mainstem, in this instance, the Service supports the criteria established in the 2010 SRAFRC Plan, accepting, based on the available scientific evidence, the premise that establishing upstream and downstream passage efficiency criteria at less than 100 percent will still allow for achievement of restoration goals for target species (USFWS 2015c, entire).

5.2.2 American Eel

The Service supports goals and objectives of the 2013 addendum to 2010 SRAFRC Plan specific to American eel restoration efforts in the Susquehanna River Basin (SRAFRC 2013).

The goal for American eel restoration is to ensure that every American eel that approaches Conowingo Dam is passed upstream into the Susquehanna River basin in order to restore American eels to the watershed, provide a net increase of out-migrating American eel, and restore the ecosystem functions provided by healthy American eel populations, including their role as predator and prey as well as acting as hosts for the larvae (glochidia) of the freshwater mussel, *Elliptio complanata* (SRAFRC 2013, p. 5).

The goal will be achieved through ensuring upstream passage for American eels throughout the Susquehanna River basin, increasing survival and escapement of American eels passing barriers and hydroelectric facilities during their downstream spawning migration, evaluating efforts to reintroduce American eels throughout the Susquehanna River basin, documenting the influences of American eel on freshwater mussel populations, and increasing public awareness, appreciation and knowledge of American eels.

Specifically, the 2010 SRAFRC Plan states that upstream passage plans will need to be developed and implemented at FERC-licensed dams to ensure adequate passage of American eels. The 2013 SRAFRC Plan addendum suggests that a trap and transport program may be most effective for American eel restoration efforts in the basin, by eliminating the cumulative upstream passage inefficiencies as a result of passing multiple mainstem dams. In addition to the restoration plan recommending a trap and transport program for American eel, the Muddy Run Pumped Storage Facility's Water Quality Certification through the Pennsylvania Department of Environmental Protection also requires that American eels be collected at Conowingo Dam or some other location and transported upstream as part of the license conditions for that facility (PADEP 2014, p. 13, Appendix 1), supporting the recommendations of the 2010 SRAFRC Plan and its 2013 addendum.

6. Actions Necessary to Accomplish Restoration Objectives

The low numbers of diadromous fish species (American shad, river herring, and American eel) currently within the Susquehanna River watershed are the result of cumulative effects of multiple factors including predation, poor fish passage effectiveness, turbine mortality, poor environmental conditions in some years, and bycatch in offshore commercial fisheries (SRAFRC

2010, p. 28). The factors of poor passage effectiveness and turbine mortality are directly related to hydropower development and operations on the river. If restoration of diadromous species is to be successful, all hydropower operations have a role in ensuring that their cumulative impacts are minimized to the extent that they are not preventing population growth of diadromous fish species.

6.1 Population Goals for Restoration

The restoration goal for American shad on the Susquehanna River is 2 million adult American shad spawning upstream of York Haven Dam (SRAFRC 2010). This restoration goal was based on the wetted area of the river and an assumed density of adult American shad. The 2010 SRAFRC plan states "These computations used an area-density estimate of 48 American shad per acre for the mainstem up to Sunbury and the entire Juniata River up to present day blockages" (SRAFRC 2010, p. 34). The assumed density of 48 adult American shad per acre was derived by St. Pierre (1979 (rev. 1981), pp. 33-34).

In St. Pierre's original estimation of the number of American shad that the river could support, he included the area of the "…mainstem to Clarks Ferry and the Juniata to Lewistown" which he estimated to have approximately 38,000 acres of habitat. With an assumed density of 48 adult shad per acre, the population in this area was expected to be 1.8 million American shad. St. Pierre also indicated that the density of shad could range from 25 to 142 per acre and thus his estimate of the number of shad that could be supported in the mainstem to Clarks Ferry and the Juniata to Lewistown could range from approximately 950,000 to 5.4 million (St. Pierre 1979 (rev. 1981), pp. 33-34).

The Service further examined the potential population of American shad that could be supported by the amount of habitat in the Susquehanna River under a range of densities of adult American shad and areas of interest. Area of reaches within the river was estimated via a GIS using NHDPlus data (http://www.horizon-systems.com/NHDPlus/NHDPlusV1_home.php) which is more accurate than the methods available at the time St. Pierre drafted the 1979 report.

Table 7 shows the area of various river reaches and the corresponding number of adult American

Shad that could be expected under assumed densities ranging from 25 – 142 per acre (St. Pierre 1979 (rev. 1981), p. 33). The West Branch of the Susquehanna River is included as this tributary also contains suitable habitat for American shad from its confluence upstream to Lock Haven (Kocovsky et al. 2008, p. 907; Kocovsky et al. 2009, pp. 113–114). The area upstream of Lock Haven is polluted with acid mine drainage from bituminous coal mines and is not included. In total, the number of American shad that the Susquehanna River could support in the absence of passage barriers ranges from approximately 2.0 to 11.6 million depending on the assumed density of adult shad. In the area described by St. Pierre (1979 (rev. 1981)), 1.1 to 6.1 million shad would be expected. In the area described in the 2010 SRAFRC plan, 723,000 to 4.1 million shad would be expected. Finally, in the area from York Haven Dam upstream to Binghamton, New York, including the Juniata River and the West Branch as far as Lock Haven, 1.0 to 5.8 million shad would be expected. The current restoration goal of 2 million adult American shad spawning upstream of York Haven Dam falls within the range of estimates based on available spawning habitat in the Susquehanna River.

Table 7. Area-density estimates of the number of American shad that could be supported by the Susquehanna River. Acres of habitat in each river reach were derived from NHDPlus data.

River Reach	Acres	Shad (25/acre)	Shad (48/acre)	Shad (142/acre)
Mouth to Conowingo	4,312	107,789	206,955	612,242
Conowingo to York Haven	23,429	329,632	632,893	1,872,310
York Haven to Clarks Ferry	12,591	314,776	604,370	1,787,928
Clarks Ferry to Sunbury	13,515	337,864	648,698	1,919,066
Sunbury to Binghamton, NY	18,653	466,335	895,363	2,648,781
Juniata River to Lewistown	2,658	66,454	127,592	377,460
Juniata River from Lewistown to Upstream Blockages	144	3,605	6,922	20,476
West Branch to Lock Haven	6,435	160,880	308,889	913,796
Total	81,737	2,043,425	3,923,376	11,606,654
St. Pierre's estimate[1]	42,990	1,074,742	2,063,505	6,104,534
2010 SRAFRC Plan Goal[2]	28,908	722,699	1,387,582	4,104,930
York Haven to Binghamton, NY[3]	41,126	1,028,154	1,974,056	5,839,916

[1]Includes habitat in the reaches of the mouth to Conowingo, Conowingo to York Haven, York Haven to Clarks Ferry, and the Juniata River to Lewistown.
[2]Includes habitat in the reaches of: York Haven to Clarks Ferry, Clarks Ferry to Sunbury, and the entire length of the Juniata River to upstream blockages.
[3]Includes habitat in the reaches from York Haven upstream to Binghamton, NY, Juniata River to upstream blockages, and the West Branch to Lock Haven.

6.2 Fish Passage Efficiency

6.2.1 American Shad

The 2010 SRAFRC management plan calls for each of the four lower river hydroelectric dams to pass upstream at least 75 percent of the adult American shad passed at the next downstream facility, or at least 85 percent of the adult American shad reaching project tailwaters (SRAFRC 2010, p. 35). Also, downstream passage should ensure at least 80 percent survival for adult alosines (American shad and river herring) and 95 percent survival for juvenile alosines (SRAFRC 2010, p. 36)

The expected growth of the American shad population in the Susquehanna River under the passage efficiency criteria specified in the 2010 SRAFRC management plan was evaluated by the Service through simulations of an American shad population model (USFWS 2015c, entire). This population model was developed by Normandeau Associates Inc. and details on the model structure are described in Exelon 2012c (entire). Briefly, this model simulates American shad upstream passage efficiency and downstream passage survival at each of the five hydroelectric facilities on the Susquehanna River. As simulated American shad encounter Conowingo Dam, a proportion of them are passed upstream, and the number of American shad passing successive hydroelectric facilities (Muddy Run, Holtwood, Safe Harbor, and York Haven in an upstream direction) is reduced during upstream passage at those facilities. Those that eventually pass York Haven Dam will spawn. The model allows for some spawning between Safe Harbor and York Haven as there is some suitable spawning habitat in this stretch of river. The model can be adjusted with assumptions of sex ratio, age structure for virgin and repeat spawning females, and a net reproductive rate which is the future recruitment per spawning female and includes fecundity and survival from egg to virgin spawner. Annual stocking and trap and transport operations can also be simulated. The model runs on an annual time step and a starting population can be specified.

The Service used this model to simulate American shad population growth under scenarios of current low upstream fish passage efficiency, increasing fish passage efficiency at each dam to 50 percent as a level suggested by FERC in its Final Environmental Impact Statement for hydropower licenses based on observations from the Columbia River (FERC 2015, p. 177), and increasing fish passage efficiency to levels specified in the 2010 SRAFRC plan. Under each of these scenarios, simulations were run with and without stocking larval American shad and trap and transport operations to determine the sensitivity of population growth over a 50-year license term to these supplementation techniques. The current upstream fish passage efficiency was estimated from counts of American shad passed at all dams from 1997 – 2014 (http://fishandboat.com/shad_susq.htm) using a ratio estimator (USFWS 2015c, p. 5). Upstream passage efficiency at Holtwood Dam, Safe Harbor, and York Haven Dams was 32, 76, and 14 percent, respectively. Upstream passage efficiency at Conowingo Dam was 37 percent which was the average measured through radio telemetry studies conducted at the dam in 2010 and 2012 (Exelon 2011a p. 15; 2012d, p. 16). The model results showed that under current low fish passage efficiency, the population would decline in the absence of stocking larval shad or trap and transport operations. Model results were corroborated by the observed American shad population decline in the Susquehanna River since 2001, coinciding with the cessation of the trap and transport program, reduction in hatchery stocking, and low fish passage efficiencies at three lower mainstem dams.

When passage efficiency increased to 50 percent, the population only grew if stocking larval American shad or trap and transport continued for the entire 50-year license term and still only reached 9 percent of the restoration goal. Restoration of 2 million adult American shad upstream of York Haven Dam was only possible within a 50-year license term if upstream passage efficiency was increased to the levels specified in the 2010 SRAFRC plan (USFWS 2015c, pp. 5-6). Stocking and trap and transport shortened the time to reach restoration when upstream passage efficiency equaled levels specified in the 2010 SRAFRC plan, but did not result in restoration if upstream passage efficiency was reduced from the SRAFRC specified efficiencies. The results from this modeling effort demonstrated that levels of upstream passage efficiency specified in the 2010 SRAFRC management plan are appropriate for restoration to occur and that restoration of American shad in the Susquehanna River cannot occur if these levels of upstream passage efficiency are not achieved at all projects.

6.2.2 River Herring

There were no upstream passage efficiency goals specified for river herring in the 2010 SRAFRC management plan and a population model for river herring in the Susquehanna River currently does not exist to gain insight as to what appropriate levels of fish passage should be for restoration to occur. However, fish passage efficiency needs to be sufficient to reach the population target of 5 million river herring upstream of York Haven Dam (SRAFRC 2010, p. 5). The 2010 SRAFRC management plan does specify that downstream passage for adult and juvenile alosines (which includes river herring) at the four lower river hydroelectric dams should be 80 and 95 percent survival at each facility, respectively (SRAFRC 2010, p. 36).

6.2.3 American Eel

The 2013 addendum to 2010 SRAFRC Plan has a goal that every American eel that approaches Conowingo Dam is passed upstream into the Susquehanna River basin. For downstream migrating silver eels, the 2010 SRAFRC Plan calls for 85 percent survival at each hydroelectric project on the river (SRAFRC 2010, p. 37; SRAFRC 2013 p. 7).

Sweka et al. (2014, entire) developed an egg-per-recruit model for American eels in the Susquehanna River to evaluate the effects of upstream and downstream passage on the reproductive output of eels in the basin. The egg-per-recruit model estimated the total number of eggs expected to be produced per individual eel encountering Conowingo Dam during its upstream migration. The model assumed different life histories for American eels that passed upstream of the dams on the Susquehanna River compared to those that remained downstream of Conowingo Dam. Those that passed upstream had a greater probability of becoming female, a longer time until maturity, and experienced lower natural mortality compared to those that remained downstream of Conowingo Dam (Sweka et al. 2014, p. 767). Upon maturity and downstream migration, silver eels that were located upstream of the dams experienced mortality at each of four dams and the MRPSP as opposed to silver eels which spent their entire freshwater life downstream of Conowingo Dam. The model showed that if any eels are passed upstream, downstream passage survival at each of the five hydroelectric projects on the river must be 80 percent or greater (33 percent cumulative survival over all five hydroelectric projects); otherwise the total reproductive output from the river would be less than what would be expected by not passing any eels upstream (Sweka et al. 2014, pp. 770 – 771). These modeling efforts support the SRAFRC goal of 85 percent survival at each hydroelectric project (SRAFRC 2010, p. 37; SRAFRC 2013 p. 7) as that goal promotes some growth of the American eel population compared to the threshold value of 80 percent determined by Sweka et al. (2014, p. 770).

6.3 Rate of Fish Passage for American Shad

Migratory delay is an important component of fish passage that must be addressed for anadromous fish to successfully complete their life cycle. Migratory delay is the decreased rate of upstream (or downstream) movement that occurs when migrating fish encounter a barrier. American shad and river herring must travel upstream at a rate that allows them to reach suitable spawning habitat and successfully spawn within the optimal seasonal spawning window. Further, timing of spawning (Olney et al. 2001, p. 892) and survival of juvenile life stages (Crecco and Savoy 1985, p. 1645; Leach and Houde 1999, p. 768) of American shad are physiologically linked to water temperature. If fish are delayed in reaching the suitable spawning habitat, they are more likely to encounter late spring water temperatures higher than those conducive to optimum spawning and survival of larval shad. Optimal spawning temperatures range from 57 ° – 70 ° F (Walburg and Nichols 1967, p. 7) and optimal temperatures for larval survival range from 59 ° – 79 ° F (Leach and Houde 1999, p. 781).

Water temperature at York Haven Dam reaches the upper end of the optimal range for American shad spawning by June 1 (Figure 4) in an average year. Fish passing York Haven Dam after this date likely encounter water temperatures greater than the optimal for spawning. The timing of American shad migration each season varies at Conowingo Dam depending on environmental conditions. Fifty percent of the seasonal run passes the project by dates ranging from April 27th to May 20th (USFWS 2015b, p. 7) with a median date of May 7th. The American shad passing Conowingo Dam have experienced a median delay of 5 days, thus we could expect that 50 percent of the shad run arrives at Conowingo Dam by May 2nd. If each dam imposed a 5-day delay for upstream migrating shad, 50 percent of the fish that migrate to York Haven Dam would be expected to pass the dam by May 22nd, leaving only one additional week for the remaining 50 percent of the run to pass the project while optimal temperatures are available. In addition, this estimate does not incorporate travel times between dams, which would further increase time required to reach spawning habitat upstream of York Haven Dam, resulting in less than half of the American shad passing York Haven Dam before temperatures exceeded the optimum range for spawning. Thus, it is important to minimize the delay fish experience at each dam so that spawning is not compromised by elevated temperature by the time shad arrive in habitat that is physically suitable for spawning.

Delays in upstream migration also result in the expenditure of additional energy in reaching the spawning grounds as fish attempt to navigate past a dam (Leggett et al. 2004, entire). The use of more energy per distance traveled can result in a decrease in the total migration distance once energy stores are depleted to a point where upstream migration ceases (Castro-Santos and Letcher 2010, p. 816). When excessive energy is expended in the upstream migration, not only can spawning be compromised, but also post-spawning survival can be reduced if energy stores are depleted to the point where fish suffer mortality before escapement to the ocean following spawning (Castro-Santos and Letcher 2010, entire). This is especially significant considering that American shad and river herring in the Mid-Atlantic region can spawn multiple times over their lifetime (ASMFC 2007, Volume I, p. 24). The impact of delay was also noted by the FERC (2004, p. 5) when it stated "Upstream-migrating fish may be delayed for hours or days searching for passage at a dam before finding the fish passage facility entrance. This delay could reduce the fitness of spawning adults or the upstream extent of their migration."

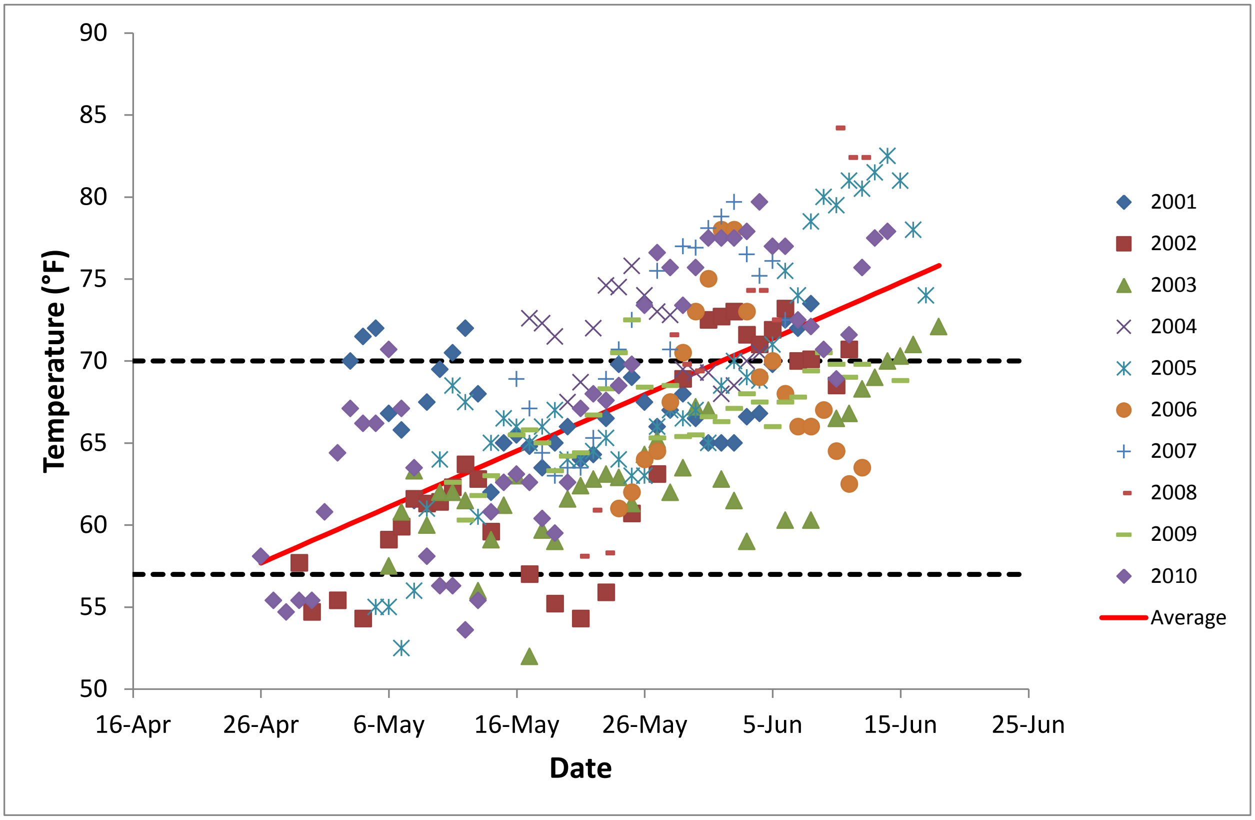

Figure 4: Water temperatures at York Haven Dam (2001 – 2010). The dashed horizontal lines represent bounds on the optimal temperature for American shad spawning and the red line represents average temperature on a given date. The average temperature reaches the upper bound of the optimal range on June 1.

The overall percentage of American shad passing Conowingo Dam is a function of the number of fish entering the tailrace of the dam each day throughout the fish passage season and the rate of passage (percentage of the population available to pass which actually do pass per day). If the rate of passage is low, then the amount of time fish are delayed increases. Also, the overall percentage of the American shad population that passes the dam decreases because fewer fish are able to pass the dam within the duration of the annual spawning run of shad which lasts 5 to 10 weeks each spring. Thus, in order to have a relatively high overall percentage passing (e.g. 85 percent) during the annual spawning run, the rate of passage must also be high. The 85 percent passage efficiency criterion at Conowingo Dam is consistent with passage efficiency goals specified in the 2010 SRAFRC management plan (SRAFRC 2010, p. 35) and was shown to result in restoration within the time period of a license term (USFWS 2015c, pp. 5-6). Finally, the passage rate that would be associated with achieving 85 percent passage efficiency has been shown to be achievable within the Susquehanna River (See Section 6.4).

6.4 Feasibility of Meeting Passage Efficiency Criteria

The Service's and SRAFRC's criterion for upstream passage efficiency of American shad has been demonstrated to be achievable within the Susquehanna River. In an analysis of fish passage at Safe Harbor Dam, counts of American shad passing Holtwood and Safe Harbor Dams were used to estimate passage rates at Safe Harbor Dam (USFWS 2015b, entire). A survivorship-type model was used to estimate the rate of passage that resulted in the observed number of fish passing Safe Harbor Dam on each day over the 1997 – 2014 fish passage seasons. The median estimated passage rate at Safe Harbor Dam was approximately 32 percent per day (which is equivalent to approximately 80 percent in 4 days). When this passage rate is applied to the proportion of the American shad run arriving at Conowingo Dam each day throughout the fish passage season, a median level of 83 percent (90th percentile range: 44.8 to 97.9 percent) of the shad entering the tailwaters of Conowingo Dam are expected to pass by the end of the run (USFWS 2015b, p. 7). Thus, the SRAFRC goal of 85 percent passage efficiency is expected to be achieved approximately 50 percent of the time at Conowingo Dam if American shad can pass at the same rate as they do at Safe Harbor Dam.

Other hydroelectric dam owners on the Susquehanna River have agreed to improvements of fish passage facilities in efforts to achieve fish passage goals specified by SRAFRC. The owners of both Holtwood and York Haven Dams are currently implementing fish passage improvements and are required to achieve upstream and downstream fish passage goals established in the 2010 SRAFRC management plan. In addition, the MRPSP will be conducting post-licensing studies to ensure that project meets the SRAFRC upstream and downstream passage criteria.

As previously stated, all hydropower facilities have a role in ensuring that their cumulative impacts are minimized so that they do not prevent population growth of diadromous fish species in the Susquehanna River. Demonstration that SRAFRC fish passage efficiency goals can be achieved at Safe Harbor Dam combined with fish passage improvements at Holtwood and York Haven Dams in efforts to meet SRAFRC fish passage goals will lead to a greater likelihood of fish restoration. However, improvements at Conowingo Dam to increase fish passage efficiency are also needed if restoration of migratory fish to the Susquehanna River is to proceed.

7. Existing Passage Facilities at Conowingo Dam

7.1 Upstream Passage – Fish Lifts

The Conowingo Dam Project includes two fish lift facilities.

7.1.1 East Fish Lift

The EFL is located on the east side of the powerhouse near the spillway. It was constructed in 1991. The EFL was designed to serve dual functions: 1) to obtain fish for the trap and transport program, and 2) to provide for passage of fish directly over the Conowingo Dam. Since 1997, the Licensee has used the EFL to pass all captured fish directly over the dam, and the trap and transport program was discontinued in 2000 from this facility (Exelon 2011b, pp. 11-12).

The EFL has had no substantial upgrades or changes to its structure since 1991 (Exelon 2011b, p. 10). The main drive motors and associated drive mechanisms were initially disassembled and lubricated after each season to extend life of the motors; however, this maintenance was terminated in 2000 (Exelon 2011b, p. 10). The EFL is in need of preventative maintenance to include sand blasting and painting of the steel structure with rust inhibitive paint. The concrete structure appears to be intact with no major spalling or discernable cracks. There is minor spalling at the location of a few of the railing anchors that should be addressed in the near term. The hopper has surface rust on the exterior steel and should have the existing rust removed and be painted with a rust inhibitive paint (Exelon 2011b, p. 10).

In addition to the lack of recent maintenance to the current EFL structure, there are additional problems with the structure that preclude it from being operated as originally designed (Exelon 2011b, pp.10). Fish passage attraction flow intended to discharge through entrance gate A is drowned every time adjacent Kaplan units are generating (Unit Nos. 8, 9, 10, and 11). For this reason, entrance gate A is normally operated in the closed position whenever the Kaplan units are scheduled to generate, making this entrance gate unavailable for fish passage (Exelon 2011b, pp.10).

7.1.2 West Fish Lift

The WFL is located on the west side of the powerhouse on the bank of the river. It began operation in 1972. It was designed as a trapping facility and cannot pass migrating fish directly over the dam and into Conowingo Pond. It was used through 1996 to obtain fish for the trap and transport program to move fish past the lower Susquehanna River dams and into spawning and rearing habitat upstream. The Licensee currently operates the WFL as a fish trapping, sorting, and egg collection facility for American shad restoration. The Licensee provides an operator for the WFL, and State of Maryland and the Commonwealth of Pennsylvania fund contractors who conduct restoration efforts from that facility.

The WFL has had no substantial upgrades or changes to its structure or operation (Exelon 2011b, p. 4). The WFL is in need of preventative maintenance, which includes replacement of crowder motors, sand blasting, and painting of the steel structure with rust inhibitive paint. The concrete structure appears to be intact with no major spalling or discernable cracks. The weir gate motors are in good condition and are not used as frequently as the crowder gate motors during lifting operations. The hopper has surface rust on the exterior steel and should have the existing rust removed and be painted with a rust inhibitive paint (Exelon 2011b, p. 4).

During a fishway inspection in May 2013 (USFWS 2013c, entire), Service fish passage engineers found the following salient issues at the WFL: the hopper maintains less water than the Service criterion of 0.1 cubic feet per pound of fish; the transfer between the hopper and the holding tank poses a high risk for fish injury; and hydraulic conditions within the fishway channel (e.g., eddies) result in misdirection of the fish and fish passage delays.

7.2 Downstream Fish Passage

There are no existing downstream fish passage facilities or measures at the Project. All fish migrating downstream through the Project must navigate through turbines or any open spill gates to reach the Project tailwaters.

8. Fish Passage Effectiveness at Conowingo Hydroelectric Project

8.1 Existing Upstream Fish Passage Efficiency

8.1.1 Upstream Fish Passage Efficiency for American Shad

The EFL is used for direct passage of migratory fish upstream over the dam into Conowingo Pond, and it is the passage facility where fish passage efficiencies have been recently evaluated. The Licensee conducted a radio telemetry study to determine the current passage efficiency of the EFL. The 2-year study found that in 2010 and 2012 only 45 percent and 26 percent of American shad that reached the tailwaters of the Project (as defined by the downstream end of Rowland Island), were able to successfully pass upstream through the fishway; no other species were evaluated (Exelon 2011a, p. 15; Exelon 2012d, p. 16). In addition to the overall low passage efficiencies, American shad that did eventually pass experienced significant migratory delays downstream of the dam. Data from these studies indicated that American shad that did pass were delayed a median of 5.24 days from the time they were initially located in the tailwaters of Conowingo Dam until they eventually passed (Exelon 2011a, Exelon 2012d). Those studies found only 24 percent and 5 percent (2010 and 2012 studies respectively) of the radio tagged American shad passed the Project within a 4-day timeframe (USFWS 2015e, entire) which is much lower than what has been demonstrated as being possible at other Susquehanna River fish lifts (USFWS 2015b, p. 7).

Current passage efficiency at Conowingo Dam is well below levels required for restoration of American shad populations in the Susquehanna River. Mitigation efforts in the forms of stocking larval American shad and trap and transport efforts can have beneficial effects on the Susquehanna River American shad population. However, population growth and timely achievement of restoration goals will still be limited, and if these mitigation efforts cease, the population would once again decline due to insufficient recruitment of juvenile fish from the

Susquehanna River (see Section 6.2.1). Therefore, the Service requires an increase in both the overall passage efficiency and rate of passage through the Project area.

8.1.2 Upstream Fish Passage Efficiency for River Herring

No upstream fish passage efficiency studies have been conducted on river herring at Conowingo Dam. However, river herring have slower swimming speeds than American shad (Bell 1991, p. 6.3). The entrance gate(s) at the EFL are operated to maintain water velocities of 3 to 8 feet per second (fps) (SRAFRC 1993 pp. 1-4). Water velocities higher than 5 fps exceed the sustained swimming speed for river herring (Bell 1991, p. 6.3). The high water velocity at the entrance gates may preclude herring from successfully entering the EFL and being passed upstream (USFWS 2014b, p. 2). Reduced water velocities at entrance gates may be necessary to efficiently pass river herring at this Project.

8.1.3 Upstream Fish Passage Efficiency for American Eel

Juvenile American eels have migrated to the base of Conowingo Dam in large numbers for decades (SRAFRC 2013, pp. 13-14). Although very few American eels have been passed upstream via the fish lifts at Conowingo Dam, resource agencies have conducted intermittent stocking programs to provide limited access to upstream habitat in the Susquehanna River basin for American eels (SRAFRC 2013, pp. 13–14). American eels require different fish passage structures than do other migratory fish (ASMFC 2013, p. 1). Currently there are no permanent American eel passage facilities or measures in place at any of the Susquehanna River hydroelectric projects to facilitate upstream or downstream eel passage. To restore access to the Susquehanna River watershed for American eels, the Service will require installation of upstream eel passage facilities to be provided at Susquehanna River hydroelectric projects.

8.2 Condition of Existing East Fish Lift Structure, Design, and Operation

Low overall migratory passage efficiency and substantial delays at Conowingo Dam can be attributed to several factors associated with the existing EFL structure and operation.

8.2.1 Preventative Maintenance

Preventative maintenance of the EFL at the Conowingo Dam has not been conducted since 2000 (Exelon 2011b, p. 10), and equipment failures have occurred during critical periods of the annual migratory fish passage season (SRAFRC 2013a, Table 3; Normandeau Associates 2014b, p. 4).

Preventative maintenance of the fish lift as well as having common replacement parts on-hand is necessary to ensure the fish passage facility will function properly, or can be quickly repaired and put back into service during the fish passage season.

8.2.2 Current Fish Passage Design Flows

EFL operators at the Project informed Service engineers inspecting the EFL in 2012 that the existing EFL cannot operate when river flows are higher than 113,000 cfs. Based on Service fish passage criteria, the upper range of the fish passage design flows at the Conowingo Project is a river flow of 143,000 cfs (USFWS 2012a, p. 10). Shutting down fish passage operations during river flows that are less than fish passage design flows can result in unwarranted delays and/or unsuccessful passage for migratory fish that would be otherwise naturally motivated to move upstream during higher river flow conditions.

8.2.3 Attraction Flow and Turbine Boils

The Service's fish passage engineers inspected the EFL structure and operation in May of 2012 and 2014 (USFWS 2012b, pp. 1-2; USFWS 2014b, pp. 1–2), and identified that attraction flow is only one-third of the 900 cfs for which this facility was designed (USFWS 2014b, pp. 1–2). The EFL attraction water is fed through the western-most spillway bay immediately upstream of the fishway. Most of this attraction flow is passed down the ogee crest and into the stilling basin (energy dissipation pool) located at the base of the dam just upstream of the EFL hopper. The drop between the top of the ogee crest and the stilling basin is approximately 85 feet. Water falling this distance has high velocity and considerable energy that needs to be dissipated prior to use for fishway attraction flows. The original design for the EFL of 900 cfs of attraction flow is necessary to achieve preferred hydraulic conditions (e.g., water velocities) at the fishway entrances and inside the fish lift (MDNR 1988, p. 2). The License Applicant informed the Service that it currently operates the EFL with only 300 cfs mainly because the size of the existing stilling basin at the base of the dam is insufficient to dissipate enough energy from the falling water, resulting in unwanted air bubbles in the fish passage flow that deter fish movement upstream. This lower flow also produces inadequate attraction flow velocities within the channel of the fish lift that may be a factor in fish retreating back downstream (fall back) after locating and entering the lift (Exelon 2011a 15-16; Exelon 2012d p. 14; USFWS 2014b, pp. 1-2). In one instance, the Service verbally requested the EFL operators to run the EFL with 900 cfs so that they could observe the hydraulic issues and the excessive air bubbles described by the License Applicant. The License Applicant declined the Service's request, stating that the physical structure of the EFL could suffer structural and mechanical damages from running 900 cfs, despite the fact that the fish lift should have originally been designed to pass this amount of flow (Exelon staff, personal communication, Conowingo Fish Passage Technical Advisory Committee Meeting, March 30, 2015).

To ensure the hydraulic cue created by a technical fish passage facility is discernible, the Service's recommended amount of attraction flow is expressed as a percentage of the sum of other competing flows (e.g., discharge from turbines) (USFWS 2013d, p. 2). The current Service design standard for attraction flow to a fishway requires at least 3 to 5 percent of the total station hydraulic capacity (i.e. 86,000 cfs; Exelon 2012a, p. B-7) to be emanating from the entrance(s) of the fishway, and that the hydraulically connected crowder/hopper system (e.g., internal channels, crowder area, and exit flume) maintain velocities that will not preclude entrance into the fishway for target fish species (USFWS 2012a, p. 11; USFWS 2013d, p. 2). In the case of Conowingo Dam's EFL, the current standard would require 2,580 to 4,300 cfs to be used for attraction flow at the EFL for successful fish passage. The current attraction flow of 300 cfs represents only 0.35 percent of the total station hydraulic capacity.

8.2.4 Zone of Passage and Project Operations

Fish lifts and ladders are long established fish passage technologies for allowing fish to pass over dams and other height barriers. Successful use of these technical fish passes depends on fish finding the fish passage facility entrance, entering the fish passage facility, and then using the lift or ladder to successfully pass the barrier. However, getting fish up to and entering the facility often presents the greater challenge. Accordingly, numerous conceptual models have been developed to describe the regions influenced by the hydroelectric project beyond the fish lift (ladder) entrance and exit. Castro-Santos and Perry (2012, p. 430) and Castro-Santos (2012, p. 77) partition this area into three regions: an approach zone, an entry zone, and a passage zone; the former two regions describing areas in front of the fish passage facility entrance, the latter zone characterized by movement within the lift, ladder or other fish passage facility. Johnson and Dauble (2006, p. 221) further partition the area in front of the entrance into approach, discovery, and decision zones. Similar terms partitioning the region downstream of the project into far-field and near-field attraction zones are used in common practice. The Service uses the comprehensive term, zone of passage (ZOP), to collectively describe these regions and has successfully incorporated this concept into other fishway prescriptions (e.g., Holyoke Project – FERC 2005, p. 5; Holtwood Project – USFWS 2009, p. 14).

Formally, the ZOP is the contiguous region of sufficient lateral, longitudinal, and vertical extent in which adequate hydraulic and environmental conditions are maintained to provide a route of passage through a stream reach influenced by a dam, hydroelectric project, or other barrier. For upstream passage, the ZOP encompasses a far-field attraction zone, a near-field attraction zone, the technical fish passage facility, and the impoundment. As illustrated in Figure 5, successful passage requires a migrating fish to enter the ZOP at “A” and promptly exit at “E” before continuing on its way upstream (without falling back downstream). Figure 5 also shows the distinction between the umbrella term “fishway” and a component part, such as the technical fish passage facility (e.g., fish lift). The ZOP is recognized as part of the fishway and this definition is in keeping with 16 U.S.C. § 811 (see details in USFWS 2014c).

An effective ZOP must maintain hydraulic and environmental conditions necessary for successful passage. Flow velocity, key among these conditions, must be high enough to trigger a rheotactic response in upstream-migrating fish and low enough to facilitate movement for even the weakest-swimming target species. Additionally, the spatial and temporal persistence of these conditions must not introduce unacceptable fatigue in the target species. On the lower Susquehanna River, river herring represent the weakest-swimming anadromous target species. Based on published biological criteria, methodologies for estimating sustained speed, and associated fatigue times (Bell 1991, p. 6.3; Bain and Stevenson 1999, pp. 146-147; Haro et al.

2004, p. 1595; Maine DOT 2008, p. 18), the Service recommends that a ZOP for upstream passage generally maintain instantaneous velocities between 1 and 3 feet per second separated only by brief regions of higher velocity that river herring may traverse in seconds at burst speeds up to 6 feet per second (e.g., flow over weir crests). To ensure passage is provided for the entire anadromous target population, these hydraulic conditions must be maintained over the range of flows or project discharges that could be experienced during any fish passage season.

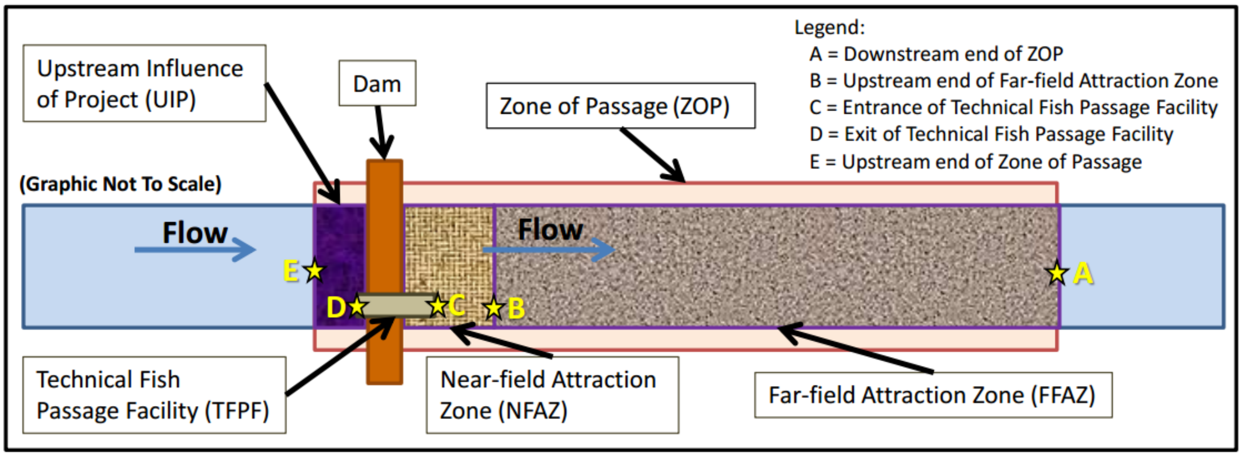

Figure 5: Diagram to illustrate fish passage definitions.

At the Conowingo Project, recent hydraulic modeling has demonstrated the persistence of hydraulic conditions that exceed the abilities of river herring. The model, developed using River 2D software (http://www.river2d.ualberta.ca), indicates that powerhouse discharges in excess of 40,000 cfs create depth-averaged velocities in the tailrace that exceed the 1 to 3 feet per second criterion. These high velocities persist along both sides of Rowland Island (Figure 6; Exelon 2012e, p. 43), for a linear distance greater than river herring are capable of covering while sprinting (i.e., anaerobic burst swim speed). As such, they create a potential barrier to upstream movement. The 30-year flow duration curve indicates that flows exceeded 40,000 cfs for 50 percent of the time during the upstream migration season (USFWS 2012a, p. 28). While the 1 to 3 feet per second criterion was met when flows dropped below 10,000 cfs, occurring only 10 percent of the time during the upstream migration season (USFWS 2012a, p. 28). These conditions demonstrate the inadequacy, on a persistent seasonal basis, of the ZOP in the tailrace downstream of the lift entrances. 3D modeling or actual flow data might demonstrate that a ZOP does exist over the full range of generation scenarios, but that information is unavailable, and the best information and modeling available indicates that this is a problem that should be remedied. Various in-stream structures including bendway weirs, jetties, rock weirs, and flow training (partitioning) walls have proven effective in reducing bankside velocities to levels consistent with Service criteria. Use of such structures in the tailrace to create a persistent ZOP could mitigate these adverse hydraulic conditions over the range of fish passage design flows experienced during the fish passage season.

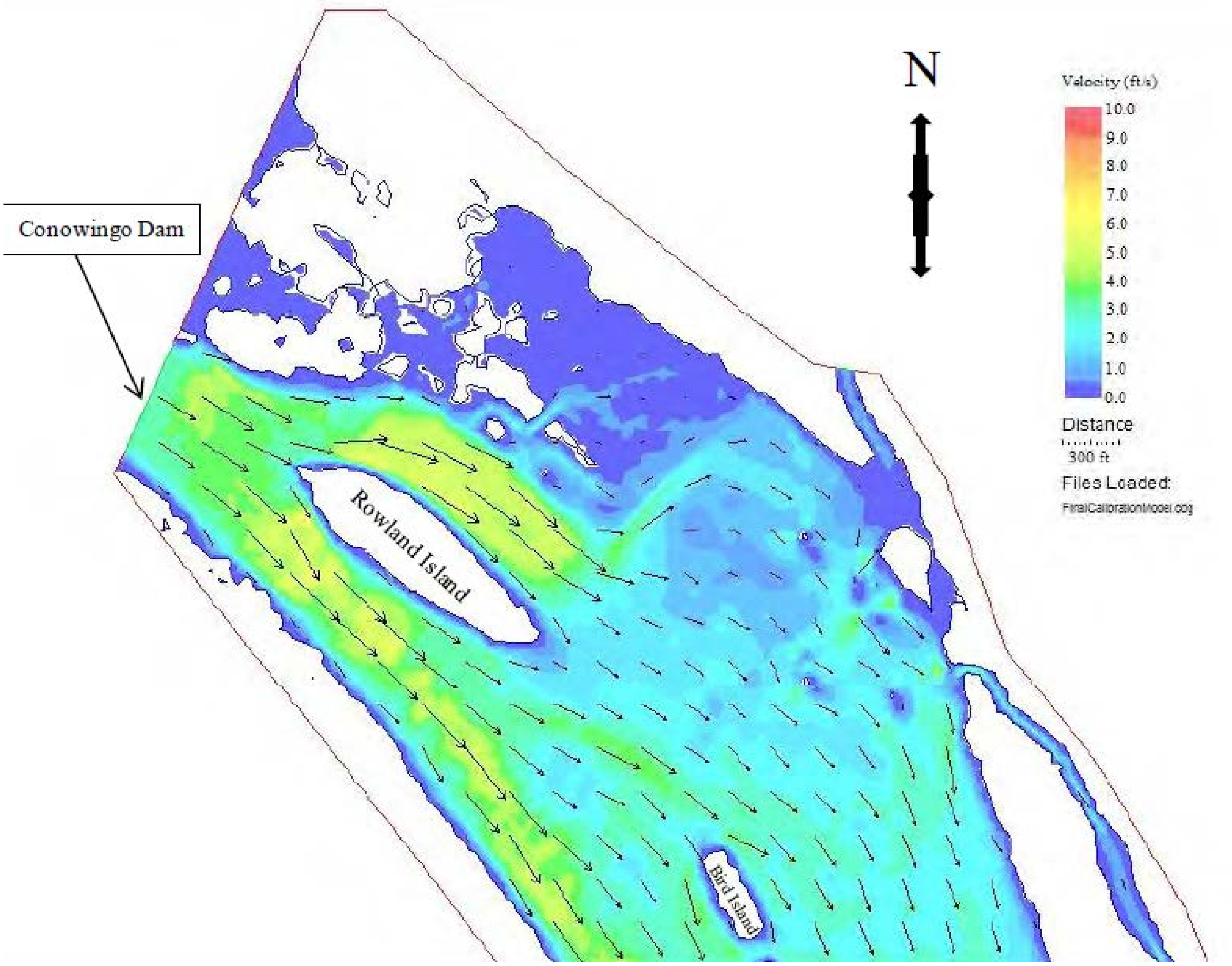

Figure 6. Water velocity in the Susquehanna River in the vicinity of Rowland Island and Bird Island as determined by River 2D Model for 40,000 cfs discharge from Conowingo Dam (Figure 4.2-7: from Exelon 2012e, p. 43).

On a daily and hourly time scale, project operations can also influence the availability of a ZOP for migratory fish. At the Conowingo Project, generation and turbine discharge fluctuate on a daily basis to meet energy demands (i.e. peaking); this cycle creates periods of high project discharge during fish lift operations (Figure 7). During these daily high discharge periods, water velocity in the tailrace may exceed the sustained swimming speeds of some or all target species. Under such circumstances, normal upstream migration is delayed until conditions change. This demonstrates that even during periods of low project (river) inflow, generation and unit operations can negatively impact the adequacy of the ZOP throughout the tailrace. Modulating tailrace conditions through adjustments to hourly and daily unit operations to provide an adequate ZOP may mitigate this negative impact.

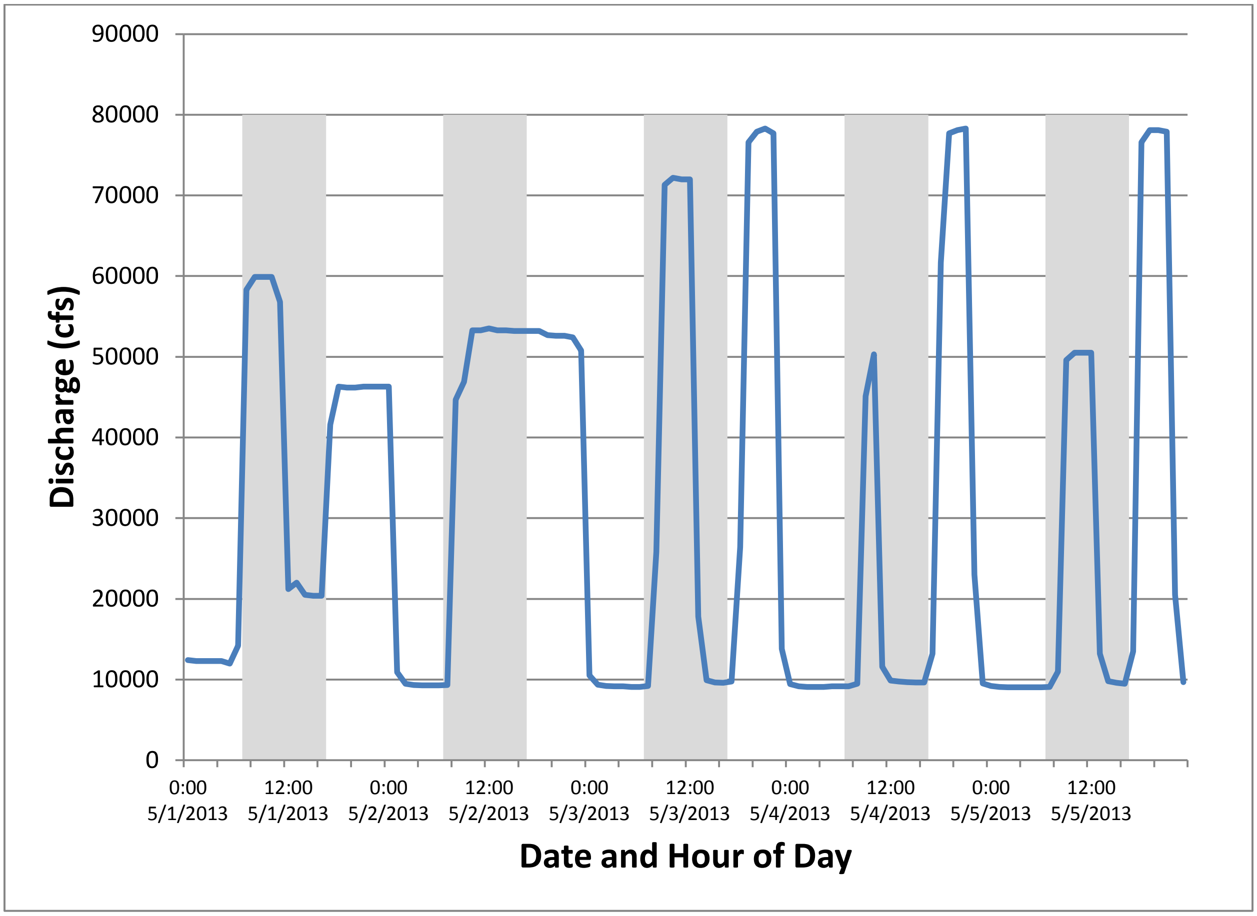

Figure 7. Hydrograph of river discharge downstream of Conowingo Dam during the spring migration season. Data acquired from USGS Gauge Station 01578310. Grey bars indicate hours of fish passage operation (07:00-16:00 daily).

The influence of the Project on the ZOP can also be highly localized. The ZOP properly extends upstream through the tailrace to the fish lift entrances (and beyond). Successful technical fish passes (e.g., fish lifts) create hydraulic cues that attract fish to one or more entrances in the presence of the competing powerhouse discharges or other false-attraction flows (USFWS 2013d, p. 1). At Conowingo, the current limits on attraction flow discharged from the existing EFL cannot adequately attract upstream migrants to the fish lift entrance while the large Kaplan units are generating. In addition, discharge from the Kaplan units adjacent to the EFL actually creates a localized (high) velocity barrier that inhibits or prevents fish from accessing the EFL entrance(s). Telemetry studies conducted in 2010 and 2012 indicated that of the American shad detected in the tailwaters, only 73 percent and 44 percent, respectively, were able to successfully enter the EFL (Exelon 2011a, p. 15; Exelon 2012d, p. 16). In previous, unsuccessful attempts to mitigate the impacts of the Kaplan discharge, entrance gates A and/or B were frequently closed to fish passage (SRAFRC 2000, pp. 1-3). This further reduced the effectiveness of the facility. The Service concludes that the existing EFL entrances are ineffective at attracting fish, and the ZOP in the vicinity of the Kaplan discharge is inadequate. The aforementioned in-stream structures (e.g., rock weirs) may be used to selectively create continuous, passable routes to the fish lift entrances within the larger tailrace region.

Safe, timely, and effective fish passage at the Conowingo Project is precluded by seasonal, daily, and localized inadequacies in the ZOP which inhibit and prevent access to the existing fish lift entrances for target migratory fish species in the Susquehanna River. The Service recommends or requires measures to avoid or minimize delays in fish migration, particularly since migration events are often time sensitive. The holistic definition of the ZOP and the documented biological criteria provide a scientifically justified framework for the design of measures and in-stream structures to improve passage at the Project.

8.2.5 Capacity of the Existing East Fish Lift

Service fish passage engineering reviews and site inspections have determined that the existing EFL has insufficient lift capacity for passing all the fish attempting passage at the Project (USFWS 2012a, p. 15; USFWS 2012b, p. 13; USFWS 2015d, entire). Fish lift capacity is a measure of the quantity of fish (in pounds per unit of time) that the facility is designed to safely convey, upstream or downstream. The fish lift(s) capacity should be designed so that the available fish of *all species* attempting to pass the project, including American shad, river herring, and other fish species in the tailrace can be passed upstream in a safe, timely, and effective manner (USFWS 2013e, p. 2).

The timing of when fish arrive during the spawning run is not uniform and is typically highly compressed (the peak of the seasonal run happens during just a few days). The seasonal run of fish can be described as normally distributed (i.e. bell curve), where the crest of the distribution is defined as the peak day of the run during the spawning season. Service experience indicates that for American shad approximately 5 percent to 15 percent of their seasonal run passes during the peak day, depending on the size of the total seasonal run. At Conowingo Dam from 1997 to 2014, 7.3 to 29 percent of total seasonal run passed on the peak day for the respective year. The annual SRAFRC reports show that the average for all years (1997–2014) was 12.8 percent of American shad passing on the peak day (SRAFRC 1998, pp. 1-18 – 1-19; SRAFRC 1999, pp. 1-15 – 1-16; SRAFRC 2000, pp. 1-16 – 1-17; SRAFRC 2001, pp. 1-15 – 1-16; SRAFRC 2002, pp. 1-12 – 1-13; SRAFRC 2003, pp. 1-14 – 1-15; SRAFRC 2004, pp. 1-12 – 1-13; SRAFRC 2005, pp. 1-13 – 1-14; SRAFRC 2006, pp. 1-13 – 1-14; SRAFRC 2008, pp. 16-18; SRAFRC 2011, pp. 11-12; Normandeau Associates 2008, Table 2; Normandeau Associates 2009, Table 2; Normandeau Associates 2010, Table 2; SRAFRC 2012, p. 19; SRAFRC 2013, pp. 23-24; Normandeau Associates 2013, Table 2; Normandeau Associates 2014b, Table 2).

Even on this peak day, the fish do not move uniformly throughout the day. Service experience indicates that approximately 15 percent of the American shad pass on the peak day of passage during the peak hour of that day. For this reason, the designed capacity of a technical fish passage facility (e.g., fish lift) is considered to be a function of the biomass load needed to be passed during the peak hour of the peak day of the seasonal run. The biomass capacity for a fish lift is then defined as the mechanical ability for its hopper, and its holding pool (fish crowding area), to move fish in a single hour. The mechanical capacity for a lift to pass fish in a single hour is a function of the volume of water in the hopper, the volume of water in the holding pool, the volume of water required per fish, and the time the hopper/elevator takes to complete a full lifting cycle as designed (USFWS 2013f, entire; USFWS 2015d, entire).

The Service's standard for American shad weight used in fish passage capacity designs is 4 pounds per fish in order to meet the biological requirements (oxygen) per unit volume for safe passage. This standard has been used for over 30 years on Atlantic coast fish passage projects. Fish passage design is not developed for the "average" size fish, but rather must be more conservative in approach to accommodate larger individuals within the population. Regional data from American shad in both the Susquehanna River Flats and the Delaware River support the use of the 4-pound design criterion when accommodating larger fish that occur in the system (Table 8). Using the Delaware River shad data as a comparison to the Susquehanna River data is appropriate because the Delaware River is geographically close. The population demographics should be similar in the size of individuals and frequency of repeat spawners. The Delaware River is also an appropriate comparison because the shad population is not impacted by mainstem dams, as is the Susquehanna River population. Because the situation warrants designing fish passage for the larger than average fish, we used the 95th percentile of American shad weights in regional datasets to support our use of the 4-pound standard in considering design and capacity of Susquehanna River fish passage facilities (Table 8).

Table 8. American shad weight used for fish passage capacity design.

Location	**Average (lbs.)**	**95th Percentile (lbs.)**
Susquehanna Flats[1]	2.34	3.17
Upper Delaware River[2]	2.55	4.03
Lower Delaware River[3]	3.71	5.97

[1]Data from MDNR, Susquehanna Flats surveys from 2009 to 2013

[2]Data from the USFWS Delaware River Coordinator, unpublished data on the Upper Delaware River American shad collections from 2009 to 2013

[3]Data from the USFWS Delaware River Coordinator, Delaware River Lewis Haul Seine Fishery from 1997 to 2006

In addition to American shad, capacity must be provided for river herring passage. River herring are smaller than American shad and their weight is calculated at 0.5 pounds per individual when determining requirements for hopper capacity.

Riverine fish also use or should have access to the fish lift structures at Conowingo Dam. Gizzard shad are a riverine migratory species whose population has increased substantially in the lower Susquehanna River in recent years. Gizzard shad readily use the fish lifts on the mainstem dams in large numbers, with the EFL passage exceeding 1 million individuals annually since 2011 (Figure 8; SRAFRC 2013a, p. 7). Because gizzard shad migrate over a similar time period as American shad (Normandeau Associates 2014b, Table 1), the Service's capacity calculations assume that the peak of the run for both fish species will overlap. This overlapping of the peak of the run has an impact on the daily capacity required at the Project. Gizzard shad are generally larger than river herring but slightly smaller than American shad. Based on collections from the current WFL, gizzard shad weigh an average of 1.2 pounds (Ray Bleistine, Normandeau Associates, personal communication, February 20, 2015).

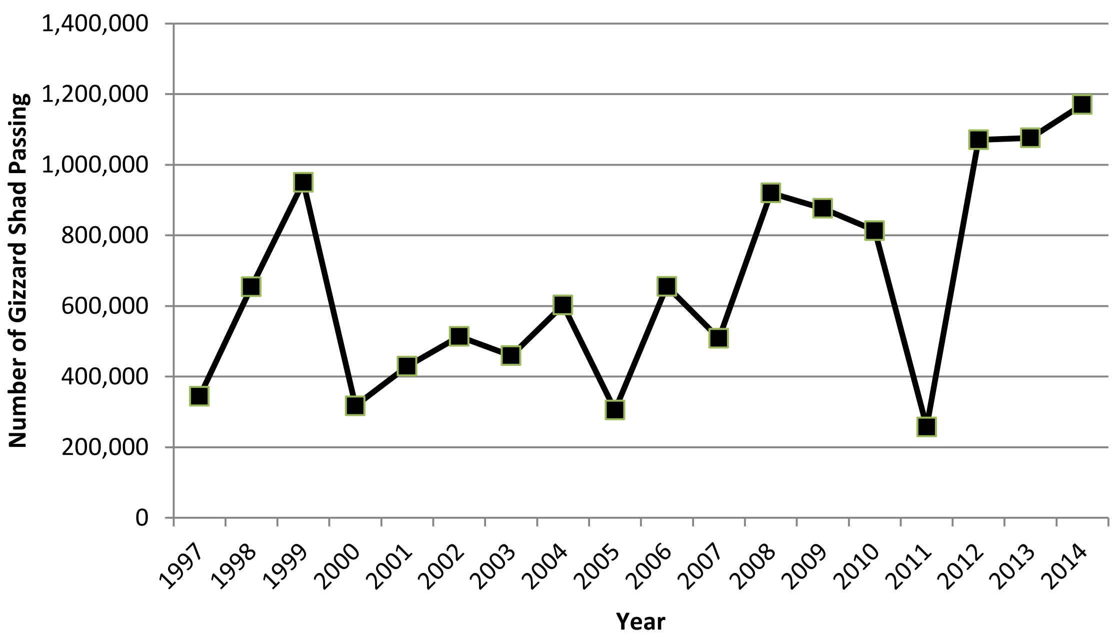

Figure 8: Number of gizzard shad passing Conowingo Dam by the East Fish Lift from 1997 to 2014 (SRAFRC 2013a, p. 11; Normandeau Associates 2013, p. 2; Normandeau Associates 2014b, p. 2). Note: EFL operations were terminated prior to the end of the migratory fish passage season in 2011.

Service's calculations demonstrate that the current 3,300-gallon hopper (Exelon 2011b, p. 11) operating at the EFL provides safe capacity to pass approximately 1.3 million pounds of fish in a single season (USFWS 2015d, entire). Using the Service standard weight of 4 pounds per American shad and assuming that only American shad used the EFL, the capacity would be

325,000 American shad during a single passage season. The actual Service calculated capacity of the current EFL is half of the License Applicant's stated design capacity (750,000 American shad; Exelon 2011b, p. i). Although the lift has never passed 325,000 American shad, it has still been operating at its lifting capacity in recent years due to the large numbers of upstream migrating gizzard shad using the lift.

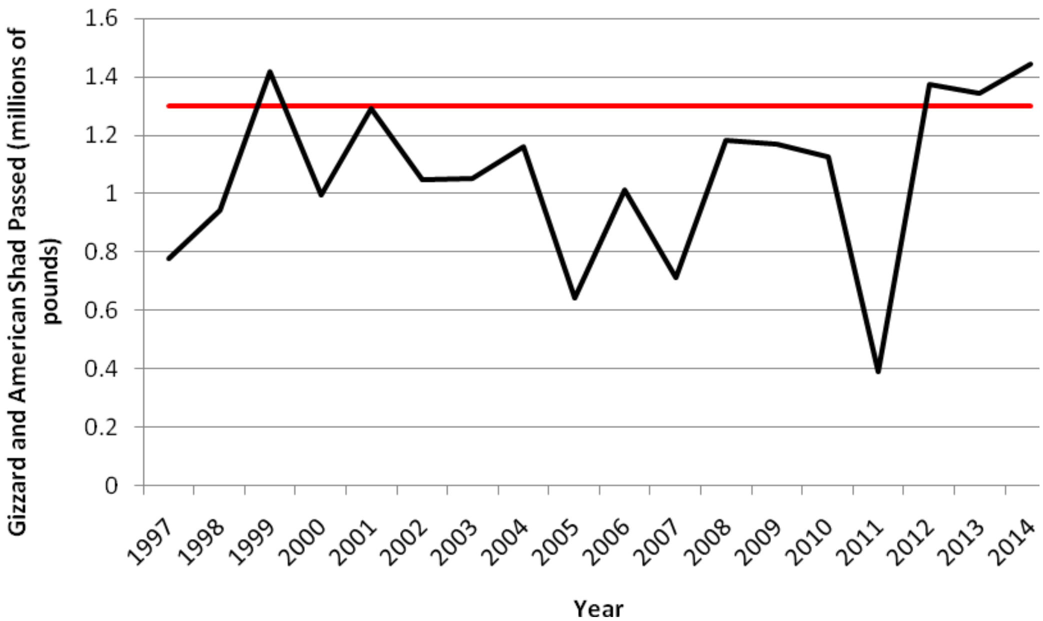

Figure 9: Pounds of gizzard shad and American shad passing Conowingo Dam by the East Fish Lift from 1997 to 2014 (SRAFRC 2013a, p. 11; Normandeau Associates 2013, p. 2; Normandeau Associates 2014b, p. 2). The red line indicates the Service calculated maximum capacity for the existing EFL. Note: EFL operations were terminated prior to the end of the migratory fish passage season in 2011 and this graphic does not include other fish species passing during the same time period which would add additional fish weight to these capacity calculations.

The current EFL hopper capacity is approximately 1.08 million gizzard shad, assuming the lift held exclusively gizzard shad (at 1.2 pounds per fish). Considering that all migratory species, including American shad, river herring, gizzard shad and other resident species that must utilize the currently available fish lift, the existing EFL structure has reached its lift capacity and has been operating at or exceeding safe capacity for at least 3 years (Figure 9). Since current capacity of the EFL has already been exceeded at the Project when considering passage of only two species, the Service concludes that additional lift capacity is necessary to have safe, timely, and effective fish passage at the Conowingo Dam to pass all migratory species at the Project.

The EFL hopper has been documented to be operating near or over its safe fish lifting capacity for several years and is a likely contributor to the low American shad passage efficiency at Conowingo Dam (Exelon 2011a, p. 15; Exelon 2012d, p. 16). Of the American shad which entered the EFL during the 2010 and 2012 telemetry studies, only 60.6 percent were eventually passed upstream [40 out of 65 in 2010 (Exelon 2011a, p. 15); 17 out of 19 in 2012 (Exelon 2012d, p. 4)]. Crowding by large numbers of gizzard shad attempting to utilize the lift may be one reason why American shad enter the lift but do not pass successfully. Although there is no assessment of efficiency of the current EFL for gizzard shad passage, the EFL is operated in a manner to reduce gizzard shad passage by operating the fishway entrance gates to create high flow velocities at the entrances (EFL operators, personal communication, May 7, 2015, during Service fish lift inspection). Since gizzard shad are smaller than American shad and are expected to be less capable swimmers by comparison (Williamson and Nelson 1985, p. 7; Bell 1991, p. 6.4), the higher velocities are expected to exclude gizzard shad from the fishway. Gizzard shad passage efficiency is likely less than American shad; therefore, the high passage numbers could indicate a possible downstream population size of several million gizzard shad. Although the Service is not establishing an upstream passage efficiency criterion for gizzard shad, we expect the Project to pass all migratory fish species upstream in a safe, timely, and effective manner.

In addition, the EFL has passed few river herring in recent years. Evidence suggests that although river herring have not been passed in large numbers in the EFL in recent years, they are present in the tailrace (MDNR, Genine Lipkey, personal communication, 2015) and crowding due to the abundance of gizzard shad, in addition to ZOP issues, could be contributing factors for why river herring are not effectively passed by the EFL. Additional fish passage capacity would address the over-crowding issue as well as provide American shad and river herring greater opportunity to access and pass through the fish lift.

The need for greater capacity was envisioned in 1989 as part of the previous settlement agreement that made provisions for increasing lift capacity when current capacity was exceeded

(Reid and Priest 1989, p. 5). The 1989 settlement agreement stated that once fish passage capacity was reached (as measured in the number of American shad that were passed) at the EFL, a new WFL facility, with the ability to pass fish directly into Conowingo Pond, would be constructed at Conowingo Dam. However, the terms of the settlement agreement were based on the number of American shad that were passed upstream and did not take into account the large numbers of other species using the fish lifts that would overwhelm the lifting capacity and reduce capacity for American shad. Based on the Service's calculations of capacity, the EFL has been operating at lifting capacity for several years based on total fish biomass being passed upstream, and will therefore not be able to support any increase in American shad passage and population growth. Implementation of additional fish passage capacity at Conowingo Dam is necessary to adequately address current and future passage of all fish in the Project tailrace attempting to migrate upstream.

8.2.6 Fish Stranding and Project Operations

Rapid down-ramping of turbines results in fish stranding at the Project (Exelon 2012f, entire). Fish stranding in the bypass channel is a concern as evidenced by the discovery of migratory fish in the spillway during pre-licensing studies (Exelon 2012f, entire) and as reported by fishery resources staff (Hendricks 2009, entire). Stranded fish may survive in some cases if they locate residual pools of water to reside in until the Project begins discharging generation flows again at levels high enough to wet the bypass channel. These strandings cause migratory delay and could result in migratory fish suffering mortality from the stranding event, which would reduce the overall Project passage efficiency. Pre-licensing studies indicate that 108 American shad were identified as stranded during 4 separate surveys, with 43 percent of those individuals suffering mortality (Exelon 2012f, p. 9). The pre-licensing studies likely underestimated stranding and mortality as many predatory and scavenging birds at the dam may have removed fish from the study area prior to the survey counts of stranded fish. A resource agency staff member witnessed mortality of fish, primarily gizzard shad, in the bypass channel as a result of rapid decreases in water elevation in the tailrace (Hendricks 2009, entire). The License Applicant also acknowledges that "current peaking operations of the Project would continue to have impacts relative to fish stranding in the Conowingo Dam spillway" (Exelon 2012a, p. E-156). Fish stranding could be reduced by limiting down-ramping operations and/or providing low flow channels linking isolated pools with a clear egress route provided to the main channel of the river downstream of the Project.

8.3 Existing Downstream Fish Passage Efficiency

8.3.1 Downstream Passage for American Shad

A study of downstream migrating juvenile American shad was conducted by Normandeau Associates Inc. for Exelon (RSP 3.2) to estimate the survival of fish passing through a Francis unit. Francis Unit 5 was selected for study because it was believed to represent a worst case scenario for juvenile shad passage (Exelon 2012g, p. 3). A total of 148 treatment fish and 78 control fish were released for the study. Treatment fish were released so that they would pass through Francis Unit 5 and control fish were released into the tailwaters of the dam. All fish were fitted with HI-Z Tags (balloon tags) which would inflate some time period after release, float tagged fish to the water surface, and allow boat crews to recover study fish for examination and assessment of turbine entrainment impacts (Exelon 2012g, pp 5). A statistical technique was used to estimate survival of treatment fish passing through a Francis unit by adjusting for mortality observed in control fish. The survival of juvenile American shad through Francis Unit 5 was 89.9 percent with 90 percent confidence intervals ranging from 84.1 to 95.7 percent (Exelon 2012g, p. 11). Based on the results of this study, there is insufficient evidence to conclude that downstream survival of juvenile American shad through the Conowingo Project was less than the 95 percent criterion specified by SRAFRC (2010, p. 36).

A similar turbine survival study for adult American shad was conducted through Francis Unit 2 and Kaplan Unit 8 at the Project. A total of 100 (Francis) and 101 (Kaplan) HI-Z tagged fish were passed through turbines and an additional 120 control fish were released downstream of the project (Exelon 2012h, p. 6). The 48-hour survival rate of recaptured fish was 88.3 percent (90 percent confidence interval from 77.8 to 98.8 percent) for Unit 2 and 84.1 percent (90 percent confidence interval from 74.2 to 94.0 percent) for Unit 8 (Exelon 2012h, p. 12). Based on the results of this study, there is insufficient evidence to conclude that downstream survival of adult American shad through the Conowingo Project was less than the 80 percent criterion specified by SRAFRC (2010, p. 36).

In addition to the turbine survival study for adult American shad, the radio-telemetry studies provide additional insight into downstream passage for post-spawned American shad at the project. At the end of the radio telemetry study aimed to evaluate upstream passage of adult shad in 2010, 23 American shad that successfully passed upstream of Conowingo Dam ultimately passed downstream through the turbine units at the Project. Fifteen of those passing downstream via the turbines were believed to be alive at their last detection while signals from the other eight shad were stationary and were considered dead (Exelon 2011a, pp 21). From these observations, an estimated 65 percent (15 out of 23) of the adult shad survived downstream passage at Conowingo Dam. Given the small sample size used in this estimate, 90 percent confidence intervals would range from 46.0 to 80.9 percent (see Fleiss 1981, p. 14 for method used to estimate confidence intervals). Based on the telemetry data, we cannot conclude that downstream passage survival of adult American shad at Conowingo Dam is meeting the criterion of 80 percent specified in the 2010 SRAFRC management plan (SRAFRC 2010, p. 36).

8.3.2 Downstream Passage for River Herring

No studies were conducted on downstream migrations of either adult or juvenile river herring at Conowingo Dam. There are no estimates of juvenile river herring survival at similarly sized projects, but a study on a smaller hydroelectric project found juvenile blueback herring survival to be 96 percent (Mathur et al. 1996, p. 159). Based on similar behavior of river herring and American shad, juvenile river herring survival could be similar to the reported juvenile American shad survival through the Conowingo Project. No information is available on adult river herring survival through other hydroelectric projects and assessment at this Project is needed to determine if adult survival is meeting the criterion of 80 percent specified in the 2010 SRAFRC management plan (SRAFRC 2010, p. 36).

8.3.3 Downstream Passage for American Eel

The Service conducted a study to evaluate potential impacts of the Project on downstream migrating American eel (USFWS 2012c, entire). Adult American eels were tagged as part of a study conducted by Exelon at MRPSP in 2011 (Exelon 2012i, entire) and the Service deployed telemetry monitoring equipment in Conowingo Pond and several miles downstream of Conowingo Dam at Havre De Grace, Maryland. Nearly 90 percent of the available American eels for the study passed the downstream monitoring location, although the physical condition of those fish was not evaluated after passing the dam. The average time from release at the MRPSP project to arrival at the monitoring station at Havre De Grace was 6.8 days, with a range from 1.2 to 32 days. Most American eels (80 percent) migrated downstream from the MRPSP within 13 days of being released (USFWS 2012c, p. 2).

8.4 Summary

Migratory fish populations on the Susquehanna River have been impacted by the multiple hydroelectric projects located on the lower river, most directly by limiting access to historical spawning and rearing habitat. The Conowingo Dam is the first dam on the river encountered by upstream migratory fish and it precludes access to historical spawning habitat in the Susquehanna River for American shad and river herring and nearly the entire Susquehanna basin for juvenile American eels. The lower 10 RM downstream of Conowingo Dam does not provide sufficient habitat area or quality for reproduction and growth of migratory fish required to increase population size and meet management goals in the SRAFRC plan.

Resource agencies have been working with the owners and operators at the remaining 4 hydroelectric projects in the lower river to improve fish passage. The Conowingo Project needs to be more efficient and effective with regards to fish passage in order for the benefits of improved fish passage efforts at the upstream hydroelectric projects to be fully realized. The number of American shad and river herring successfully passing the Conowingo Project is currently at the lowest level since fish passage was implemented in the 1990s, down from a high of nearly 200,000 American shad passing Conowingo Dam in 2001 to less than 10,000 passing Conowingo Dam in 2015 (Figure 3). The inadequate upstream passage efficiency and insufficient fish lift capacity must be addressed to realize restoration of migratory fish to the Susquehanna River Basin as established in the SRAFRC Plan.

9. Engineering Alternatives Considered

The Service examined several alternatives for improving fish passage at the Conowingo Project. The alternatives considered included 2 proposals from the License Applicant, the proposal from FERC’s EIS, 8 alternatives generated by the Service, and an alternative that was developed as part of a Settlement Agreement with the License Applicant. For the Service generated alternatives, a matrix for selection and comparison purposes was developed (USFWS 2013g, entire). They are based on existing fish passage facilities found acceptable for passing large numbers of American shad in big rivers (>1,000 square mile drainage area). The Service has determined that migratory delay resulting in poor passage efficiency and insufficient fish lift capacity are critical issues to overcome at the Conowingo Project. Alternatives were developed with the objective of improving fish passage efficiency and capacity. As discussed further below, the Service adopts herein the alternative reflecting the terms of the settlement agreement, and rejects each of the alternatives.

9.1 Service's Amended Preliminary Prescription: New West Fish Lift at License Issuance and East Lift Modifications

The Service filed an Amended Preliminary Prescription for Fishways in August 2015 (USFWS 2015g, attachment A, pp. 97-129). The Amended Preliminary Prescription focused on requiring new construction as well as modifications to the existing fish passage structures at the Project in order to achieve 85 percent passage efficiency for American shad. This alternative included a complete rebuild of the West Fish Lift immediately upon license issuance, which included two 6,500-gallon hoppers, 3 to 5 percent of Project hydraulic capacity to be used for attraction, and modifications to the ZOP so that fish could reach the fish lift in a safe, timely, and effective manner over the full range of fish passage design flows. The alternative also included a series of modifications to the project through time, based on results of efficiency testing, to improve fish passage efficiency at the project to meet the 85 percent passage criterion for American shad. Initially, the EFL structure was required to improve attraction flow from the current 300 cfs to 900 cfs. Future modifications that may have been implemented if fish passage efficiency was less than 85 percent included modifications to the EFL including modifying entrance gates A & B, constructing a new entrance D, replacing the single 3,300-gallon hopper with two 6,500-gallon hoppers, and constructing an auxiliary water supply. Other modifications at the Project to improve fish passage would include modifications to unit operations and modifications to the ZOP.

Although this proposal has the capacity and passage efficiency to achieve restoration of

American shad during the proposed license term, population growth would initially be slow as few fish would be reaching the primary spawning grounds upstream of York Haven Dam due to the inefficiencies in upstream passage at the three upstream projects (Holtwood, Safe Harbor, and York Haven dams). This alternative does not include a trap and transport program that would provide an initial increase in the number of American shad reaching the spawning grounds by bypassing the other facilities on the river. Other than the timing of Project modifications and the addition of the trap and transport program, the components of the Modified Prescription for Fishways are essentially the same as those in this alternative. The Service concludes that as long as the upstream passage efficiency at the project is achieved, the addition of trap and transport provides an additional benefit to population growth of American shad and river herring during the early years of the license term (USFWS 2016).

9.2 Proposal by License Applicant in License Application: Status Quo and Modifications to Turbine Operations (first on, first off)

The alternative proposed by the License Applicant (Exelon 2012a (E-149 to E-153) states that no significant changes to the existing fish passage facilities are warranted. The License Applicant proposes to study different combinations of generating units in order to enhance fish passage effectiveness, presumably to increase fish attraction to the fishway entrances. It proposes no increase in capacity at either of the fish lifts, no modifications or additional entrances to the fish lifts, and no stream channel modifications in the tailrace to provide an adequate zone of passage to the fish lift entrances.

The biomass of fish currently attempting to pass upstream via the existing 3,300-gallon hopper at the EFL exceeds its capacity for safe upstream passage. In order to allow the Susquehanna River American shad and river herring populations to grow, additional lift capacity is needed. The Service concludes that the License Applicant’s proposed alternative does not address the issues identified with poor attraction to the fishway entrances and it will fall short of achieving 85 percent passage efficiency. The results of the two radio-telemetry studies do not indicate any correlation existed between a particular configuration of turbine operation and passage efficiency. Therefore, studying alternative turbine operation scenarios alone will not address the fish passage problems documented at the Project. Existing data also indicates that tagged fish may be approaching the Project closer to the west bank of the tailwaters, away from the discharge of the Kaplan-type turbine units (i.e., Units 8, 9, 10, and 11), and away from the location of the existing EFL entrances (Exelon 2011c).

The Service concludes that, in addition to increases in lift capacity, additional fish passage facility entrances that provide fish attraction and passage access at various locations within the tailwaters offers the best opportunity to increase passage efficiency and reduce migratory delays. In terms of fish passage conditions at the tailrace, the results from hydraulic modeling identified potential problems with the ability of all target species to move through high flow velocity locations in the tailrace.

9.3 Proposal by FERC (EIS): West Fish Lift and East Fish Lift Upgrades, Additional Hopper at the East Fish Lift, Restart the Trap and Transport Program

The alternative presented by FERC staff in their FEIS (FERC 2015, pp. 63-64) proposes the replacement of the outdated hopper at the WFL with a new 1,500-gallon hopper. It also recommends an additional 3,300-gallon hopper to be added to the EFL that would be located immediately behind the existing hopper. It would require the Licensee to reestablish the trap and transport program that was suspended back in the year 2000. FERC's alternative also requires mechanical and electrical upgrades at both fish lifts, increasing the attraction flow at the EFL to the original design of 900 cfs, and changes to entrances A and B if deemed beneficial to fish passage.

Although FERC's alternative represents an improvement from current conditions, it does not explain how fishway capacity will track and serve a restored American shad population. The Service concludes that the proposed FERC modifications will not achieve full restoration of American shad in the Susquehanna River within the anticipated license term (i.e., next 50 years; see section 6.2.1). The FERC alternative is very similar to the License Applicant's alternative (section 9.3) and reasons for rejection of this alternative are the same as in the previous section.

9.4 Proposals by the Service

9.4.1 Engineering Alternative A: East Fish Lift, Half Collection Gallery and Kaplan Modifications

Engineering Alternative A is defined by the following upgrades to the EFL in order to increase the number of fish that can be passed (hereafter termed passage capacity). Upgrades in this alternative include reductions in the lift cycle time, construction of a second, larger hopper designed to operate simultaneously with the existing 3,300-gallon hopper, additional entrances provided by a half collection gallery that would span the horizontal length of the area in front of the Kaplan units (eastern half of the powerhouse), and modifications to the discharge of all Kaplan units (allowing for a more attractive entrance signal).

Service calculations demonstrate that a new 6,500-gallon hopper in addition to the current 3,300-gallon hopper, while providing sufficient capacity for the current gizzard shad and American shad needs at the Project (assuming 1.2 million gizzard shad and 40,000 American shad passing annually), would not support even moderate growth of migratory fish populations. The Service also foresees that this alternative will not achieve 85 percent passage efficiency (of the available American shad located in the tailwaters) mainly because this alternative does little to address current issues with attraction efficiency. Existing data indicate that fish might be approaching the Project closer to the west bank of the tailwaters, away from the discharge of the Kaplan units and the proposed half collection gallery (Exelon 2011c). Modifications to the Kaplans' discharge could only be considered as an experimental approach because these types of modifications have not been tested at other projects in the Northeast.

9.4.2 Engineering Alternative B: East Fish Lift, Full Collection Gallery and No Kaplan Modifications

Engineering Alternative B proposes upgrades to the EFL that would increase passage capacity. This would be accomplished via reductions in the lift cycle time as well as a second larger hopper designed to operate simultaneously with the existing one. This alternative recognizes discharge from the Kaplan turbines as a longitudinal barrier and resolves it by providing a full collection gallery that spans the horizontal length of the entire powerhouse to minimize delay. Additional entrance locations provided by the full collection gallery are considered in this alternative for the purpose of enhancing attractive entrance signals and improving passage efficiency. The additional entrance locations minimize the problem of turbine turbulence which will result in attraction and passage of more fish.

This alternative has similar deficiencies as Engineering Alternative A. In addition, the lengthened collection gallery is still limited by the insufficient lift capacity which is the main cause for rejection of this alternative.

9.4.3 Engineering Alternative C: East Fish Lock and Half Collection Gallery

Engineering Alternative C would address the issue of insufficient capacity under the current super structure by construction of a fish lock to provide additional capacity. Fish locks work similar to fish lifts in attracting fish through a collection gallery and crowding them at a holding pool before moving them over the dam. The main difference between these two technologies is the lock uses water to elevate the fish up into the exit channel at the top of the dam. Instead of using a hopper (or bucket), a lock produces a column of water that starts at the tailwater elevation and rises to the head pond elevation. This method of elevating the fish upstream of the dam puts less stress on the migrating fish by handling them in a more benign way. The half collection gallery would serve as a channel into the holding pool of the lock.

The capacity of a lock is driven by the capacity of the holding pool, which means that renovations to the existing entrance channel would still be needed. The Service also concludes that this alternative will not achieve 85 percent passage efficiency (of the available American shad located in the tailwaters) for the same reasons cited in Engineering Alternative A.

9.4.4 Engineering Alternative D: East Fish Lift, Half Collection Gallery, Kaplan Modification and Sorting

Engineering Alternative D upgrades the EFL to increase fish passage capacity via reductions in the lift cycle time as well as the addition of a second larger hopper designed to operate simultaneously with the existing one. Additional entrance locations would be provided through addition of the half collection gallery, accompanied by modifications to the discharge of the Kaplan units (producing a more attractive fish lift entrance signal) to enhance passage efficiency.

Before raising the lift, gizzard shad would be sorted out of the hopper and returned to the tailwaters. Gizzard shad entering the EFL hopper have been documented utilizing a large portion of the fish lifting capacity, making it unavailable for target species. Removing these non-target fish from the hopper would result in an increase in the overall net capacity for American shad and river herring and improve passage efficiency for target species.

A difference this alternative has relative to A, B, and C is the element of sorting out of non-target fish species. The Service concludes that the handling associated with fish sorting places additional stress on migratory fish which are in spawning condition and is best avoided. Modifications to the Kaplan unit discharge and fish sorting are considered experimental approaches. The difficulty with effectively discerning a gizzard shad from an American shad lies in the strong similarities between these two species. They share almost identical migration periods, the average size of migrants is not so different as to make sorting easy, and their swimming speed capabilities are relatively comparable. Sorting out gizzard shad could also result in removal of other target species, including river herring. In addition, recycling of gizzard shad back into the tailwaters will exacerbate crowding issues and could negatively impact fish passage efficiency for target species.

9.4.5 Engineering Alternative E: Complete West Fish Lift with Two 6,500-gallon Hoppers

Engineering Alternative E proposes a new and complete WFL to provide full upstream passage for all migratory fish. The newly renovated WFL would also include two 6,500-gallon hoppers to increase capacity and a trap and transport facility to monitor migratory fish and enhance upstream restoration efforts. The EFL would be decommissioned soon after the construction of the WFL.

The results of the radio telemetry studies for upstream passage of American shad at Conowingo (Exelon 2011a, p. 15; Exelon 2012d, p. 16) indicate that providing upstream passage on only one side of the 800-foot-wide tailrace likely will not achieve passage efficiency for American shad at the required criterion of 85 percent. Even if the WFL alone does achieve efficiency criteria and the American shad population increases, two hoppers with separate crowding pools should be expected to reach maximum capacity (i.e., 9 million pounds of fish) within the first half of the license term (see Section 12.1.3.3 for discussion on capacity calculations).

9.4.6 Engineering Alternative F: Kaplan Draft Tubes Extension, East Fish Lift, Half Collection Gallery and Complete West Fish Lift with Two 6,500-gallon Hoppers

Engineering Alternative F proposes upgrades to the EFL to increase fish passage capacity. This would be accomplished via reductions in the lift cycle time as well as addition of a second larger hopper designed to operate simultaneously with the existing one. Additional entrance locations would be provided by the half collection gallery to enhance fish passage efficiency. The Kaplan draft tubes extension would move the current turbulent boil (which confuses fish and prevents them from finding the EFL entrance) downstream and away from the EFL entrances in an attempt to make the fish passage attraction jet from the fish lift entrance more discernible, thus improving the ability of fish to find the entrance. The complete WFL would provide upstream passage to fish approaching the dam on the western side of the powerhouse. The newly renovated WFL would also include two 6,500-gallon hoppers and a trap and transport facility.

The main cause for rejection of this alternative is the expected high cost and experimental nature of the extension of the Kaplan draft tubes.

9.4.7 Engineering Alternative G: East Fish Lift Entrances Relocation, Half Collection Gallery and Complete West Fish Lift with Two 6,500-gallon Hoppers

Engineering Alternative G provides upgrades to the EFL and also would increase its fish passage capacity. This would be accomplished via reductions in the lift cycle time as well as a second hopper designed to operate simultaneously with the existing one. Existing entrances A and B would be relocated to avoid the boil in front of the Kaplan units which currently renders them ineffective and/or inoperable (Figure 10, USFWS 2013h). Entrance A’s attraction jet is effectively drowned out by the discharge of the Kaplans, and relocation of entrance A would be designed to address this problem. Access to entrance A would be available along the catwalk, through the area behind the piers (similar to the configuration at the Safe Harbor Project fishway). Additional entrance locations provided by the half collection gallery are proposed in this alternative for the purpose of enhancing passage efficiency. A new and complete WFL would provide upstream passage for migratory fish migrating to the western side of the powerhouse. The newly renovated WFL would also include a trap and transport facility.

The simultaneous implementation of all of these measures might result in some infrastructure investments that may be premature or excessive for meeting fish passage efficiency and population restoration goals, particularly during the early stages of restoration. A phased approach to the implementation of fish passage solutions, with periodic studies between phases, would contribute crucial information on the effectiveness of each solution; and it would allow the Licensee and resource agencies the ability to diagnose any salient and unresolved issues and address them accordingly.

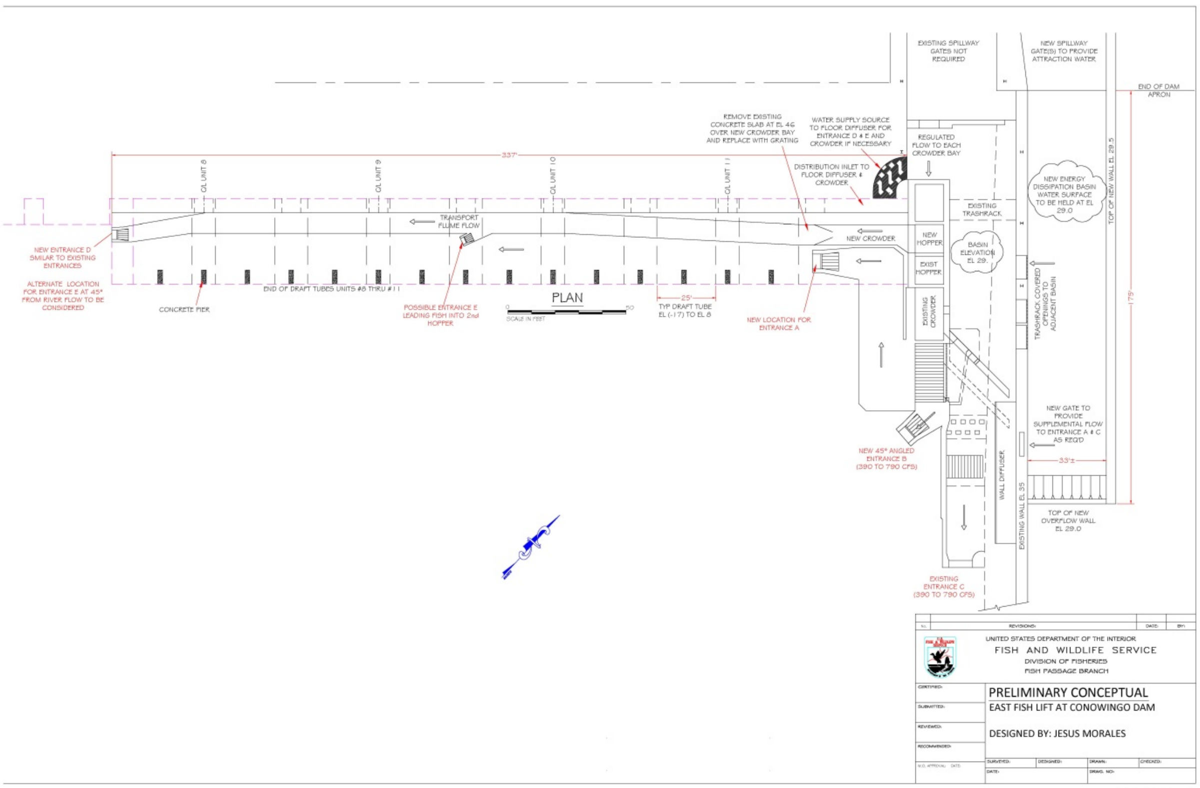

Figure 10. Service conceptual drawing of the proposed modifications at the East Fish Lift.

9.5 Settlement Agreement: Phased East Fish Lift and West Fish Lift Improvements with a Trap and Transport Program

The Settlement Agreement includes a phased approach to implementing fish passage measures on both the east and west sides of Conowingo Dam. The components of this alternative initially include modification to the EFL facility by increasing attraction flows to 900 cfs, replacing the current 3,300-gallon hopper with two 6,500-gallon hoppers, and constructing a ZOP to the EFL and WFL. Both the EFL and WFL structures would be modified to facilitate a trap and transport program that would take 80 percent of the American shad and river herring collected at the EFL and WFL and transport them upstream of York Haven Dam, with a maximum of 100,000 of each species to be transported each year. The project will be required to meet an 85 percent upstream passage efficiency criterion for American shad and periodic testing will ensure that the criterion is being met. In the event that passage efficiency is less than 85 percent, there are a suite of structural and operational modifications that can be made to improve fish passage efficiency. Modifications include improvements to the ZOP, turbine operational modifications, modifying or constructing new entrances at the EFL, adding an auxiliary water supply to the EFL, and construction of a new West Fish Lift with trap and transport capability and associated zone of passage. The Service developed a plan that describes the components, as well as the phasing and triggers for the construction of each component of this alternative in more detail in Section 12.

The Service concludes that this alternative will achieve safe, timely, and effective upstream anadromous fish passage at Conowingo Dam. The Modified Prescription combines the high passage efficiencies required by the Preliminary Prescription, and offers a credit program toward the required upstream passage efficiency for implementing a trap and transport program, which will also benefit early restoration efforts by getting more adult American shad into suitable spawning habitat earlier in the license term. Similar to the Preliminary Prescription, the Modified Prescription follows an adaptive approach to construct or implement fish passage improvements as they are needed through the license term to track changes in fish populations. This adaptive approach assures that high passage efficiencies will be maintained through the license term. The Service also concludes that this alternative will achieve restoration or 2 million American shad upstream of York Haven Dam earlier in the license term compared to the Preliminary Prescription or other alternatives considered because of the addition of the trap and transport program that will get target species to the spawning grounds in higher numbers earlier in the license term (Figure 11).

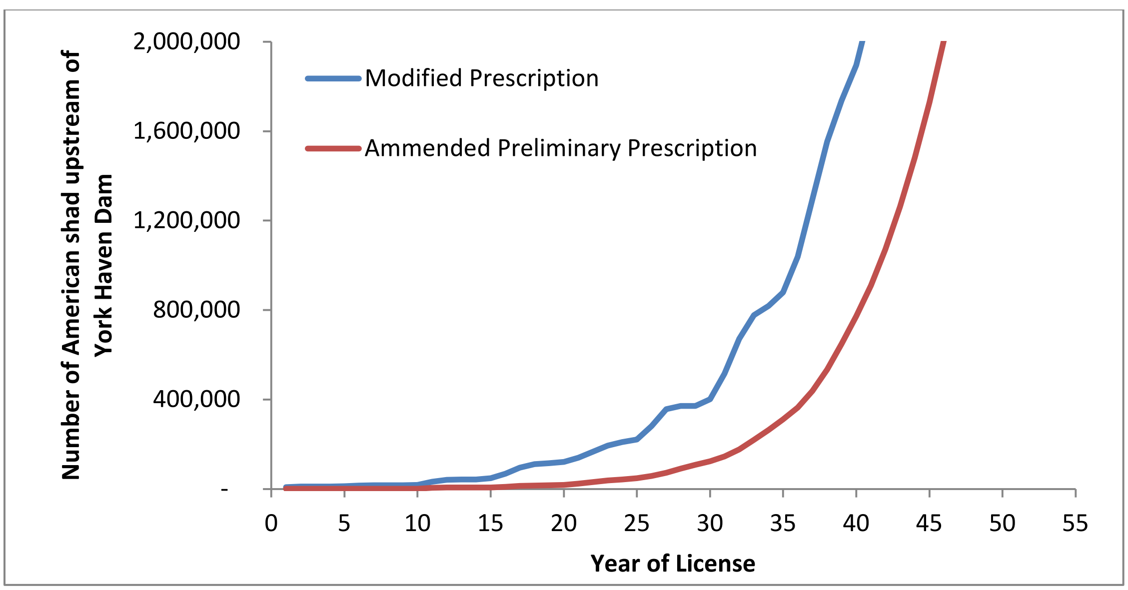

Figure 11. Comparison of the rates of restoration American shad between the Amended Preliminary Prescription and the Modified Prescription (see USFWS 2016).

10. Statutory Authority

Section 18 of the Federal Power Act, 16 USCS §811, states in pertinent part:

The Commission shall require the construction, maintenance, and operation by a Licensee at its own expense of …such fishways as may be prescribed by the Secretary of the Interior or the Secretary of Commerce, as appropriate.

Section 1701(b) of the National Energy Policy Act of 1992, P.L. 102-486, Title XVII, §1701(b), 106 Stat. 3008, states:

The items which may constitute a 'fishway' under Section 18 [16 USCS §811] for the safe and timely upstream and downstream passage of fish will be limited to physical structures, facilities, or devices necessary to maintain all life stages of such fish, and project operations and measures related to such structures, facilities or devices necessary to ensure the effectiveness of such structures, facilities, or devices for such fish.

11. Reservation of Authority to Prescribe Fishways

In order to allow for the timely implementation of fishways, including effectiveness measures, the Secretary of the Department reserves her authority to prescribe fishways during the term of the license and requires that the following condition be included in any license(s) the Commission may issue for the Project:

Pursuant to Section 18 of the Federal Power Act, the Secretary of the Interior herein exercises her authority under said Act by reserving that authority to prescribe fishways during the term of this license and by prescribing the fishways described in the Department of Interior's Modified Prescription for Fishways at the Conowingo Hydroelectric Project.

12. Modified Prescription for Fishways

12.1 Design Criteria

12.1.1 Design Populations

12.1.1.1 American Shad

The goal for this fishway prescription is to ultimately be able to pass up to 5 million American shad annually in order to maintain self-sustaining populations of 2 million American shad annually migrating to and reproducing in the Susquehanna River upstream of York Haven Dam and in suitable tributaries.

12.1.1.2 River Herring

The goal for this fishway prescription is to ultimately be able to pass up to 12 million river herring annually in order to maintain self-sustaining populations of 5 million river herring annually migrating to and reproducing in the Susquehanna River upstream of York Haven Dam and in suitable tributaries.

12.1.1.3 American Eel

The Licensee shall construct, operate, and maintain fishway(s) at Conowingo Dam sufficient to pass upstream migrating eels that arrive to the Project into the mainstem of the Susquehanna River upstream of York Haven Dam.

12.1.2 Design Capacity

Capacity is determined by a given weight of fish transferred over a given period of time. Capacity calculations take into consideration all species of fish using a fish passage facility; e.g., fish lift(s), and their corresponding weights, and proportional availability.

12.1.2.1 Initial Capacity

Considering that American shad passage efficiency has been measured to be as low as 25 percent (Exelon 2012d, p. 26), and the Project has passed an average of 1.1 million gizzard shad per season from 2012 - 2014 (SRAFRC 2013a, p. 7; Normandeau Associates 2013, p. 3; Normandeau Associates 2014b, p. 3), the Service estimates that as many as 4.4 million gizzard shad could potentially be in the tailrace annually attempting to move upstream. Based on the estimated biomass of gizzard shad attempting to pass upstream at the current time (4.4 million gizzard shad = 5.3 million pounds of fish) as well as allowing additional capacity for growth of American shad and river herring populations, the Service estimates a fish lift biomass capacity of at least 7 million pounds of fish per season needs to be provided immediately after license issuance. Two 6,500-gallon hoppers sharing the same holding pool, with a cycle time of 15 minutes, provides capacity to move 7 million pounds of fish in a single season (assuming a peak day run of 5 percent of the seasonal run, a peak hour run of 15 percent of the peak day and hopper minimum water volume of 0.1 cubic feet per pound of fish). Based on projected numbers of a successful American shad restoration using the population model, a fish lift capacity of 7 million pounds of fish should provide safe passage at the Conowingo Project for approximately half of a fifty (50) year license term (assuming that the gizzard shad population does not grow larger than 4.4 million fish). For details on calculating fish lift capacity, refer to Appendix A.

12.1.2.2 Final Potential Capacity

The Service anticipates that restored populations of American shad and river herring may require passage capacity for up to 5 million American shad and 12 million river herring as well as other species at the Project. American shad and river herring would require 26 million pounds of hopper capacity in addition to the potential 5 million pounds that may be required by riverine species. However, the fishway prescription does not require construction of sufficient capacity to pass this number immediately; rather, capacity is added only as populations grow enough to impede efficiency in the event that fishway capacity becomes a bottleneck to future population growth. This fishway prescription incorporates a fish passage efficiency target and measures to assess fish passage efficiency throughout the term of the license in order to test for future conditions that would require corrective actions contained in this prescription. This fishway prescription includes measures providing for an ultimate fishway capacity of up to 18 million pounds per season (four 6,500-gallon hoppers with separate holding pools). The Department recognizes the potential lack of capacity for this current fishway prescription during the later years of American shad and river herring restoration, and may exercise its reservation of authority to address this issue at a later date if fishway capacity appears to be a limiting factor to population restoration, as reflected in declining upstream fish passage efficiency due to lack of fishway capacity.

12.1.3 Design Flows

The Licensee shall design new fishway(s) to ensure operation under river flows in the range of 6,330 cfs to 143,000 cfs. However, the Licensee shall not be required to operate the fishway(s) at flows greater than 113,000 cfs unless data available at the time demonstrates that operation of fishways at flows greater than 113,000 cfs is necessary to achieve the target efficiency. Furthermore, the fishways shall be designed with sufficient freeboard (or other protection) to minimize damage from river flows of up to the 50-year return interval.

12.2 Efficiency Criteria

The Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC 2010, 2013) and the Service (USFWS 2015b) have established upstream and downstream passage efficiency criteria for the Susquehanna River basin that are the basis for this Prescription for Fishways. The Service defines upstream fish passage efficiency as the proportion of the fish in the Project tailwaters that successfully move through the fishway and continue upstream migrations, calculated as a percentage. Downstream fish passage efficiency is the proportion of the fish that approach the upstream side of the Project and survive unharmed as they pass the Project and continue downstream migrations. Definitions for fish passage terms used in this document are provided in Section 14. Where no numeric efficiency criteria were set, the Service's goal is to minimize Project impacts to migratory fish populations, with a goal of 100 percent passage and the understanding that no project is likely to fully achieve that goal despite application of the best available technology. Where the Service has information or modeling indicating that restoration may be achieved with less than 100 percent passage, the Service has been able to adopt numeric targets that will achieve restoration, and measures to reach those targets.

12.2.1 Criteria for Upstream American Shad Passage Efficiency[6]

The Licensee shall operate the Project to achieve the upstream passage efficiency criterion of

[6] FWS has agreed to meet with the Licensee in 2043 if the upstream hydroelectric projects are not meeting their target passage efficiencies consistently by then, to discuss the passage efficiency criterion for American shad at the Conowingo project based on then available data. The Service may consider adjusting the passage efficiency criterion at that time.

passing 85 percent of all adult American shad that enter the Project tailwaters ("Target Efficiency"). The tailwaters of the project are defined as extending to the downstream tip of Rowland Island.

The Licensee can receive additional credit toward achieving the upstream passage efficiency criterion for adult American shad by trapping at Conowingo and transporting American shad to upstream of York Haven Dam and thus avoiding upstream passage impediments at the intervening hydroelectric projects on the Susquehanna River (see Section 12.7.2.1).

12.2.2 Criteria for Downstream American Shad Passage Efficiency

The Licensee shall operate the Project to achieve the downstream survival efficiency criterion of at least 80 percent of the adult American shad moving downstream past the Project.

The Licensee shall operate the Project to achieve the downstream survival efficiency criterion of at least 95 percent of the juvenile American shad moving downstream past the Project.

12.2.3 Criteria for Upstream River Herring Passage Efficiency

In accordance with sections 12.5 and 12.6, the Licensee shall operate the Project to minimize the impact of the Project on upstream migration for adult river herring that approach the Project tailwaters.

Numerical criteria for upstream river herring passage efficiency may be developed in the future when additional information about Susquehanna River herring populations becomes available. Any needed change in fishway requirements resulting from such new targets is not provided for in this Prescription, and would be the subject of independent administrative processes.

12.2.4 Criteria for Downstream River Herring Passage Efficiency

The Licensee shall operate the Project to achieve the downstream survival efficiency criterion of at least 80 percent of the adult river herring moving downstream past the Project.

The Licensee shall operate the Project to achieve the downstream survival efficiency criterion of at least 95 percent of the juvenile river herring moving downstream past the Project.

12.2.5 Criteria for Upstream American Eel Passage Efficiency

The Licensee shall operate the Project to minimize the impact of the Project on upstream migration for juvenile American eel that approach the Project tailwaters.

Numerical criteria for upstream American eel passage efficiency may be developed in the future when additional information about the Susquehanna River American eel population becomes available. Any needed change in fishway requirements resulting from such new targets is not provided for in this Prescription, and would be the subject of independent administrative processes.

12.2.6 Criteria for Downstream American Eel Passage Efficiency

The Licensee shall operate the Project to achieve the downstream survival efficiency criterion of at least 85 percent of the adult (i.e., silver) American eel moving downstream past the Project.

12.3 Seasonal Implementation of Fish Passage

The Licensee shall operate a fishway for upstream passage of anadromous fish daily during the American shad and river herring upstream *Migration Period* (Table 9). The Licensee shall operate the fish lift(s) daily during the upstream *Migration Period*, and begin releasing attraction flows at least one hour prior to the start of daily lift operations. The fish lift(s) will operate at the following times during the *Migration Period*: (1) in March, from 7 a.m. to 7 p.m.; (2) in April, from 6:30 a.m. to 7.30 p.m.; and (3) in May and June from 6:00 a.m. to 8:00 p.m.

The Licensee shall provide attraction flow and operate fish passage facilities for continuous upstream American eel passage (i.e. 24 hours per day) during the entire upstream *Migration Period* (Table 9).

The Licensee shall ensure prior to the start of the *Migration Periods* that all mechanical elements of the fishway(s) are working properly. The Licensee shall repair, maintain, and test fishway(s) as necessary in advance of the migration period, in accordance with the *Fishway Operation and*

Maintenance Plan (FOMP) so as to begin operations when required. The Licensee shall maintain and operate fishways to maximize fish passage effectiveness throughout the upstream and downstream *Migration Periods* (Table 9).

Table 9. Upstream and downstream *Migration Periods* for species covered in this Modified Prescription for Fishways.

Species	**Upstream Migration Period**[1]	**Downstream Migration Period**[1]
American shad	Starting when river temperature reaches 50 ^{o} F, until river temperatures rise above 72 ^{o} F for four consecutive days, but ending no earlier than June 1, and no later than June 15[2]	July 1 through November 15 (juv.) May 1 through July 1, as long as river temperature is above 65 ^{o} F[2] (adult)

Species	**Upstream Migration Period**[1]	**Downstream Migration Period**[1]
Alewife and blueback herring	Starting when river temperature reaches 48 ^{o} F for three consecutive days and no earlier than March 1, until river temperatures rise above 72 ^{o} F for four consecutive days, but ending no earlier than June 1, and no later than June 15[2,3,4]	June 15 through October 14 (juv.) April 15 through July 1 (adult)
American eel	May 1 through September 15[5]	September 15–February 15, whenever river temperature is above 37 ^{o} F for 4 consecutive days[2,6]

[1] Subject to notice and comment, any of these migration periods may be changed during the term of the license by the Department, based on new information, and in consultation with the other fishery agencies and the Licensee. At any time during the new license term, Licensee may submit new information to the Department in support of a request to change the migration periods. In the event the Department seeks to require downstream passage by means other than through the units, the downstream migration periods automatically will be reviewed jointly by the

Department, other fishery agencies, and the Licensee.

[2] Water temperatures shall be monitored once daily at 11 a.m. at Monitoring Station 643 (Shure's Landing) or some other location agreed upon by the Licensee and the Service.

[3] This migration period is based on alewife migration timing from other tributaries to the Chesapeake Bay (Sutherland 2000, p. 9; Eyler et al. 2002, p. 59; Slacum et al. 2003, p. 13).

[4] The Service recognizes that, because of factors outside of the Licensee's control, safety considerations may preclude the Licensee's personnel from performing duties necessary to commence fish passage measures at Conowingo by the commencement date. When such conditions arise, the Licensee shall notify the Service and the Service and the Licensee shall consult regarding the anticipated schedule for commencing such measures.

[5] This initial operational period is based on preliminary data on American eel migration at Conowingo Dam (Minkkinen and Park 2014, Figure 4).

[6] This initial operational period is based on preliminary data on American eel migration timing from other tributaries to the Chesapeake Bay (Eyler 2014, pp. 44-46). Results from the "Downstream American Eel Effectiveness Monitoring" (Section 12.7.5) shall be used to further refine this migration period.

12.4 Fishway Operation and Maintenance Plan

The Licensee shall develop and submit a Fishway Operation and Maintenance Plan (FOMP) to the Service, FERC, and resource agencies (states of Maryland and Pennsylvania, Susquehanna River Basin Commission, and National Marine Fisheries Service) for review and approval by the Service. The Licensee shall keep the FOMP updated on an annual basis, to reflect any changes in fishway operation and maintenance planned for the year. If the Service requests a modification of the FOMP, the Licensee shall respond to the requested modification within 30 days of the request by filing a written response with the Service and serving a copy of the response on FERC and the resource agencies.[7] Any modifications to the FOMP by the Licensee shall require approval by the Service and, if necessary, FERC prior to implementation.

The FOMP shall include:

- Schedules for routine maintenance, pre-season testing, and the procedures for routine fishway operations, including seasonal and daily periods of operation, and associated dam and powerhouse operational measures needed for proper fishway operation;

[7] Requested modifications to the FOMP will not include changes to turbine operations. Any modifications to turbine operations shall be implemented only pursuant to Section 12.5.4.

- Details of how the Project shall be operated during the migration season to provide for adequate fish passage conditions, including:
    - pre-season preparation and testing;
    - sequence of turbine start-up and operation under various flow regimes to enhance fishway operation and effectiveness;
    - debris management at the fishway entrance, guidance channels, and the exit;
    - plant operations to provide near- and far-field attraction flows required for the fishway zone of passage in the tailrace;
- Trap and transport logistics plan and design plans for west and east fish lift modifications needed for trap and transport, including provisions for planning trap and transport logistics so as to avoid, to the extent possible, trapping a population unrepresentative of the migrating population as a whole.
- Trap and transport logistics plan for American eel;[8]
- Standard operating procedures for monitoring and enumerating fish passage by species, including the American eel passage facilities;
- Standard operating procedures for collecting biological samples from target species to assess restoration efforts;
- Standard operating procedures for monitoring and reporting operations that affect fish passage;
- Standard operating procedures in case of emergencies and Project outages to first, avoid, and second, minimize, potential negative impacts on fishway operations and the effectiveness of upstream and downstream passage for target species; and
- Plans for post-season maintenance, protection, and winterizing the fish lifts and eel passage facilities.

The Licensee shall provide written documentation to the Service, FERC, and resource agencies that all fishway operational personnel have reviewed and understand the FOMP and it shall be signed by the operations manager of the Project. Copies of the approved FOMP and any modifications shall be provided to the Service, FERC, and resource agencies on an annual basis.

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[8] The Licensee can incorporate by reference American eel plans and logistics developed pursuant to the Eel Passage Advisory Group.

By December 31 of each year, the Licensee shall provide an annual report to the Service, FERC, and resource agencies detailing: the implementation of the FOMP, including any deviations from the FOMP and a process to prevent those deviations in the future; any proposed modifications to the FOMP, or in the case of emergencies or project outages, the steps taken by the Licensee to minimize adverse effects on fisheries including any proposed modifications to those steps to further enhance their effectiveness in the future; and operational data for both fishways and the Project to allow the Parties to examine correlations between particular operational patterns and successful or unsuccessful fishway operation, and to confirm, once an operational regime with known effectiveness is settled upon, that the Project continues to operate under that regime. The Service understands that details of operation constitute confidential business information, and agrees to protect them from disclosure as such to the extent it is able to do so by law.

The annual report shall also include:

- Description of routine maintenance as well as repairs made to the fishways or eel passage facilities during the previous fish passage season;
- Average daily flows at the Marietta gauging station;
- Daily water temperature and dissolved oxygen readings[9] in the fish lift and tailwater areas;
- Hourly individual turbine unit operations and discharge, hourly total discharge from the powerhouse, hourly discharge over the spillway, and hourly passage counts of all fish species at each hopper;
- Daily counts of American eel collected at each facility;
- Thirty-minute recordings of total flow discharging from behind the hopper, total flow discharging from the attraction water supply diffuser, water surface elevation immediately upstream from the entrance gates, water surface elevation at the tailwaters, elevation to the crest of the entrance weir gates, and any irregularities such as the identification of a visible boil in the zone over the floor diffusers;

[9] The Licensee shall provide dissolved oxygen readings, commencing each year when the Project's NPDES permit requires annual data collection to begin, through the end of the upstream migration period.

- Number of fish by species trapped and transported, including date, time, and location of release;
- Weekly collection of a subsample of biological information from passing adult American shad and river herring consisting of sex ratio, spawning condition, length, weight, and age.

In addition to the annual report, the data for daily flows, water quality, project operations, fishway operations and fish passage as described above shall be recorded in a database during the fish passage season and the Service shall be provided open access to that database. Data shall be entered into the database no later than one week after collection.

These data shall be used to assess impacts of river conditions and hydropower operations on successful fish passage through the lifts, with the goal of achieving a better diagnosis of potential fish passage issues at the Project. The operational data will not provide the Service with an independent basis to require modifications and improvements beyond those that may be implemented through the process described below.

By January 31 of each year, the Licensee shall meet with the Service and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) to discuss the FOMP (and FEMP – See Section 12.7.1). This meeting shall occur no later than January 31 of each year unless the Licensee and the resource agencies agree on a different date. At this annual meeting the Licensee shall discuss with the Service and SRAFRC the fish passage results from the previous year, review regulatory requirements for fish lift and eel passage operations, and discuss any upcoming modification or testing the Licensee shall conduct during the upcoming season.

12.5 Sequencing of Upstream Fish Passage Construction and Implementation

Timely construction, operation, and maintenance of fishways are necessary to ensure their effectiveness and to achieve restoration goals. Therefore, the Licensee shall (1) notify, and (2) obtain approval from the Service and FERC for any extension of time to comply with conditions the Department prescribes.

12.5.1 Trap and Transport of American Shad and River Herring

The Licensee has agreed to and will trap and transport American shad and river herring to areas upstream of York Haven Dam annually. The number of American shad and river herring trapped and transported annually will be up to 80 percent of the number of each species captured in the fish lifts up to a maximum of 100,000 of each species annually. Trap and transport operations shall continue until the Licensee can achieve a measured 85 percent upstream passage efficiency for American shad at the Project without reliance on the trap and truck credit provided for in Section 12.7.2.1.

12.5.2 Initial Construction

Unless otherwise stated, the Licensee shall implement the items defined in Section 12.6.1 "*Initial Construction Items*" within 3 years following license issuance. Construction shall be conducted in a way as to allow for trap and transport operations as well as volitional passage at the EFL to continue uninterrupted during this time period.

12.5.3 Operation in the First Passage Season after License Issuance

Within 1 year of license issuance, trap and transport operations from the EFL and WFL shall begin. A total of 80 percent of the run, up to 100,000 American shad and 100,000 river herring per year shall be trapped and transported to the mainstem Susquehanna River upstream of York Haven.

12.5.4 Efficiency Testing and Triggering of Subsequent Modifications

In the 5th year after license issuance, the Licensee shall begin the "*Initial Efficiency Test*" of fish passage at the Project. The Licensee shall conduct the *Initial Efficiency Test* as defined in Section 12.7.2 in order to evaluate passage performance relative to upstream efficiency criteria for American shad and river herring as described in Section 12.2. In the 5th year after license issuance, the Licensee shall also assess mortality of American shad during the trap and transport process.

If at the end of the *Initial Efficiency Test*, the combined results of the three-year study (the combination of measured efficiency of the *Initial Efficiency Test* and the *Trap and Transport*

Credit resulting in an *Adjusted Efficiency*) meet the *Target Efficiency* of 85 percent for upstream passage of American shad, the Licensee shall operate the Project using the FOMP implemented during the *Initial Efficiency Test*. The Licensee shall then conduct a two-year *"Periodic Efficiency Test"* as defined in Section 12.7.2 in every 5th year thereafter to ensure that the upstream-prescribed efficiency criterion continues to be met through the term of the license.[10]

If at the end of the *Initial Efficiency Test* or after any *Periodic Efficiency Test* thereafter during the license term, or after any subsequent "*Post-Modification Efficiency Test*" as defined in Section 12.7.2, the study results indicate that the Licensee is not meeting the required *Adjusted Efficiency,* the Licensee shall conduct an evaluation of the radio telemetry data and any other data available to the Service and/or the Licensee to determine if the passage inadequacy is related to fishway attraction or fish lift capacity. Concurrent with the submission of the final report from an efficiency study, the Licensee shall propose a course of action most likely to achieve the *Target Efficiency*. Both the Service and the Licensee have agreed on a tiered list of options and the types of either attraction or capacity problems which the tiers may address. If the reason for not achieving the *Target Efficiency* is insufficient fishway attraction, then the Licensee shall follow the actions in Section 12.6.2. If the reason for not achieving the *Target Efficiency* is lack of fish lift capacity, then the Licensee shall follow the actions in Section 12.6.3. In the event that both fishway attraction and fish lift capacity are limiting factors to achieving the *Target Efficiency*, the Licensee shall address items listed under both sections 12.6.2 and 12.6.3, but only to the extent both attraction and capacity measures are necessary to achieve the required *Target Efficiency*. The list of measures in sections 12.6.2 and 12.6.3 is not exclusive and does not preclude either party from identifying and proposing other measures commensurate with the required level of improvement and corresponding tier. The Service shall react to the Licensee's proposal for improving fish passage efficiency within 90 days of receipt. It may:

A. Say nothing, in which case the Licensee shall proceed with its proposed course of action;
B. Agree affirmatively with the Licensee's proposed course of action, in which case the Licensee shall proceed;
C. Propose a different option, not on the tiered list of options, which the Licensee shall

[10] At the Licensee's election, and with Service concurrence, the Periodic Efficiency Test may be extended an additional 1 year. Only after the efficiency tests are completed will the Licensee be required to propose, as may be necessary, a course of action to achieve the Target Efficiency.

proceed with if it agrees;

D. Require, instead, that the Licensee implement an option or options from the appropriate (or lower numbered) tier to address each problem. The Service will choose that option(s) it deems most likely to achieve the *Target Efficiency*. The Service may select an option from a higher-numbered tier only if all options from an appropriate or lower-numbered tier have been implemented. If two or more options appear equally likely to achieve the efficiency criterion, the Service will present the Licensee with the choice, and the Licensee may proceed with whichever it prefers. The Service shall explain, in writing, its reasons for finding that its choice(s) is more likely than the Licensee's to lead to the desired passage efficiency. The Licensee shall then proceed with the selected course of action.

12.5.5 General construction requirements.

All functional (i.e., 30 percent, 60 percent, and 90 percent) and final design plans, operation and maintenance plans, construction schedules, and hydraulic model studies for the new fishways or modifications to existing fishways described herein shall be developed in consultation with the Service and submitted to the Service and FERC for approval. The planning and design process for structures shall generally include CFD modeling prior to construction and post-construction shakedown and testing to confirm modeling.

12.6 Fish **Passage Facilities**

12.6.1 Initial Construction Items

East Fish Lift Modifications – The Licensee shall modify the EFL facility to provide 900 cfs attraction flow to the EFL. Modifications to the EFL facility will include replacing spillway gates A & B, replacing the crowder system, addressing structural vibration issues, replacing diffuser gates A and B, replacing the control system, and upgrading the electrical system to allow for a 15 minute lift cycle.

Replace the current 3,300-gallon hopper with two 6,500-gallon hoppers at the EFL

The Licensee shall remove the current hopper and install two 6,500-gallon hoppers within the existing superstructure of the EFL. One hopper will replace the current 3,300-gallon hopper and the second hopper will be located immediately upstream from the current location of the existing EFL hopper (see Figure 10). Access to both hoppers will be provided by the current entrance gates (A, B, and C) and the hoppers will share the same holding pool.

Trap and Transport Facilities at the EFL

The Licensee shall reduce cycle time at each hopper at the EFL to be able to lift fish four times per hour and complete modifications to the EFL structure to allow for trapping and sorting fish at the EFL facility and transporting them to the western side of the dam to a truck for transport upstream. Modifications to the EFL shall include two new sorting tanks; a loading tank; and a hy-rail truck and forklift, or functionally similar equipment, to facilitate movement of American shad from sorting tanks at the EFL to the west shore. These improvements shall be accomplished without losing a season of the passage provided by the EFL.

Trap and Transport Facilities at the WFL

WFL modifications shall be made to facilitate trap and transport including: decreasing lift cycle time by replacing the crowder linkage system and raising the elevation of the sorting tank(s), and providing a mechanism to allow for direct sluicing of fish into tanks mounted on the transport vehicle. These initial improvements shall be accomplished without losing a season of the passage provided by the EFL or trap and transport from the WFL.

Provide a Zone of Passage (ZOP) to the Fish Passage Facilities

The Licensee shall construct and maintain structures, to provide American shad and river herring a ZOP (i.e., route of passage) as described in this section.

In advance of any ZOP development and/or construction, the Service and Licensee will review CFD modeling results from the tailrace. The Licensee shall run the model under a predetermined number of structures arrangements (e.g., different angles, different spacing between the weirs, different weir slopes). In consultation with the Service, the Licensee shall choose to construct the configuration of structures that provides the most conducive hydraulic conditions for fish passage of river herring. The area to be considered for potential ZOP improvements includes approximately 2,500 feet on the west bank and 3,500 feet on the east side of Rowland Island. Based on CFD modeling results that analyze discharge velocities and turbulence, the Licensee shall provide stone weirs, and/or other suitable alternatives or measures that provide a contiguous zone of passage (ZOP) from the southern tip of Rowland Island to one or both of the lifts. The Licensee shall install up to ten stone weirs, with the option of considering other configurations for structures, so long as the total cost does not exceed the cost estimated for up to ten weirs.[11] Model results will guide the placement and formation of these structures to provide for the hydraulic conditions necessary for the weakest swimmers (river herring) to reach the lifts. Specifically, the ZOP must be designed to maintain instantaneous velocities below 3 feet per second, separated only by brief regions of higher velocity that river herring may traverse in seconds at burst speeds up to 6 feet per second, over the full range of operational flows for the EFL, and in all generation scenarios.

After ZOP construction is completed, the Licensee shall assess the ZOP for upstream migrating river herring under the full range of the current fish passage design flows (i.e., up to 113,000 cfs of river flow).

Eel Passage – Eastern Location – The Licensee shall, consistent with the Eel Passage Plan established by Muddy Run license, evaluate potential trapping locations for American eel on the east side of Conowingo Dam including Octoraro Creek starting in May of the first calendar year after license issuance or immediately if license issuance occurs during the upstream American eel migration period. The plan and schedule for implementation of temporary and permanent eel passage facilities and other design criteria shall follow requirements established by the Muddy Run license and be approved by the Service and FERC following consultation with the Licensee and the respective resource agencies. The Licensee shall operate any temporary or permanent eel passage facility continuously (24 hours per day, 7 days per week) during the American eel Upstream Migration Period and shall submit proposed stocking locations for collected American eels to the Service and resource agencies for review and approval by the Service prior to beginning such measures.

[11] The estimated cost of ten weirs plus a contingency of 30% is no more than $2.3 million in 2016 dollars.

Eel Passage – Western Location

The Licensee shall conduct a trap and transport operation for American eels at the west side of Conowingo Dam beginning immediately after license issuance. The eel passage facility shall be designed to provide volitional passage for American eels no later than 2031, and will be sited taking into consideration the potential for a new West Fish Lift. [12]

Design criteria shall follow the components described in the Muddy Run license. The Licensee shall conduct trap and transport of American eels until 2030, and will implement volitional American eel passage starting in the 2031 season. The Licensee shall operate the eel passage facility continuously (24 hours per day, 7 days per week) during the American eel upstream Migration Period. The Licensee shall submit proposed stocking locations for collected American eels to the Service and resource agencies for review and approval by the Service prior to beginning trap and transport of American eels.

12.6.2 Improving Attraction Efficiency

Included is a list of physical and operational modifications to the Project intended to address observed deficiencies in fishway attraction efficiency. The tiered process for improving attraction efficiency is based on passage efficiency during the most recent efficiency test. The items included in the different tiers were developed to be commensurate with the degree of shortfall from the *Target Efficiency*. If, based on the *Adjusted Efficiency* of the current test, all appropriate options from the corresponding tier, including any option proposed by the Licensee and approved by the Service, have been exhausted, the items from the next highest numbered tier may be required, regardless of the current project passage efficiency. More than one item from a tier may be completed at one time depending on the degree of the *Adjusted Efficiency* shortfall.

[12] Consistent with the Eel Passage Plan established by the Muddy Run license, construction of the volitional passage facility will eliminate the Licensee’s obligation to participate in the trap and transport program once the volitional upstream eel passage facility is operational. However, if the upstream eel trap and transport and periodic evaluation program continues beyond 2030, the Licensee will continue to provide access to the Conowingo eel collection facilities for as long as the program continues. The Licensee, however, shall bear no cost responsibility for the trap and transport and periodic evaluation program until 2046, at which time cost responsibility shall be shared among all participants in the program.

12.6.2.1 Improving Attraction Efficiency – Tier I (*Adjusted Efficiency 70*%-85%)

In the year following any failure by the Licensee to reach the *Target Efficiency* due to inadequate fishway attraction, the Licensee shall implement one or more of the modifications to Project operations and facilities described in this section.

Correct any Technical Operational Problems and/or Implement Internal Modifications

The Licensee shall correct any technical operational problems that may have been detected during the fish passage season and/or implement internal modifications to the West and/or East fish lift (e.g., energy dissipation, hydraulic attraction).

Implementation of preferential turbine operating schemes

The Licensee shall develop a turbine operation scheme that can range from simply first on/last off to modification of specific Francis and Kaplan unit operation to ensure that fish are able to successfully locate and access the fish lift entrances.

12.6.2.2 Improving Attraction Efficiency – Tier II (*Adjusted Efficiency* 55%-69%)

Within 2 years following any failure to meet the *Target Efficiency* due to inadequate attraction to the fishway, the Licensee may implement either one of the modifications to the Project facilities described in this section to reach upstream passage efficiency.[13]

Relocate EFL Entrances A & B

If the CFD modeling results indicate modifications to Entrances A & B will improve guidance to and accessibility of the lift entrances, then the Licensee shall extend the entrance channel at entrance A with two 45-degree turns in the fish passage facility channel, so as to discharge into the area behind the catwalk piers and upstream from the Kaplan turbine discharge/boil. The attraction flow should be effective along the catwalk and through the space between the piers (Figure 10, USFWS 2013h). The Licensee shall also modify the existing entrance B so that the

[13] The Service may require relocation of Entrances A&B and, if the *Adjusted Efficiency* continues to be between 55%-69%, Entrance D at a later point, but then, per Tier III (and consistent with the “not before” dates), may only require the AWS, not the WFL. Alternatively, the Service may require the relocation of Entrance A&B, and in subsequent cycles proceed to choose the WFL (again, consistent with the “not before” dates) if (a) the *Adjusted Efficiency* is below 55% and Entrance D has not been constructed or (b) the *Adjusted Efficiency* is between 55%-69% and the Service determines that Entrance D is not likely to achieve the efficiency criterion.

centerline of the discharge plume will be at a 45-degree angle to the river flow.

Construct a new Entrance D with a separate crowder and holding pool

The Licensee shall build a new additional entrance, Entrance D, with a separate crowder and holding pool (Figure 10). The hopper will be accessed from the new entrance and through a proposed collection gallery that will span the full length of the Kaplan turbine section of the powerhouse. Entrance D and the collection gallery are intended to provide access to the EFL from the Francis turbine section of the powerhouse. The new collection gallery will be located against and along the powerhouse wall. This improvement will not be required by the Service to be operational before year 15 of the license.

12.6.2.3 Improving Attraction Efficiency -Tier III (*Adjusted Efficiency* less than 55%)

Following any failure by the Licensee to reach upstream passage efficiency due to inadequate fishway attraction, the Licensee may implement one or more of the modifications to Project operations and facilities described in this section.

Construct an Auxiliary Water Supply at the EFL

The Licensee shall construct a new AWS stilling basin and system so the energy from up to 4,300 cfs can be dissipated and incorporated into effective attraction flows emanating from the multiple fish lift entrances. This improvement will not be required by the Service to be operational before year 25 of the license.

WFL Construction

Licensee shall construct a new WFL (as described below, in parts 1-5) in the west corner of the powerhouse tailrace. The Licensee shall operate the new WFL as a tailwater to headpond fish lift with a collection facility for fish sampling that, at the Licensee's option, could be used as a fish trap and transport facility. This improvement will not be required by the Service for reasons of attraction efficiency to be operational before year 25 of the license, and only if neither Entrance D nor the EFL AWS stilling basin and system have been constructed. If the Service requires construction of the WFL for reasons of attraction efficiency, it has agreed not to subsequently require the EFL AWS stilling basin and system under this Prescription.

WFL Construction – Part 1

The Licensee shall construct a facility that provides the capability of enumerating fish passage by species, allows for the collection of and holding of fish for biological sampling, and that can also be used for trapping and transporting American shad and available river herring per year, with the potential for captured fish to be transported upstream of the York Haven Dam.

WFL Construction – Part 2

The Licensee shall install two 6,500-gallon hoppers, with separate crowders, in the new WFL, capable of operating simultaneously.

WFL Construction – Part 3

The Licensee shall construct the WFL to have the ability to provide up to 5 percent of hydraulic capacity of the Project (or up to 4,300 cfs) for attraction flow to the fishway entrance(s). During the design phase and during preconstruction, the Licensee shall conduct computational fluid dynamics (CFD) modeling and other supporting analysis to develop appropriate fish lift entrance attraction flows, velocities, and hydraulic conditions. The Licensee shall operate the WFL to provide attraction flow of at least 2,600 cfs (3 percent of hydraulic capacity of the Project) during the Upstream Migration Period for American shad and river herring. With the goal of improving fish passage efficiency at the WFL following initial start-up of the new WFL, the Service may require the lift operator to modify operation of the fish lift, the allocation of flows through its Auxiliary Water System (AWS), and/or the total amount of flow being supplied to the WFL (up to a maximum of 4,300 cfs or 5 percent of the Project hydraulic capacity).

WFL Construction – Part 4

The Licensee shall design and construct an AWS that meets Service criteria for energy dissipation of the attraction flow while maintaining water quality standards.

WFL Construction – Part 5

The Licensee shall conduct an assessment of the ZOP downstream of the WFL to ensure that it continues to be passable over the range of flows in which the WFL is operational.

12.6.3 Improving Fish Lift Capacity

Included is a list of physical and operational modifications to the Project intended to address possible deficiencies in fish lift capacity. The tiered process for improving capacity is based on passage efficiency during the most recent efficiency test. The items included in the different tiers were developed to be commensurate with the degree of missing the required 85 percent passage efficiency criterion. If, based on the *Adjusted Efficiency* of the current test, all options from the corresponding tier have been exhausted; the items from the next highest numbered tier may be required, regardless of the current project passage efficiency. Implementation of modifications in the capacity tiers is independent of the implementation of similar items used to improve attraction efficiency in section 12.6.2. Both attraction and capacity improvements can be required simultaneously if deemed appropriate from the most recent study results, but only to the extent both improvements are needed to meet the *Target Efficiency*.

12.6.3.1 Improving Fish Lift Capacity - Tier I (Adjusted Efficiency 70% – 85%)

Within 2 years following any failure by the Licensee to reach upstream passage efficiency due to inadequate fishway capacity, the Licensee shall implement the modification to Project facilities described in this section.

<u>Construct a new Entrance D with a separate crowder and holding pool</u>

The Licensee shall build a new additional entrance, Entrance D, with a separate crowder and holding pool (Figure 10). The new hopper will be accessed from the new entrance and through a proposed collection gallery that will span the full length of the Kaplan turbine section of the powerhouse. Entrance D and the collection gallery are intended to provide access to the EFL from the Francis turbine section of the powerhouse. The new collection gallery will be located against and along the powerhouse wall. This improvement will not be required by the Service under this Prescription to be operational before year 15 of the license.

12.6.3.2 Improving Fish Lift Capacity - Tier II (*Adjusted Efficiency* less than 70%)

Within 3 years following any failure by the Licensee to reach upstream passage efficiency due to inadequate fishway capacity, the Licensee shall implement the modifications to Project facilities described in this section.

WFL Construction

The Licensee shall construct a new WFL (as described in section 12.6.2.3) in the west corner of the powerhouse tailrace. The Licensee will operate the new WFL as a tailwater to headpond fish lift with a collection facility for fish sampling that, at the Licensee's option, could be used as a fish trap and transport facility. This improvement will not be required by the Service under this Prescription to be operational for reasons of capacity before year 25 of the license.

12.7 Fish Passage Effectiveness Monitoring

Efficiency testing of both upstream and downstream fish passage, and determining mortality rates of American shad when using trap and transport are critical to evaluating the success of fish passage structures and operations, diagnosing problems, and determining both when modifications are needed and what modifications are likely to be effective. These measures are essential to ensuring the effectiveness of fishways over the term of the license, particularly in cases where the increasing size of fish populations as a result of improved upstream passage may also lower upstream fish passage efficiencies due to migrating fish crowding and exceeding daily or annual lift capacity, thus keeping some fish from successfully passing the project and limiting net effectiveness.

12.7.1 Fishway Effectiveness Monitoring Plan

The Licensee shall develop a Fishway Effectiveness Monitoring Plan (FEMP) in consultation and with the approval of the Service, and will submit the FEMP to the FERC for approval within 6 months of license issuance. The FEMP will contain the plans for the studies described in Sections 12.7.2 through 12.7.5. If the Service requests a modification of the FEMP, the Licensee shall file a written response with the Service within 30 days and send a copy of the response to FERC and resource agencies. Any modifications to the FEMP by the Licensee will require approval by the Service and, if necessary, FERC prior to implementation.

The Licensee shall submit yearly interim study reports to the Service and FERC following the conclusion of each study year. The interim and final reports for upstream passage studies will be submitted to the Service by December 31st of each study year. The interim and final reports for downstream passage studies will be submitted to the Service by August 1 following each study year. The final study report will include results for each life stage and type of study conducted with a determination of the Licensee's success or failure in achieving the passage efficiency criteria established in Section 12.2. In conjunction with submitting the final study report(s), the Licensee shall also provide electronic copies of all data collected from studies to the Service.

The Licensee shall meet with the Service and the Susquehanna River Anadromous Fish Restoration Cooperative (SRAFRC) to discuss the FEMP and FOMP. This meeting will occur no later than January 31 each year unless the Licensee and the Service agree on a different date. At this annual meeting the Licensee shall discuss with the Service and SRAFRC the fish passage results from the previous year, review regulatory requirements for fish lift and eel passage operations, and discuss any upcoming modification or testing the Licensee proposes for the upcoming fish passage season.

12.7.2 Initial Efficiency Test, Post-Modification Efficiency Tests, and Periodic Efficiency Tests for Upstream Passage of American Shad and River Herring

The *Initial Efficiency Test* and any *Post-Modification Efficiency Tests* will consist of a three-year fish tagging and monitoring study of American shad and river herring using radio telemetry, or other best tracking technology. The *Periodic Efficiency Tests* will consist of a two-year American shad tagging study using the same techniques unless the Licensee elects, with Service concurrence, to conduct an additional one year of study. The *Initial Efficiency Test* will begin in the 5th passage season after license issuance. The *Post-Modification Efficiency Test* will begin in the first fish passage season immediately following any required modification implemented from the tiers. The *Periodic Efficiency Test* will be conducted on every 5th year after a previous study determines that the *Adjusted Efficienc*y of the project is achieving 85 percent passage efficiency for American shad. Early Periodic Efficiency Tests may be delayed by up to two years to coincide with the schedule for tests at Muddy Run agreed upon in the 2015 Settlement Agreement between the Service and the Licensee.

These studies will use sufficient numbers of test fish to account for drop-back and other fish loss.

These fish will be collected from a downstream location, and be representative of the migrating population as a whole. Specific details of the telemetry studies such as sample sizes, collection of and release location of tagged American shad and river herring, arrangement of telemetry receivers, and appropriate statistical analyses shall be developed by the Licensee in conjunction with the Service and other resource agencies. The Licensee shall submit final study plans to the Service and FERC for review and approval prior to initiating any study.

12.7.2.1 Trap and Transport Credit for American Shad

The Licensee will receive additional credit toward the upstream passage efficiency criterion for adult American shad that are trapped and transported upstream of York Haven Dam. The Service will recognize the benefits to the species by giving credit towards the calculation of whether the efficiency criterion for upstream shad passage is met, due to the value to restoration of avoiding the passage of impediments at the upstream hydroelectric projects.

Details of the credit toward the efficiency criterion are provided in Appendix B. Part of the calculation of the credit toward efficiency criterion requires an estimate of the mortality associated with trap and transport operations. In the 4th year after license issuance, the Licensee shall work with the Service and other resource agencies to develop a one-year study to estimate the mortality of fish which are trapped and transported to areas upstream of York Haven Dam. Such a study will include assessment of immediate mortality (mortality occurring during transport) as well as delayed mortality (mortality occurring during some time period after release). The results of the study will be used to modify, as necessary, the mortality input utilized in the trap and truck credit. The Service's proposed methodology for this study is included in Appendix C; however the Licensee and the Service have not agreed upon a final methodology and final study design is expected to take place post-licensing.

12.7.3 Upstream American Eel Effectiveness Testing

Unless the Service and the Licensee agree that no effective technology is available to enable such testing, the Licensee shall conduct an upstream efficiency study on juvenile American eel at the WFL facility in the year immediately following license issuance. The study will determine the American eel upstream passage efficiency of the eelway throughout the upstream migration season. The study will consist of two components, including determining attraction efficiency to the facility and passage efficiency of the facility once an eel enters the structure. Efficiency studies will be repeated following any modifications to the operation or physical structure to evaluate the relative success of the modifications. The Licensee shall provide an annual report on the efficiency study to the Service by December 31 of the study year.

12.7.4 Downstream Adult and Juvenile American Shad and River Herring Effectiveness Testing

The Licensee shall conduct downstream passage effectiveness studies of American shad and river herring in 2027 in coordination with the Service. As part of the Conowingo FEMP for downstream passage, the Licensee will evaluate both juvenile and adult life stages using a study protocol developed cooperatively with the Service to include a Conowingo Pond route of passage study. A route of passage study will be conducted to determine the routes chosen by downstream migrating fish through the Project under various generation conditions to determine if there are preferred routes of passage at the dam. The route of passage study will be conducted for 2 years to account for inter-annual variation in flow conditions. The Licensee will have the option to extend the route of passage study for an additional year.

In addition to the route of passage study, a one year separate and discrete passage study for both adult and juvenile American shad and river herring shall be conducted to estimate survival through the Kaplan and Francis turbines under best gate efficiency. This study will commence in 2027. The effects of barotrauma during turbine passage will be included as part of the turbine survival studies for all life stages when possible. Results of the studies will be used to determine through-Project survival (i.e. via spill, Francis turbines, Kaplan turbines, etc.), and immediate and latent mortality for each route to achieve the passage criteria.

In the event the Licensee is unable to achieve the efficiency criteria for survival based on the results of the downstream studies, the Department may exercise its reservation of authority to address the issue.

12.7.5 Downstream American Eel Effectiveness Monitoring

The Licensee shall conduct or participate in two separate studies on downstream migrating American eel in the Susquehanna River. The studies can be done concurrently or separately, and will be conducted in conjunction with the American eel downstream studies undertaken by the Licensee of the Muddy Run Hydroelectric Project. The Licensee shall initiate studies when the Service determines that sufficient numbers of downstream migrants can be collected in the upper watershed to conduct a valid study.

First, the Licensee shall participate in a basin-wide study coordinated by the Service to determine timing of downstream migration of American eels in the Susquehanna River (see USFWS 2014d). To complete this study, the Licensee shall contribute $75,000 to the Service to collect and tag fish for use in the basin-wide study. Radio telemetry monitoring will be conducted by the Licensee year-round for 3 consecutive years.[14]

In addition to the basin-wide migration timing study, the Licensee will conduct a study at Conowingo Dam to determine migratory delay, route of downstream passage (i.e. via spill, Francis turbines, Kaplan turbines, etc.), and immediate and latent mortality for each route. If a sufficient number of tagged fish encounter the Project, a route of passage study can be done concurrently with the basin-wide downstream migration study using the same tagged eels assuming appropriate tag technology is available to assess latent mortality of those fish during the study.

In the event the Licensee is unable to achieve the efficiency criterion for survival based on the results of the downstream studies, the Department may exercise its reservation of authority to address the issue.

12.8 Fishway Inspections

The Licensee shall provide Service personnel and other Service-designated representatives, timely access to the fish passage facilities at the Project and to pertinent Project operational

[14] Mobile tracking and data analysis for this study will be the responsibility of the Service. Annually, the Service will share with the Licensee all data collected as part of the basin-wide study.

records for the purpose of inspecting the fishways to determine compliance with the Fishway Prescription.

13. Pre-License Actions Agreed to by the Licensee

13.1. Items to be completed in 2016 - 2017

The License Applicant has agreed to develop and finalize a detailed logistics plan and operating protocol for trap and transport of American shad and river herring from both the EFL and WFL. The Logistics plan will address near-term operations, as well as logistics necessary to support the collection and transport of up to 80 percent of the American shad and river herring passing the project with a maximum transport of 100,000 American shad and 100,000 river herring annually. This plan will be completed by December 31, 2017.

The License Applicant has agreed to develop detailed computational fluid dynamics (CFD) models of the zones of passage, in consultation with the Service, to the EFL and WFL to assess the ability of fish to reach them.

The License Applicant has agreed to develop its initial FOMP (as described in Section 12.4) and submit to the Service by September 30, 2017.

13.2. Items to be completed in 2017 - 2018

The License Applicant has agreed to finalize design plans for initial fishway improvement and improvements to facilitate the trap and transport program.

14. Scientific Names

Alewife *(Alosa pseudoharengus)*
American eel *(Anguilla rostrata)*
American shad *(Alosa sapidissima)*
Atlantic sturgeon (*Acipenser oxyrinchus)*
Blueback herring *(Alosa aestivalis)*
Gizzard shad (*Dorosoma cepedianum*)
Hickory shad *(Alosa mediocris)*

Largemouth bass *(Micropterus salmoides)*

Sea lamprey *(Petromyzon marinus)*

Shortnose sturgeon *(Acipenser brevirostrum)*

Smallmouth bass *(Micropterus dolomieu)*

Striped bass (*Morone saxatilis*)

15. Definition of Technical Terms

Adjusted Efficiency– The calculated fish passage efficiency that accounts for the biological benefit of fish trapped and transported from the project to areas upstream of other mainstem dams. This calculated efficiency gives credit towards efficiency targets for the number of fish that are trapped and transported.

Alosines – collective term for American shad, blueback herring and alewife

Anadromous – migratory fish that spawn in freshwater rivers but spend most of their life in the ocean

Attraction Efficiency – The proportion of the migrating population that successfully passes a designated downstream point at the Project (i.e. the downstream end of Rowland Island), and successfully enters the fish lift

Barotrauma – trauma due to changes in barometric pressure such as the expansion and rupture of a fish's swim bladder

Biomass – pounds of fish

Catadromous – migratory fish that spawn in the ocean but spend most of their life in freshwater

Diadromous – includes both anadromous and catadromous migratory fish

Downstream Fish Passage Efficiency – the percentage of the fish that approach the upstream side of the Project and survive unharmed as they pass the Project and continue downstream migrations

Effective Passage – the combination of fish passage facilities and project operations that provide conditions where fish can approach and move past a barrier with little or no impact to their migration. Effectiveness may include both qualitative and quantitative components; however, a different term, efficiency, is typically reserved for quantitative evaluations of effectiveness.

Entrainment – fish passage via a particular structure, usually referring to directing fish passage through turbines or into downstream fish passage facilities

Fecund – more fertile, having more eggs

Fish Ladder – an engineered ramp-like structure, typically constructed of concrete and/or metal, used to provide upstream fish passage

Fish Lift – an elevator-like structure with a hopper used to convey fish from the tailwaters to the headpond of high dams

Fish Passage Facility – the physical structure of the fishway used to convey fish upstream; with the term being synonymous with "fish lift" at this Project

Fishway – shall have the definition provided in P.L. 102-486, § 1701(b) (1992)

Headpond – the body of water located on the upstream side of the dam

Hopper – the structural part of the fish lift used to hold fish as they are transported from the tailwaters to the head pond

Impingement – to trap fish against a structure, usually referring to intake screens

Nature-Like Fishway – a ramp-like structure, typically constructed of natural materials (rocks, logs), used to provide upstream fish passage

Panmictic – of one spawning population with no genetic differentiation between geographic areas

Peaking – a hydro-electric facility that rarely spills water has the ability to store water and release on demand for power generation, typically having the ability to significantly impact flows downstream of the project

Repeat Spawning – ability to spawn over multiple years

Run-of-River – a hydro-electric facility that has limited (if any) ability to store water, with water typically flowing over the crest of the dam at all times

Safe Passage – the movement of fish through the zone of passage that does not result in any unacceptable stress, incremental injury, or death of the fish.

Self-Sustaining - Ability to maintain migratory fish populations at the level of their restoration goal without supplementation from trap and transport or hatchery products.

Tailrace – the area downstream of the dam that is in the hydraulic influence of Project operations

Tailwaters – the area downstream of Conowingo Dam located between the dam and the downstream end of Rowland Island

Timely Passage – the successful movement through the zone of passage that proceeds without a delay that would impact the natural behavior patterns or life history requirements of a fish

Trap and Transport – fish that are collected at a downstream project and loaded in a tank truck and transported and released into some location upstream of that project

Upstream Fish Passage Efficiency – the percentage of the fish present in the Project tailwaters that successfully move through the fish lift and continue upstream migrations; e.g. the proportion of fish that start at point B (downstream end of Rowland Island in the case of Conowingo Dam) and passes point E in Figure 5

Volitional Passage – a fish passage facility that allows fish to swim unimpeded from the tailwaters to the headpond; fish lifts are not considered volitional passage because the fish rely on the operation of the lifts in order to pass upstream into the headpond

Zone of Passage (ZOP) – The contiguous area of sufficient lateral, longitudinal, and vertical extent in which adequate hydraulic and environmental conditions are maintained to provide a route of passage through a stream reach influenced by a dam (or stream barrier); e.g. the area between point A and point E in Figure 5.

16. Acronyms and Abbreviations

2010 SRAFRC Plan - Susquehanna River Anadromous Fish Restoration Cooperative's Migratory Fish Management and Restoration Plan for the Susquehanna River Basin

ACFCMA - Atlantic Coastal Fisheries Cooperative Management Act of 1993

ASMFC – Atlantic States Marine Fisheries Commission

AWS – Auxiliary Water System

cfs – cubic feet per second

Commission – Federal Energy Regulatory Commission

Department – U.S. Department of the Interior

DO – dissolved oxygen

EEZ - Exclusive Economic Zone

EFL – East Fish Lift

ESA – Endangered Species Act

FEMP – Fishway Effectiveness Monitoring Plan

FERC – Federal Energy Regulatory Commission (formerly FPC)

FMC - Fishery Management Council

FMP – Fishery Management Plan

FOMP – Fishway Operation and Maintenance Plan

FPA – Federal Power Act

FPC – Federal Power Commission

fps – feet per second

ft^3 – cubic feet

hr - hour

lbf – pounds of fish

MDNR – Maryland Department of Natural Resources

min - minute

MRPSP – Muddy Run Pumped Storage Project

NYSDEC – New York Department of Environmental Conservation

NMFS – National Marine Fisheries Service

PADEP – Pennsylvania Department of Environmental Protection

PECO – Philadelphia Electric Company

PFBC – Pennsylvania Fish and Boat Commission (formerly PFC)

PFC – Pennsylvania Fish Commission

PPL – Philadelphia Power & Light Company

ppm – parts per million

Project – Conowingo Hydroelectric Project

REA – Ready for Environmental Analysis

Resource agencies - states of Maryland and Pennsylvania, Susquehanna River Basin Commission, and National Marine Fisheries Service

River herring – alewife and blueback herring

RM – river mile

(see repeat, below)Service – U.S. Fish and Wildlife Service

SHWPC – Safe Harbor Water Power Corporation

SRAFRC – Susquehanna River Anadromous Fish Restoration Cooperative (formerly Committee)

SRBC – Susquehanna River Basin Commission

SSAC – Susquehanna Shad Advisory Committee

WFL – West Fish Lift

YHPC – York Haven Power Company

YOY – young-of-year (juvenile fish)

ZOP – zone of passage

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Appendix A. Calculation of Fishway Capacity for a 6,500-Gallon Hopper

Biological Parameters		
	λ_m= 0.052 (season/day)	Season-to-Day run compression coefficient; empirically determined designed parameter
	β=0.15 (day/hr)	Hour-to-Day run compression coefficient; empirically determined design parameter
	T=15 min	Lift cycle time (recommended)
Hopper Size		
	Vol_H=868.9ft^3	Estimate of proposed hopper volume (6,500 gallons)
	V_{fH}=0.1 (ft^3/lbf)	Volume required per fish-pound; USFWS criterion; for lift times greater than 15 minutes, a 30 percent increase in V_{fH} is recommended
Allowable peak biological loadings		
Flb_h= (Vol_H/v_{fH}*T)	Flb_h= 34,756 lbf/hr	Allowable loading of fish in pounds per peak hour
Flb_d=Flb_h/ β	Flb_d= 231,706 lbf/day	Allowable loading of fish in pounds during the peak day
Flb_s = Flb_d/ λ_m	Flb_s= 4,455,897 lbf/season	Allowable loading of fish in pounds during an entire season

Appendix B. Calculating Trap and Transport Credit

Credit Towards an Overall Efficiency Criterion (85 percent of the fish entering the Conowingo Tailrace)

For a given number of shad trapped and transported we can estimate the number that would need to pass Conowingo Dam via the fish lift to result in the same number of spawners upstream of York Haven Dam. This number is termed "lift equivalents" (L_e) and is calculated as:

[1] $$L_e = (\sum_{i=1}^{n} TT_i) \cdot (1 - TT_m)/D$$

Where TT_i is the number trapped and transported each year during a single or multi-year study to measure passage efficiency, and TT_m is the mortality associated with trapping and transporting shad. Harris and Hightower (2011) estimated mortality of trapped and transported shad in the Roanoke River to be 15 percent. However, SRAFRC (1997) gave estimates of mortality for holding shad prior to trap and transport, mortality during the transport, and delayed mortality following release. When all these factors are considered, the overall mortality associated with trap and transport operations was 6 percent, which was used in this model. The denominator (*D*) in equation [1] will be calculated using the maximum efficiency of each of the two upstream dams with the highest passage efficiency over the three year study and the average of these efficiencies. For example, if the highest efficiencies of Holtwood, Safe Harbor, and York Haven Dams over the three year study were 0.60, 0.78, and 0.50, respectively, then the denominator would be calculated as $D = 0.60 \cdot 0.78 \cdot \left(\frac{0.60+0.78}{2}\right) = 0.3229$. It was assumed that other than the mortality associated with trap and transport operations, no other negative impacts on their fitness occurred compared to shad that would migrate via multiple fish passage facilities to areas upstream of York Haven Dam.

The L_e can be added to the observed number that were lifted past Conowingo Dam during the study period to arrive at an adjusted total number that are passed via the fish lift (L_a).

[2] $$L_a = L_e + \sum_{i=1}^{n} L_i$$

where L_i is the observed number lifted in each year.

During a radio telemetry study at Conowingo Dam, an estimate of passage efficiency will be made and given the total number of shad actually passed (lifted and released into Conowingo Pond + trapped and transported upstream), an estimate of the total number of shad downstream of Conowingo Dam during all years of the study can be made.

[3] $N = (\sum_{i=1}^{n} P_i)/E_o$

where P_i is the total number passed each year and E_o is the estimated passage efficiency during the study. Equation [3] also assumes that no mortality is suffered while attempting to pass Conowingo Dam.

The variance of N can be estimated by the delta method using the estimated variance of E_o.

[4] $Var(N) = [Var(E_o)/E_o^4] \cdot (\sum_{i=1}^{n} P_i)^2$

The adjusted passage efficiency is then the adjusted number that are lifted during the study divided by the total number of shad downstream of Conowingo Dam during all years of the study.

[5] $E_a = L_a/N$

The associated variance from the delta method is:

[6] $Var(E_a) = [Var(N)/N^4] \cdot L_a^2$

The 95 percent confidence interval for E_a can be approximated as:

[7] $95\%\ C.I. \approx 1.96 \cdot \sqrt{Var(E_a)}$

If the upper 95% confidence limit is greater than or equal to the efficiency criterion, then the criterion is considered to be met.

Appendix C. Service's Proposed Methodology for Trap and Transport Mortality Study

To assess the mortality associated with trap and transport (T&T) of American shad collected at Conowingo Dam and transported to areas upstream of York Haven Dam, a study design similar to that of Millard et al. (2005) will be employed. This study will have both a treatment (T&Ted shad) and a control group (shad not T&Ted). The purpose of having both a treatment and a control group is to evaluate both the immediate and delayed mortality associated with T&T operations while controlling for mortality associated with handling stress while carrying out the study.

Control groups will consist of shad that are caught in the lifts at Conowingo Dam, sorted from non-target species, and rather than being loaded into a truck and transported upstream, they will be released to a large holding tank located at Conowingo Dam (size to be determined) and monitored for 72 hours post-release.

Treatment groups will consist of shad that are caught in the lifts at Conowingo Dam, sorted from non-target species, loaded into a truck, and driven around in the truck for a length of time equivalent to the trip duration to areas upstream of York Haven Dam. After simulating transport, the shad will be placed into a holding tank located at Conowingo Dam and monitored for 72 hours post-release.

Experimental tanks for both treatment and control groups will be located at Conowingo Dam in order to eliminate any confounding effects of differences in water temperature/chemistry between treatment and control groups and to isolate the effects of transport. Experimental tanks will be set up with flow through conditions using water pumped from the tailrace of Conowingo Dam.

Each week throughout the fish passage season, a truck load's worth of fish (exact number yet to be determined) will be used in both treatment and control groups. Thus, the experiment will be temporally replicated for 4 – 8 weeks depending on the duration of the spawning run in a given year. This will allow assessment of mortality over the range of water temperatures experienced by shad throughout the season.

During the 72 hour monitoring period, dead shad will be removed from the tank as soon as they are noticed. Mortality will be quantified as the number of dead shad divided by the number of shad that entered either the treatment or control group. Mortality in the treatment group will include all shad that died during the entire process from loading them into the truck to those found dead at the end of the 72 hour monitoring period.

Statistical Analysis

It will be assumed that total mortality of the treatment group consists of two components: 1) mortality associated with transport and release of the shad; and 2) mortality associated with experimental handling of the shad. Thus, total mortality of the treatment group = T&T mortality + handling mortality. The control group would only experience mortality associated with experimental handling. The instantaneous handling mortality rate (m_h) will be estimated from the control group as

$$M_h = -ln(S_c)$$

where S_c is the survival of the control group over all replicates throughout the season. The instantaneous total mortality in the treatment group will be estimated as

$$M_t = -ln(S_t)$$

where S_t is the survival of the treatment group over all replicates throughout the season. The conditional mortality associated with trap and transport (conditioned on handling mortality) is

$$u_{TT} = A - \left[\frac{A \cdot M_h}{-ln(1 - A)}\right]$$

where A is the fraction of fish that die from all causes (1-S_t). This equation is based on the traditional fisheries expression $u = A \cdot F/Z$ where u = the expectation of death from fishing, A = total mortality rate from all causes, F = the instantaneous fishing mortality rate, and Z = the total instantaneous mortality rate. Estimation of the conditional mortality associated with trap and transport (u_{TT}) according the above equation is preferred because it account for the probability that the two sources of mortality, trap and transport stress and handling stress, occur simultaneously over the monitoring period (Millard et al. 2005).

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