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ENVIRONMENTAL CONSULTANTS

Summary of Operations at the Holtwood Fish Passage Facility Spring and Fall, 2018

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Executive Summary

Per the settlement agreement for the Holtwood Redevelopment Project, 2018 marks the fifth year of fish passage operations for both resident and migratory fish species. This year also marks the first time that the fish passage facility was operated by local staff (Brookfield employees). The Holtwood fish passage facility commenced resident fish passage operations on April 2, 2018 for six hours per day (river flow permitting), switching to ten hour days of operation when a sufficient number of American Shad were passed at Conowingo Dam or observed in the catch, then back to the six hour operating schedule for resident fish passage after the official end of the American Shad season (per concurrence with Resource Agencies) until June 30. The fall season component of resident fish passage was only conducted on 6 days in 2018 due to persistent high river flows and a mechanical failure of the Gate 9 internal gearing. The settlement agreement allows Holtwood to suspend fish passage operations when river flows are ≥ 100,000 cfs during any fish passage season.

We started spring resident fish passage operations on April 2, with suspension to operations on April 17 due to repairs of both fishway hoppers, and from April 18 to 21 due to river flows exceeding 100,000 cfs. We then operated in resident fish passage mode from April 22 to 29, switching to migratory fish passage mode on April 30 due to the increased passage of American Shad at Conowingo (113 on April 29). Migratory fish passage operations were suspended due to high river flows from May 15 through May 25. Migratory fish passage operations ended on June 6, with agency concurrence, due to increasing water temperatures and low numbers of shad in the daily passage counts. Resident fish passage operations resumed on June 7 and continued through June 30 per the settlement agreement. The facility operated a total of 74 days between April 2 and June 30, 2018, (Tailrace = 65 days; Spillway = 72 days). Fall resident fish passage operation was conducted on 6 days in September when river flows were below 100,000 cfs and prior to the Gate 9 mechanical failure of the internal gearing. This fish passage season marks the twenty-second year of operation at Holtwood.

During the American Shad passage season (27 days of operation from April 30 to June 6), the lifts passed 151,678 fish of 20 taxa and 1 hybrid. Gizzard shad dominated the catch, and comprised nearly 98% of the total fish collected and passed. American Shad represented the sole *Alosa* species collected and passed at Holtwood in 2018. A total of 1,483 American Shad were passed by the Holtwood fishway in 2018 (1,458 during the “official” shad passage season, with 25 American Shad passed on June 7 and 8 during resident fish passage operations).

The 2018 American Shad passage rate at Holtwood (21% of American Shad passing Conowingo passed Holtwood) was the eleventh lowest rate observed since operations commenced in 1997. The American Shad passage season at Holtwood appeared to be hampered by the higher river flows experienced and the limited integrity of the flashboards during spring fish passage operations.

During spring, 2018, resident fish passage operations occurred on 23 days in April and 24 days in June. The facility operated 6 hours per day from 0900 to 1500 hrs per the settlement agreement. A total of 10,011 fish of 19 taxa was collected and passed during resident fish passage operations this spring. We compared the passage of 7 resident species (smallmouth bass, walleye, channel catfish, shorthead redhorse, quillback, carp, and gizzard shad) passed during resident passage periods to passage of those same species during the migratory passage season. During spring, 2018, nearly 94% or more of the total resident fish observed were passed during the American Shad migratory fish passage season.

Fall resident fish passage operations were conducted using both the tailrace and spillway fish lifts. During 6 days of operation, a total of 1,364 fish comprised of 9 species were passed. Comely shiner (900) accounted for nearly 66% of the total catch. Channel catfish (201) and smallmouth bass (198) combined comprised an additional 29% of the total catch. It is anticipated that all repairs to the fish passage facility will be completed before commencement of fish passage operations on April 1, 2019.

This year was the twenty-second year of fish passage operations at the Holtwood fish passage facility. Future operation of the fishway will build on these past years of operation as we continue to refine operations due to modifications made to the fishway and the overall area as part of the redevelopment of the Holtwood Hydroelectric Project.

1.0 Introduction

On June 1, 1993 representatives of PPL, two other upstream utilities, various state and federal resource agencies, and two sportsmen clubs signed the 1993 Susquehanna River Fish Passage Settlement Agreement. This agreement committed the Holtwood Hydroelectric Project (now owned and operated by Brookfield Renewable) and the two other upstream hydroelectric projects to provide migratory fish passage at their facilities by the spring of 2000. A major element of this agreement was for PPL, the owner/operator of Holtwood at that time, to construct and place a fishway into operation by April 1, 1997. PPL started construction on the fishway in April 1995, and met the spring 1997 operational target. The upstream passage facility consisting of a tailrace and spillway lift has been successfully operated each spring since 1997, as well as in fall, 2014, 2015, 2017, and 2018. This year marked the twenty-second operational season.

Objectives of 2018 upstream fishway operation were to (1) monitor and maximize passage of migratory fishes through the fishway; (2) minimize interruptions to fish passage operations due to equipment breakdowns or malfunctions and (3) continue resident fish passage operations in spring and fall per the redevelopment settlement agreement.

2.0 Holtwood Operation

2.1 Project Operation

Holtwood, built in 1910, is situated on the Susquehanna River (river mile 24) in Lancaster and York counties, Pennsylvania (see figure in Normandeau Associates, Inc. 1998). It is the second upstream hydroelectric facility on the river. The project now consists of a concrete gravity overflow dam 2,392 ft long by 55 ft high, the legacy powerhouse with ten turbine units having a combined generating capacity of 107 MW, the new powerhouse containing 2 large Kaplan turbines (100 MW capacity) and a reservoir (Lake Aldred) of 2,400 acres surface area. Each legacy unit is capable of passing approximately 3,000 cfs with each Kaplan turbine passing approximately 15,000 cfs. Spills occur at the project when river flow or project inflow exceeds the station hydraulic capacity of approximately 62,000 cfs.

Hydraulic conditions in the Holtwood spillway are controlled by numerous factors that change hourly, daily and throughout the fishway operating season. The primary factors are natural river flows, operation of the power station, operation of the Obermeyer gates controlling flow into Piney channel, and operation of the Safe Harbor Hydroelectric Project.

In 2018, all spillway Obermeyer gates were operable. Operations began at the Holtwood Fish Lift facility on April 2, 2018 to initiate passage of resident fish species prior to passage of American Shad at Conowingo Dam (Table 1). We were unable to operate the fishway on April 17 due to repair work conducted on both hoppers and from April 18 to 21 due to high river flows in excess of 100,000 cfs. American Shad passage operations at Holtwood (10-hr days) were initiated on April 30, one day after the Conowingo East fish lift passed 113 American Shad. River flows greater than 100,000 cfs occurred from May 15 through 25 during fish passage operations in 2018, resulting in the suspension of passage operations on these dates, and may have impacted American Shad passage this year at Holtwood (Table 1). Spill at the project occurred frequently this spring due to above

average river flows and damaged or missing flashboards. The flashboards were replaced/repaired on 2 separate occasions in spring, 2018 (May 8 to 11 and June 19 to 21). In 2018, passage operations for migratory fish (American Shad, etc.) ended on June 6, with agency concurrence, due to increasing water temperatures and low American Shad passage. Spring passage operations for resident fish species resumed on June 7. A speed fault to the tailrace hopper hoist control occurred during the afternoon of June 9. The issue was investigated and it was discovered that the main circuit board needed to be replaced. The parts were ordered and the tailrace hopper hoist repair was completed on June 18. From June 10 through June 18, operations were conducted using only the spillway lift. Spring resident fish passage operations concluded on June 30 per the settlement agreement.

2.2 Fishway Design and Operation

2.2.1 Fishway Design

The Holtwood fishway is sized to pass a design population of 2.7 million American Shad and 10 million river herring. The design incorporates numerous criteria established by the USFWS and state resource agencies. Physical design parameters for the fishway are given in Normandeau Associates, Inc. (1998).

The fish passage facility at Holtwood is comprised of a tailrace and spillway lift (see figure in Normandeau Associates, Inc. 1998). The tailrace lift has two entrances (gates A and B) and the spillway lift has one entrance (gate C). Each lift has its own fish handling system that includes a mechanically operated crowder, picket screen(s), hopper, and hopper trough gate. Fishes captured in the lifts are sluiced into one trough through which the fish swim into Lake Aldred. Attraction flows, throughout the entire facility, are supplied via a piping system and five diffusers that are gravity fed from two trough intakes and the additional attraction water pipe. Generally, water conveyance and attraction flow is controlled by regulating the three entrance gates and eight motor-operated valves. Fish that enter the tailrace and/or spillway entrances are attracted by water flow into the mechanically operated crowder chambers. Once inside, fish are crowded into the hoppers (6,700 gal capacity). Fish are then lifted in the hoppers and sluiced into the trough. Fish swim upstream through the trough past a counting facility and into the forebay through a 14 ft wide fish lift exit gate.

In 2018, all four Obermeyer gate sections were available for operation. Obermeyer gate sections 2 and 3 were installed and tested during fall, 2015. Generally, the Obermeyer gates are in the closed (up) position during fish passage operations excepting those times when the river flow approaches and exceeds 100,000 cfs.

Design guidelines for fishway operation include seven entrance combinations. These are: (1) entrances A, B, and C; (2) entrances A and B; (3) entrances A and C; (4) entrances B and C; (5) entrance A only; (6) entrance B only; and (7) entrance C only. Completion of the attraction water system after the 1997 season resulted in the drafting of operating protocols and guidelines that are flexible and utilize experience gained during previous years of fish lift operation. In 2014, after installation of the additional attraction water supply pipe and valve (MOV 8), a new operating matrix was developed, but testing and fine-tuning of the matrix continues. The following gate combinations were utilized in spring, 2018: entrances A, B, and C (63 days); entrances A and B (2 days); and entrance C only (9 days).

2.2.2 Fishway Operation

Daily operation of the Holtwood fishway was based on the American Shad catch, and managed to maximize that catch. Pre-season equipment preparations began in March, and were completed before season start-up. Per the Holtwood redevelopment settlement agreement, the fish passage facility was scheduled to operate daily this spring from April 1 to June 30 for passage of both resident and migratory fish species and again in fall (5 days per week; 6 hours per day) from September 1 through October 15 for passage of resident fish species. Fish passage operations were to be suspended when river flows exceeded 100,000 cfs and resumed when flows fell below 100,000 cfs.

Holtwood fish passage operations in spring, 2018 commenced on April 2 and ended on June 30 (total days of operation = 74). The migratory fish passage season (based on presence of American Shad in the catch) ran from April 30 to June 6 (27 days of operation). During the migratory fish passage season, fishway operations were suspended from May 15 through May 25 due to high river flow exceeding 100,000 cfs.

During the spring fish passage season, the tailrace lift operated on 65 days while the spillway lift operated on 72 days. Resident fish passage operational hours were 0900 to 1500 hrs in spring, 2018, and we operated from 0800 to 1800 hrs during the migratory fish passage season per the redevelopment settlement agreement. Fall 2018 resident fish passage operations were conducted with both the tailrace and spillway fish lifts but operations occurred on only 6 days in September due to persistent high river flows greater than 100,000 cfs and the mechanical failure of Gate 9 on September 24. Repairs will be conducted during the offseason to ensure availability of the entire fish passage facility in spring, 2019.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. Due to the increased pre-season maintenance efforts by the local staff, the fish lift was operated in automatic mode by local staff. This is the first time this has occurred since the fish lift went into operation. A detailed description of the fishway's major components and their operation are found in the 1997 and 1998 summary reports (Normandeau Associates, Inc. 1998 and 1999).

2.3 Fish Counts

Fish passing the counting window are identified to species and counted/estimated by a biologist or biological technician. The counting area is located immediately downstream of the main attraction water supply area in the trough. As fish swim upstream and approach the counting area, they are directed by a series of fixed screens to swim up and through a 3 ft wide, 12 ft long channel on the west side of the trough. The channel is adjacent to a 4 ft by 10 ft window located in the counting room where fish are identified and counted. Passage from the fishway is controlled by one set of gates located just downstream of the viewing window. During the day, fish passage is controlled by the technician who opens/closes the set of gates downstream of the viewing window. At night, fish are denied passage from the fishway by closing these gates. When necessary, flow is maintained through the exit channel to ensure that adequate water quality exists for fish that may be in the trough overnight.

Fish passage data is handled by a single system that records and processes the data. The data (species and numbers passed) is recorded on a worksheet by the biologist or biological technician as

fish pass the viewing window. At the end of each hour, fish passage data is entered into a Microsoft Excel spreadsheet and saved. Data processing and reporting is PC-based and accomplished by program scripts, or macros, created within Microsoft Excel spreadsheet software.

At day's end, the data is checked and verified by the biologist or biological technician. After data verification is completed, a daily summary of fish passage is produced and distributed to plant personnel. Each day's data is backed up to a flash drive and stored off-site. Daily reports and weekly summaries of fish passage numbers are electronically distributed to members of the Holtwood FPTAC and other co-operators.

3.0 Migratory Fish Passage Results

3.1 Relative Abundance

The diversity and abundance of fishes collected and passed daily in the Holtwood fishway during the spring 2018 migratory fish passage period (April 30 to June 6) is presented in Table 2. A total of 151,678 fish of 20 taxa plus one hybrid passed upstream into Lake Aldred. Gizzard shad (147,984), American Shad (1,458), smallmouth bass (882), shorthead redhorse (481), and channel catfish (382), comprised 99% of all fishes passed. Other abundant fishes passed included carp (298), and walleye (121). The peak one-day passage of all species occurred on May 12, when 15,843 fish were passed, comprised mostly of gizzard shad (15,422), American Shad (291), and smallmouth bass (77).

3.2 American Shad Passage

A total of 1,458 American Shad were passed in 27 days at Holtwood during the 2018 official migratory fish passage season (April 30 to June 6); 842 American Shad passed in the tailrace lift while the spillway lift accounted for 616 American Shad (Table 3). An additional 25 American Shad was passed after the official migratory season ended, (11 from Tailrace and 14 from Spillway), for an overall passage total of 1,483 American Shad. Collection and passage of shad varied daily with 90% of the overall total shad (1,361) passed by May 13 (Figures 1 and 2). The highest daily American Shad catch occurred on May 12 when 291 shad moved upstream during 9.7 hours of operation. On a daily basis, overall shad passage was consistent through the fishway between 0800 hrs and 1759 hrs, with the highest hour of shad passage occurring from 0900 to 0959 hrs (Table 4). Migratory fish passage operations were conducted at average water temperatures ranging from 54.9°F to 73.9°F and river flows between 35,300 and 95,400 cfs. Spillage occurred on 8 days during the spring migratory season and on 27 of the 75 days that the facility operated in spring, 2018. River water temperatures did not reach 70°F until May 27 and river flows were higher than the flows experienced in 2015, 2016, and 2017.

The capture of American Shad at the fishway in 2018 occurred over a relatively broad range of station operation and discharge conditions this spring (Table 1). Shad were attracted to the tailrace lift at tailrace water elevations ranging from 110.7 ft. to 118.2 ft. Tailrace elevations correspond to unit operation, which varies due to river flow and power demand. Spillway lift operation now occurs with Unit #1 discharging into the spillway and with the use of the additional attraction water supply pipe, simultaneous operation of both the spillway and tailrace fish lifts is now and will continue to be a common occurrence.

Passage of American Shad into Lake Aldred occurred at Holtwood forebay elevations ranging from 164 ft. to 170.7 ft. (Table 1). Spillage was a common occurrence at Holtwood during the 2018 migratory fish passage season, due in part to damaged flash boards (caused by ice and high river flows from February 17 through March 6) and above average river flows that hindered the scheduling of flashboard repair work. Fish passage operations were suspended from May 15 through May 25 due to river flows greater than 100,000 cfs which has historically been a period of strong migration and passage for American Shad.

The hourly passage numbers of American Shad at Holtwood are provided in Table 4. American Shad passage was consistent throughout the day, but strongest from 0900 hrs to 0959 hrs. The highest number of American Shad passed in one hour (76) occurred from 0900 to 0959 hrs on May 5.

Each year, we attempt to qualitatively assess the relative number of shad using the tailrace and spillway lifts by viewing each hopper of fish and estimating the number of shad in each lift as they are sluiced into the trough. We summarized this information by lift, and applied results to the daily shad passage count. We determined the number of shad captured by each lift and/or the percentage of daily passage that was attributable to each lift. Based on this assessment, 853 and 630 shad were captured in the tailrace and spillway lifts over the total operating period in spring, 2018, respectively (Table 3). The percentage of American Shad passed by the spillway lift in recent years continues to be higher than those years of operation prior to the modifications made in the Piney Channel during redevelopment activities.

3.3 Other Alosids

In 2018, American Shad was the only Alosa species captured and passed at Holtwood this season.

3.4 Maryland DNR tag-recapture

For most of the spring migratory fish passage season, water clarity was subpar due to above average river flows, with visibility at the viewing window generally ranging from 12 to 18 inches. The viewing technicians identified 1 American Shad with an attached Maryland DNR blue floy tag in 2018, from this year's tagging efforts downstream of Conowingo Dam. The floy-tagged American Shad was observed on May 13.

3.5 American Shad Passage Evaluation

In spring 2018, our fishway evaluation efforts focused on maximizing the passage of American Shad at both the tailrace and spillway lifts with minimal interruptions to passage operations due to equipment breakdowns or malfunctions. Two mechanical issues occurred prior to and after the American Shad migratory season. The Holtwood maintenance team identified a need to make an adjustment to both the tailrace and spillway hoppers on April 16. The facility was out of service on April 17 to make the necessary adjustments. On June 9, during the third tailrace lift, the tailrace hopper experienced a speed fault on the hopper hoist controls. The repair crew investigated and discovered that the control circuit board needed to be replaced. The required parts were ordered and then installed on June 18. The tailrace lift was placed back in service on June 19. A total of 57 hours of resident fish passage operation was lost due to these 2 malfunctions.

We started spring resident fish passage operations on April 2, with suspension to operations on April 17 due to repairs of both fishway hoppers, and from April 18 to 21 due to river flows exceeding

100,000 cfs. We then operated in resident fish passage mode from April 22 to 29, switching to migratory fish passage mode on April 30 due to the increased passage of American Shad at Conowingo (113 on April 29). Migratory fish passage operations were suspended due to high river flows from May 15 through May 25. During the entire spring fish passage season (74 days), the tailrace lift operated on 65 days while the spillway lift operated on 72 days.

We present a summary of American Shad passage at three river flow ranges in Table 5. A low, stable, river flow appears to be critical for enhancing American Shad passage rates. We documented 94% of American Shad passed at river flows less than 40,000 cfs, with 3% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. The remaining 3% of shad were passed when river flows were greater than 60,000 cfs. During migratory fish passage operations in 2018, river flows ranged from 35,300 cfs to 144,000 cfs; a much higher range of flows than observed during the 3 prior seasons.

The 2018 American Shad passage rate at Holtwood (20.9% of American Shad passing Conowingo passed Holtwood) was well below the historical average (31.4%) observed from Holtwood since 1997 (Table 6). The American Shad passage season at Holtwood appeared to be hampered by the higher river flows experienced during the spring season.

We seek to optimize future migratory fish passage operations by continuing to improve upon the maintenance and operation of the facility with local Brookfield employees.

4.0 Resident Fish Passage

4.1 Spring

During spring, 2018, resident fish passage operations were conducted from April 2 through April 29 (excepting April 17 through April 21) and again from June 7 through June 30. The facility operated 6 hours per day from 0900 to 1500 hrs per the settlement agreement. A total of 10,011 fish of 19 taxa was collected and passed during resident fish passage operations this spring (Table 7). We compared the passage of 7 resident species (smallmouth bass, walleye, channel catfish, shorthead redhorse, quillback, carp, and gizzard shad) passed during resident passage periods to passage of those same species during the migratory passage season (Table 8). During spring, 2018, nearly 94% of the total resident fish observed were passed during the migratory fish passage season.

4.2 Fall

Fall 2018 resident fish passage operations were conducted with both the tailrace and spillway fish lifts but operations occurred on only 6 days in September due to persistent high river flows greater than 100,000 cfs and the mechanical failure of Gate 9 (Table 9). During 6 days of operation, a total of 1,364 fish comprised of 9 species were passed (Table 10). Comely shiner (900) accounted for nearly 66% of the total catch. Channel catfish (201) and smallmouth bass (198) combined comprised an additional 29% of the total catch. It is anticipated that all repairs to the fish passage facility will be completed before commencement of fish passage operations on April 1, 2019.

5.0 Maintenance Performed in 2018

Pre-season maintenance included calibration and replacement of some instrumentation and valve feedback boards. Maintenance and calibration allowed the lifts to be run in automatic mode. All of the MOV limits were tested and set to the proper locations. All entrance Gates were calibrated and the limits were set. A pre-season drawdown inspection was performed with Resource Agency personnel on site. Debris was removed from the lift where needed. The cross beams on the entrance gates were also removed as requested by the Resource Agencies. During mid-season, the tailrace hopper hoist was realigned to reduce vibration and increase the life of the hopper lifting equipment.

6.0 Recommendations

1. Continue to improve the current maintenance program to identify additional equipment maintenance inspection and testing activities to reduce in-season disruptions to operation. Unusual conditions, (e.g. severe flood events and additional operating requirements) require a more thorough review of the impacts to the equipment.

2. Continue, as a routine part of fishway operation, a maintenance program that includes periodic scheduled drawdowns and cleaning of the exit channel as necessary, inspections of picket screens, and daily checks of crowder and hopper doors. Routine maintenance activities minimize disruption of fishway operation.

7.0 Literature Cited

Normandeau Associates, Inc. 1998. Summary of operation at the Holtwood Fish Passage Facility in 1997. Report prepared for PPL, Inc., Allentown, PA.

Normandeau Associates, Inc. 1999. Summary of the operation at the Holtwood Fish Passage Facility in 1998. Report prepared for PPL, Inc., Allentown, PA.

Figures

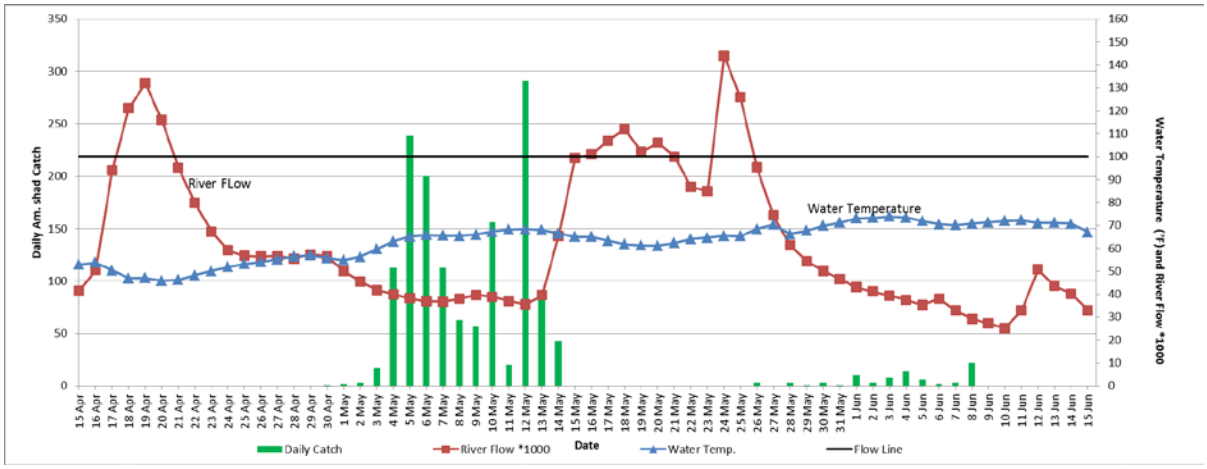

Figure 1. A plot of river flow (USGS Marietta Gauge) and water temperature (°F) in relation to the daily American Shad catch at the Holtwood Fish Passage Facility, spring 2018.

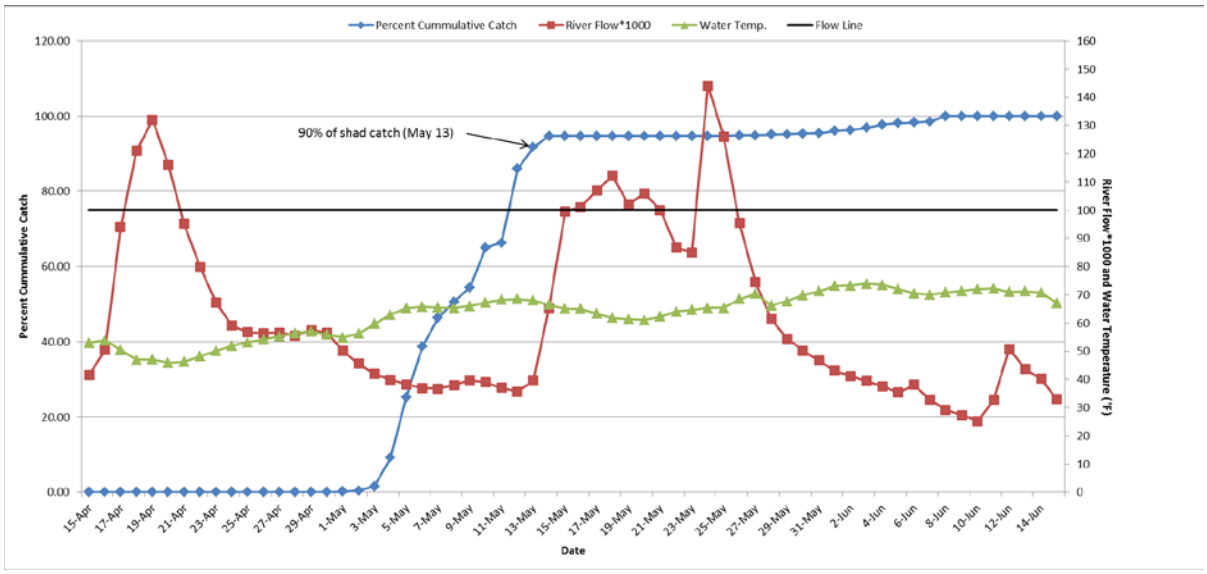

Figure 2. A plot of river flow (x 1000 cfs) and water temperature (°F) in relation to the percent cumulative American Shad catch at the Holtwood Fish Passage Facility, spring 2018.

Tables

Table 1. Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in spring, 2018.

Date	River Flow (cfs)	Ave. Water Temp. (°F)	Secchi (in)	Total # of Units	Weir Gate Operation A	B	C	Elevation (ft) Forebay	Tailrace	Spillway
1 Apr	61,700									
2 Apr	93,100	48.2	30	12	X	X	X	171	118	124
3 Apr	89,100	46.4	30	12	X	X	X	171	118	123.3
4 Apr	88,000	44.9	8	12	X	X	X	170.3	118.3	130.5
5 Apr	91,300	44.2	6	5	X	X		172	114.3	127.7
6 Apr	94,900	44.3	10	11	X	X		172	115.4	126.4
7 Apr	89,200	44.9	10	5	X	X	X	173	113.9	129.4
8 Apr	83,300	44.8	18-24	12	X	X	X	170.3	117.4	122
9 Apr	74,800	44.4	18-24	12	X	X	X	170.2	117	121.8
10 Apr	65,700	44.5	22	12	X	X	X	169	116.8	120.5
11 Apr	58,400	44.8	24	12	X	X	X	167.5	117.1	120
12 Apr	52,400	45.8	24	12	X	X	X	166.1	116.8	120
13 Apr	47,900	47.4	24	12	X	X	X	166	117	119
14 Apr	44,300	49.8	24	12	X	X	X	166.4	114.5	118
15 Apr	41,500	53.0	28	11	X	X	X	165.2	114.9	118.9
16 Apr	50,500	53.8	26	11	X	X	X	165.9	115.7	119.5
17 Apr	94,000	50.4								
18 Apr	121,000	47.0								
19 Apr	132,000	47.1								
20 Apr	116,000	45.9								
21 Apr	95,200	46.2								
22 Apr	79,800	48.3	15	12	X	X	X	169.8	117.1	121.2
23 Apr	67,300	50.1	18	10	X	X	X	169.5	115	120.8
24 Apr	59,100	51.9	18	12	X	X	X	167.6	116.8	120.2
25 Apr	56,700	53.2	18	12	X	X	X	166.4	116.4	118.6
26 Apr	56,400	54.1	18	12	X	X	X	171	113.8	124
27 Apr	56,600	55.3	18	12	X	X	X	168.4	116.1	120.7
28 Apr	55,500	56.4	18	12	X	X	X	165.7	115.4	120
29 Apr	57,400	57.0	18	12	X	X	X	166.7	115.4	120
30 Apr	56,600	55.8	18	12	X	X	X	168.3	115.9	120
1 May	50,100	54.9	18	12	X	X	X	167.3	115.8	120
2 May	45,600	56.3	18	12	X	X	X	165	114.8	120
3 May	41,900	59.7	18	12	X	X	X	164.7	114.3	118.2
4 May	39,900	63.0	18	12	X	X	X	164.7	113.7	118.3
5 May	38,200	65.2	18	11	X	X	X	164.7	113	118.7
6 May	36,900	65.8	18	12	X	X	X	164.7	112.4	118
7 May	36,700	65.5	18	10	X	X	X	164.2	113.1	118.6
8 May	38,000	65.4	18	9	X	X	X	164.3	112.9	119
9 May	39,700	66.0	18	10	X	X	X	164.3	112.9	117.9
10 May	38,900	67.3	18	9	X	X	X	164.3	113	118
11 May	37,000	68.2	18	9	X	X	X	164	113	118.2
12 May	35,600	68.4	18	8	X	X	X	169.1	110.7	118.5
13 May	39,600	68.0	16	11	X	X	X	168	113.5	119.2

Table 1. (Continued)

Date	River Flow (cfs)	Ave. Water Temp. (°F)	Secchi (in)	Total # of Units	Weir Gate Operation A	Weir Gate Operation B	Weir Gate Operation C	Elevation (ft) Forebay	Elevation (ft) Tailrace	Elevation (ft) Spillway
14 May	65,400	66.5	16	12	X	X	X	168.7	115.2	118.7
15 May	99,500	65.0								
16 May	101,000	65.0								
17 May	107,000	63.3								
18 May	112,000	61.8								
19 May	102,000	61.3								
20 May	106,000	61.1								
21 May	100,000	62.3								
22 May	86,700	64.1								
23 May	85,000	64.6								
24 May	144,000	65.4								
25 May	126,000	65.3								
26 May	95,400	68.4	6	12	X	X	X	170.7	118.2	131.6
27 May	74,700	70.4	8	12	X	X	X	170.4	117	121.3
28 May	61,400	66.2	14	12	X	X	X	169.6	116.4	121.6
29 May	54,400	67.7	12	11	X	X	X	169.6	114.3	122.4
30 May	50,200	69.8	12	10	X	X	X	169	114.7	120
31 May	46,600	71.2	12	8	X	X	X	169	114.4	119.9
1 Jun	43,000	73.1	12	8	X	X	X	168.3	114.5	120
2 Jun	41,200	73.3	22-6	11	X	X	X	168.6	114.7	120
3 Jun	39,400	73.9	8	12	X	X	X	169.5	114.5	118.8
4 Jun	37,600	73.5	12	11	X	X	X	169	114.8	119.8
5 Jun	35,300	72.0	8	11	X	X	X	169	114.3	119
6 Jun	38,100	70.5	12	11	X	X	X	169	114.3	118.3
7 Jun	32,800	70.1	15	9	X	X	X	169	112.4	118
8 Jun	29,200	70.8	16	10	X	X	X	169.5	112	118.2
9 Jun	27,300	71.3	10	8	X	X	X	169.8	112	118.8
10 Jun	25,200	72.0	12	8			X	169	112	118.7
11 Jun	32,800	72.2	10	10			X	169.3	112	119.2
12 Jun	50,800	71.0	6	12			X	169.3	116.7	119.7
13 Jun	43,600	71.2	10	11			X	168.2	113.7	118.9
14 Jun	40,200	70.8	11	11			X	168.5	114.6	119.6
15 Jun	33,000	67.1	12	10			X	169	113.4	120
16 Jun	28,300	73.1	12	8			X	169	111	118.8
17 Jun	25,300	74.4	10	8			X	168.4	110.2	119.1
18 Jun	22,300	75.8	12	8			X	168.4	111	118
19 Jun	21,000	78.4	14	10	X	X	X	164	109	118.7
20 Jun	20,600	76.1	16	10	X	X	X	164	110.7	119
21 Jun	21,000	77.0	18	7	X	X	X	164	110.2	118.8
22 Jun	20,900	80.0	16	7	X	X	X	168.6	111.5	118.3
23 Jun	25,800	79.1	16	7	X	X	X	169	110.5	118
24 Jun	24,500	78.3	18	7	X	X	X	169	110.5	119
25 Jun	26,800	77.0	12	5	X	X	X	168.8	110.8	119
26 Jun	25,300	76.0	12	7	X	X	X	168.9	111.2	118.1
27 Jun	23,000	74.4	14	9	X	X	X	168.9	110.8	118.1
28 Jun	25,200	77.0	18	9	X	X	X	169	111.1	119
29 Jun	32,500	76.2	14	11	X	X	X	169	113	119
30 Jun	26,200	78.7	14	11	X	X	X	168.6	112.2	118.6

Table 2. Summary of daily fish passage at Holtwood during the American Shad passage season (April 30 - June 6) in spring, 2018.

Date	4/30	5/1	5/2	5/3	5/4	5/5	5/6	5/7	5/8	5/9
Hours of Operation-Tailrace:	8.7	9.7	9.7	9.8	9.7	9.8	10.3	9.8	9.7	9.8
Number of Lifts - Tailrace	10	11	10	12	12	13	12	12	11	12
Hours of Operation - Spillway:	8.8	9.8	9.8	9.8	9.6	9.7	10.2	9.7	9.8	9.7
Number of Lifts - Spillway:	11	12	14	12	12	13	12	12	11	12
Water Temperature (F)	55.8	54.9	56.3	59.7	63.0	65.2	65.8	65.5	65.4	66.0
American shad	1	2	3	17	113	239	200	113	63	57
Hickory shad										
Blueback herring										
Alewife										
Gizzard shad	1,135	1,945	2,905	5,550	8,734	10,640	10,804	10,219	2,460	6,031
American eel										
Sea lamprey				1						
Brown trout				1	1					
Rainbow trout								1		
Muskellunge						1				
Carp				1	8	6	10	18	15	4
Quillback										
Shorthead redhorse	4	1	18	55	86	36	99	35	12	13
Channel catfish	2							2	1	
Flathead catfish										
Striped bass										
Rock bass										
Redbreast sunfish										
Green sunfish										
Bluegill						1				
Smallmouth bass	6	2	38	167	60	95	187	61	23	29
Largemouth bass										
Walleye	4				2	2	10		4	2
Tiger musky							1			
Daily Totals	**1,152**	**1,950**	**2,964**	**5,792**	**9,004**	**11,020**	**11,311**	**10,449**	**2,578**	**6,136**

Table 2. (Continued)

Date	5/10	5/11	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19
Hours of Operation-Tailrace:	9.8	9.6	9.7	9.7	9.4					
Number of Lifts - Tailrace	12	11	15	11	11					
Hours of Operation - Spillway:	9.6	9.3	9.6	9.6	9.7					
Number of Lifts - Spillway:	12	13	11	10	12					
Water Temperature (F)	67.3	68.2	68.4	68.0	66.5	65.0	65.0	63.3	61.8	61.3
American shad	156	20	291	86	43					
Hickory shad										
Blueback herring										
Alewife										
Gizzard shad	4,645	2752	15,422	11,051	10,459					
American eel										
Sea lamprey	1			1						
Brown trout										
Rainbow trout			2							
Muskellunge										
Carp	11	11	2	10	11					
Quillback	1	1		34						
Shorthead redhorse	2	26	30	34	19					
Channel catfish	15	1	7	9	24					
Flathead catfish										
Striped bass										
Rock bass	1			1						
Redbreast sunfish	1									
Green sunfish		1								
Bluegill			1							
Smallmouth bass	57	4	77	17	25					
Largemouth bass			1							
Walleye	7	4	10	28	6					
Tiger musky										
Daily Totals	**4,897**	**2,820**	**15,843**	**11,271**	**10,587**	**0**	**0**	**0**	**0**	**0**

Table 2. (Continued)

Date	5/20	5/21	5/22	5/23	5/24	5/25	5/26	5/27	5/28	5/29
Hours of Operation-Tailrace:							9.5	9.6	9.7	9.7
Number of Lifts - Tailrace							10	10	10	10
Hours of Operation - Spillway:							9.4	9.7	9.8	9.8
Number of Lifts - Spillway:							9	10	10	10
Water Temperature (F)	61.1	62.3	64.1	64.6	65.4	65.3	68.4	70.4	66.2	67.7
American shad							3	0	3	1
Hickory shad										
Blueback herring										
Alewife										
Gizzard shad							1,482	5,791	5,917	2,924
American eel								1		
Sea lamprey										
Brown trout										
Rainbow trout										
Muskellunge										
Carp								1	5	1
Quillback									1	
Shorthead redhorse								1	1	
Channel catfish							4	8	25	21
Flathead catfish										1
Striped bass										
Rock bass										
Redbreast sunfish										
Green sunfish										
Bluegill										
Smallmouth bass									3	3
Largemouth bass										
Walleye								2		5
Tiger musky										
Daily Totals	**0**	**0**	**0**	**0**	**0**	**0**	**1,489**	**5,804**	**5,955**	**2,956**

Table 2. (Continued)

Date	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	Season Totals
Hours of Operation-Tailrace:	9.8	9.9	9.8	9.8	9.8	9.6	9.7	9.8	261.9
Number of Lifts - Tailrace	11	12	10	10	10	10	11	11	300.0
Hours of Operation - Spillway:	9.8	9.8	9.8	9.7	9.7	9.7	9.7	9.9	261.5
Number of Lifts - Spillway:	11	11	11	10	10	10	10	10	301.0
Water Temperature (F)	69.8	71.2	73.1	73.3	73.9	73.5	72.0	70.5	
American shad	3	1	10	3	8	14	6	2	1,458
Hickory shad									0
Blueback herring									0
Alewife									0
Gizzard shad	2,543	2,217	4,490	4,270	11,899	1,109	425	165	147,984
American eel									1
Sea lamprey									3
Brown trout									2
Rainbow trout									3
Muskellunge									1
Carp	8	16	3	11	52	40	29	25	298
Quillback	2				7	3			49
Shorthead redhorse		5	2		2				481
Channel catfish	29	48	8	58	30	40	34	16	382
Flathead catfish									1
Striped bass			1						1
Rock bass									2
Redbreast sunfish									1
Green sunfish									1
Bluegill			2				1		5
Smallmouth bass	5	10			4	7	1	1	882
Largemouth bass									1
Walleye	1	14	5	1	11	1	1	1	121
Tiger musky									1
Daily Totals	**2,591**	**2,311**	**4,521**	**4,343**	**12,013**	**1,214**	**497**	**210**	**151,678**

Table 3. Visually derived estimate of the American Shad catch in the tailrace and spillway lifts at the Holtwood Power Station in spring, 2018.

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
1-Apr					
2-Apr	0	0	0		
3-Apr	0	0	0		
4-Apr	0	0	0		
5-Apr	0	0	0		
6-Apr	0	0	0		
7-Apr	0	0	0		
8-Apr	0	0	0		
9-Apr	0	0	0		
10-Apr	0	0	0		
11-Apr	0	0	0		
12-Apr	0	0	0		
13-Apr	0	0	0		
14-Apr	0	0	0		
15-Apr	0	0	0		
16-Apr	0	0	0		
17-Apr	0	0	0		
18-Apr	0	0	0		
19-Apr	0	0	0		
20-Apr	0	0	0		
21-Apr	0	0	0		
22-Apr	0	0	0		
23-Apr	0	0	0		
24-Apr	0	0	0		
25-Apr	0	0	0		
26-Apr	0	0	0		
27-Apr	0	0	0		
28-Apr	0	0	0		
29-Apr	0	0	0		
30-Apr	1	1	0	100%	0%
1-May	2	2	0	100%	0%
2-May	3	3	0	100%	0%
3-May	17	9	8	53%	47%
4-May	113	56	57	50%	50%
5-May	239	122	117	51%	49%
6-May	200	120	80	60%	40%
7-May	113	55	58	49%	51%
8-May	63	0	63	0%	100%
9-May	57	0	57	0%	100%
10-May	156	78	78	50%	50%
11-May	20	20	0	100%	0%
12-May	291	233	58	80%	20%
13-May	86	69	17	80%	20%

Table 3. (Continued)

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
14-May	43	22	21	51%	49%
15-May					
16-May					
17-May					
18-May					
19-May					
20-May					
21-May					
22-May					
23-May					
24-May					
25-May					
26-May	3	3	0	100%	0%
27-May	0	0	0		
28-May	3	3	0	100%	0%
29-May	1	1	0	100%	0%
30-May	3	3	0	100%	0%
31-May	1	1	0	100%	0%
1-Jun	10	8	2	80%	20%
2-Jun	3	3	0	100%	0%
3-Jun	8	8	0	100%	0%
4-Jun	14	14	0	100%	0%
5-Jun	6	6	0	100%	0%
6-Jun	2	2	0	100%	0%
7-Jun	3	2	1	67%	33%
8-Jun	22	9	13	41%	59%
9-Jun	0	0	0		
10-Jun	0	0	0		
11-Jun	0	0	0		
12-Jun	0	0	0		
13-Jun	0	0	0		
14-Jun	0	0	0		
15-Jun	0	0	0		
16-Jun	0	0	0		
17-Jun	0	0	0		
18-Jun	0	0	0		
19-Jun	0	0	0		
20-Jun	0	0	0		
21-Jun	0	0	0		
22-Jun	0	0	0		
23-Jun	0	0	0		
24-Jun	0	0	0		
25-Jun	0	0	0		

Table 3. (Continued)

Date	Shad Catch	Number Collected		Percent Collected	
		Tailrace	Spillway	Tailrace	Spillway
26-Jun	0	0	0		
27-Jun	0	0	0		
28-Jun	0	0	0		
29-Jun	0	0	0		
30-Jun	0	0	0		
Total	***1,483***	***853***	***630***	***58%***	***42%***

Table 4. Hourly summary of American Shad passage at the Holtwood fish passage facility in 2018 (April 30 - June 8).

DATE	4/30	5/1	5/2	5/3	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11	5/12	5/13
Viewing Time (Start)	9:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00
Viewing Time (End)	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00
Viewing Time (hrs)	9.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Water Temp.(°F)	55.8	54.9	56.3	59.7	63.0	65.2	65.8	65.5	65.4	66.0	67.3	68.2	68.4	68.0
Military Time (hrs)														
0600 to 0659														
0700 to 0759														
0800 to 0859		0	0	0	10	36	37	4	0	0	3	0	43	24
0900 to 0959	0	0	0	1	22	76	28	4	1	4	11	1	22	29
1000 to 1059	0	0	0	3	16	22	31	12	2	6	18	2	15	14
1100 to 1159	0	0	0	0	21	18	17	17	1	3	29	2	8	2
1200 to 1259	0	0	1	1	12	14	18	25	9	5	15	2	22	3
1300 to 1359	0	0	1	2	8	13	20	6	9	5	16	0	38	1
1400 to 1459	0	0	0	5	4	11	9	19	15	10	33	3	19	3
1500 to 1559	1	0	0	1	6	24	14	13	17	17	19	4	17	4
1600 to 1659	0	2	0	1	11	11	15	6	6	5	11	3	52	3
1700 to 1759	0	0	1	3	3	14	11	7	3	2	1	3	55	3
1800 to 1859														
1900 to 1959														
2000 to 2059														
Total	**1**	**2**	**3**	**17**	**113**	**239**	**200**	**113**	**63**	**57**	**156**	**20**	**291**	**86**

Table 4. (Continued)

DATE	5/14	5/15	5/16	5/17	5/18	5/19	5/20	5/21	5/22	5/23	5/24	5/25	5/26	5/27
Viewing Time (Start)	8:00												8:00	8:00
Viewing Time (End)	18:00												18:00	18:00
Viewing Time (hrs)	10.0												10.0	10.0
Water Temp.(°F)	66.5	65.0	65.0	63.3	61.8	61.3	61.1	62.3	64.1	64.6	65.4	65.3	68.4	70.4
Military Time (hrs)														
0600 to 0659														
0700 to 0759														
0800 to 0859	4												0	0
0900 to 0959	3												0	0
1000 to 1059	1												0	0
1100 to 1159	1												0	0
1200 to 1259	4												0	0
1300 to 1359	7												0	0
1400 to 1459	4												0	0
1500 to 1559	16												0	0
1600 to 1659	3												0	0
1700 to 1759	0												3	0
1800 to 1859														
1900 to 1959														
2000 to 2059														
Total	**43**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**

Table 4. (Continued)

DATE	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8		***Season Totals***
Viewing Time (Start)	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	8:00	9:00	9:00		
Viewing Time (End)	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	18:00	15:00	15:00		
Viewing Time (hrs)	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	6.0	6.0		**281.0**
Water Temp.(°F)	66.2	67.7	69.8	71.2	73.1	73.3	73.9	73.5	72.0	70.5	70.1	70.8		
Military Time (hrs)														
0600 to 0659														**0**
0700 to 0759														**0**
0800 to 0859	2	1	0	0	0	0	0	1	0	0				**165**
0900 to 0959	0	0	0	1	0	0	1	0	0	0	0	9		**213**
1000 to 1059	0	0	0	0	2	0	2	0	0	0	0	0		**146**
1100 to 1159	0	0	0	0	1	2	0	3	0	0	1	3		**129**
1200 to 1259	0	0	0	0	0	0	1	3	1	0	0	5		**141**
1300 to 1359	0	0	0	0	2	1	2	0	1	0	1	3		**136**
1400 to 1459	1	0	1	0	1	0	1	0	0	0	1	2		**142**
1500 to 1559	0	0	1	0	3	0	1	4	2	2				**166**
1600 to 1659	0	0	0	0	1	0	0	2	1	0				**133**
1700 to 1759	0	0	1	0	0	0	0	1	1	0				**112**
1800 to 1859														**0**
1900 to 1959														**0**
2000 to 2059														**0**
Total	**3**	**1**	**3**	**1**	**10**	**3**	**8**	**14**	**6**	**2**	**3**	**22**		**1,483**

Table 5. Holtwood fishway summary table evaluating American Shad passage at three river flow ranges (1997-2018).

	1997	1998*	1999	2000*	2001	2002*	2003*	2004*	2005	2006	2007
Migration season start date	18 Apr	27 Apr	25 Apr	06 May	27 Apr	15 Apr	28 Apr	26 Apr	27 Apr	11 Apr	01 May
Migration season end date	14 Jun	12 Jun	03 Jun	14 Jun	08 Jun	07 Jun	02 Jun	03 Jun	10 Jun	06 Jun	04 Jun
Season duration (days)	58	47	40	40	43	55	36	39	45	57	35
Number of days of operation	55	41	40	36	42	35	34	39	36	57	35
Am. shad season total (Conowingo)	90,971	39,904	69,712	153,546	193,574	108,001	125,135	109,360	68,926	56,899	25,464
Am. shad season total (Holtwood)	28,063	8,235	34,702	29,421	109,976	17,522	25,254	3,428	34,189	35,968	10,338
River flow ≤40,000 cfs											
Number of days	48	22	34	19	40	19	15	2	33	48	27
Percent of season	87%	54%	85%	53%	95%	54%	44%	5%	92%	84%	77%
No. of Am. shad passed	26,201	7,512	34,069	19,712	109,342	10,322	20,229	2	34,060	35,302	9,549
Daily ave. of Am. shad passed	546	341	1,002	1,037	2,733	543	1,348	1	1,032	735	354
Percent of total passage	93%	91%	98%	67%	99%	59%	80%	0%	99.6%	98.1%	92.3%
River flow 40,001 to 60,000 cfs											
Number of days	7	2	6	12	2	14	18	20	3	5	8
Percent of season	13%	5%	15%	33%	5%	40%	53%	51.3%	8%	9%	23%
No. of Am. shad passed	1,862	230	633	9,536	634	7,029	5,019	1,943	129	566	789
Daily ave. of Am. shad passed	266	115	106	795	317	502	279	97	43	113	99
Percent of Total Passage	7%	3%	2%	32%	1%	40%	19.8%	56.7%	0.4%	1.6%	7.6%
River flow >60,000 cfs											
Number of days	0	17	0	5	0	2	1	17	0	4	0
Percent of season	0%	41%	0%	14%	0%	6%	3%	43.6%	0%	7%	0%
No. of Am. shad passed	0	493	0	173	0	171	6	1,483	0	100	0
Daily ave. of Am. shad passed	0	29	0	35	0	86	6	87	0	25	0
Percent of total passage	0%	6%	0%	1%	0%	1%	0.02%	43.3%	0.0%	0.3%	0.0%

Table 5. (Continued)

	2008*	2009*	2010	2011*	2012	2013	2014*	2015	2016	2017*	2018*
Migration season start date	21 Apr	03 May	21 Apr	20 May	07 Apr	29-Apr	27-Apr	1-May	21-Apr	18-Apr	30-Apr
Migration season end date	09 Jun	07 Jun	09 Jun	05 Jun	05 Jun	5-Jun	8-Jun	2-Jun	8-Jun	7-Jun	6-Jun
Season duration (days)	50	36	50	17	60	38	43	33	49	51	38
Number of days of operation	49	36	48	10	58	38	37	33	49	44	27
Am. shad season total (Conowingo)	19,914	29,272	37,757	20,571	22,143	12,733	10,425	8,341	14,276	16,248	6,992
Am. shad season total (Holtwood)	2,795	10,896	16,472	21	4,238	2,503	2,589	5,286	6,696	3,169	1,458
River flow ≤40,000 cfs											
Number of days	20	20	40	0	31	34	16	31	42	13	14
Percent of season	40%	56%	83%	0%	53%	89%	37%	94%	86%	29%	52%
No. of Am. shad passed	2,242	8,939	15,606	0	3260	2,355	2248	5203	6,071	1,516	1,368
Daily ave. of Am. shad passed	112	447	372	0	105	70	141	168	144	117	97
Percent of total passage	80.2%	82%	95%	0%	77%	94%	87%	98%	91%	48%	94%
River flow 40,001 to 60,000 cfs											
Number of days	22	14	8	2	18	4	12	2	7	17	9
Percent of season	44%	39%	17%	12%	30.0%	11%	28%	6%	14%	39%	33%
No. of Am. shad passed	533	1,846	866	0	967	148	314	83	625	1,430	41
Daily ave. of Am. shad passed	24	132	108	0	54	37	26	41	89	84	4
Percent of Total Passage	19.0%	17.0%	5%	0.0%	22.8%	5.9%	12.0%	2.0%	9.0%	45%	3.0%
River flow >60,000 cfs											
Number of days	8	2	0	15	4	0	15	0	0	14	4
Percent of season	16%	5%	0%	88%	6.7%	0.0%	34.9%	0.0%	0.0%	32%	15%
No. of Am. shad passed	20	111	0	21	11	0	27	0	0	223	49
Daily ave. of Am. shad passed	2	55	0	2	3	0	2	0	0	16	12
Percent of total passage	0.7%	1.0%	0%	100%	0.3%	0.0%	1.0%	0.0%	0.0%	7.0%	3.0%

* Denotes seasons of high river flow or frequent spillage.

Table 6. Summary of American Shad passage counts and percent passage values at Susquehanna River dams, 1997-2018.

	Conowingo East	Holtwood		Safe Harbor		York Haven	
		Number	% of C.E.L.	Number	% of Holt.	Number	% of S.H.
1997	90,971	28,063	30.8%	20,828	74.2%	-	-
1998	39,904	8,235	20.6%	6,054	73.5%	-	-
1999	69,712	34,702	49.8%	34,150	98.4%	-	-
2000	153,546	29,421	19.2%	21,079	71.6%	4,687	22.2%
2001	193,574	109,976	56.8%	89,816	81.7%	16,200	18.0%
2002	108,001	17,522	16.2%	11,705	66.8%	1,555	13.3%
2003	125,135	25,254	20.2%	16,646	65.9%	2,536	15.2%
2004	109,360	3,428	3.1%	2,109	61.5%	219	10.4%
2005	68,926	34,189	49.6%	25,425	74.4%	1,772	7.0%
2006	56,899	35,968	63.2%	24,929	69.3%	1,913	7.7%
2007	25,464	10,338	40.6%	7,215	69.8%	192	2.7%
2008	19,914	2,795	14.0%	1,252	44.8%	21	1.7%
2009	29,272	10,896	37.2%	7,994	73.4%	402	5.0%
2010	37,757	16,472	43.6%	12,706	77.1%	907	7.1%
2011	20,571	21	0.1%	8	38.1%	0	0.0%
2012	22,143	4,238	19.1%	3,089	72.9%	224	7.3%
2013	12,733	2,503	19.7%	1,927	77.0%	202	10.5%
2014	10,425	2,589	24.8%	1,336	51.6%	8	0.6%
2015	8,341	5286*	63.3%	3,896	73.7%	43	1.1%
2016	14,276	6,718	47.0%	4,242	63.1%	178	4.2%
2017	16,265	3,170	19.5%	2,007	63.3%	62	3.1%
2018*	**6,992**	**1,458**	**20.9%**	**661**	**45.3%**	**NA**	**NA**

*Am. Shad passed at Holtwood from April 30 to June 6.

Table 7. Daily summary of Holtwood fish passage prior to, during, and after the American Shad passage season (2 April to 30 June) in spring, 2018.

DATE	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18
Hours of Operation - Tailrace		5.8	5.8	5.8	6.0	5.8	6.0	5.7	5.7	5.8	5.7	5.8	5.9	5.8	5.8	5.8		
Number of Lifts - Tailrace		7	8	8	7	6	7	7	6	8	6	5	6	6	6	7		
Hours of Operation - Spillway		5.8	5.9	3.5	0.0	0.0	5.8	5.8	5.8	5.7	0.8	5.8	5.8	5.7	5.8	5.8		
Number of Lifts - Spillway		7	7	4	0	0	6	6	6	7	1	6	6	6	8	7		
Water Temperature (°F)		48.2	46.4	44.9	44.2	44.3	44.9	44.8	44.4	44.5	44.8	45.8	47.4	49.8	53.0	53.8	50.4	47.0
American shad		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Hickory shad																		
Blueback herring																		
Alewife																		
Gizzard shad		6	5	3	3	5	8	4	3	2	0	27	31	110	208	244		
American eel																		
Sea lamprey																		
Brown trout																		
Rainbow trout																		
Muskellunge																		
Carp																		
Quillback																		
White sucker																		
Shorthead redhorse		2	1	1								1				1		
Channel catfish																		
Flathead catfish																		
Striped bass																		
Rock bass		1																
Redbreast sunfish																		
Green sunfish																		
Bluegill																		
Smallmouth bass		2	1											1	12	24		
Largemouth bass																		
Yellow perch		1		1														
Walleye			3						1	1								
Tessellated darter									1									
Tiger musky																		
Banded darter					2	1												
Totals	**0**	**12**	**10**	**5**	**5**	**6**	**8**	**4**	**5**	**3**	**0**	**28**	**31**	**111**	**220**	**269**	**0**	**0**

Table 7. (Continued)

DATE	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/5	5/6
Hours of Operation - Tailrace				5.8	5.9	5.9	5.8	5.9	5.8	4.8	6.2	8.7	9.7	9.7	9.8	9.7	9.8	10.3
Number of Lifts - Tailrace				7	7	7	8	8	7	5	7	10	11	10	12	12	13	12
Hours of Operation - Spillway				5.8	5.8	5.8	5.8	5.8	5.9	4.8	6.1	8.8	9.8	9.8	9.8	9.6	9.7	10.2
Number of Lifts - Spillway				7	8	8	7	7	8	6	8	11	12	14	12	12	13	12
Water Temperature (°F)	47.1	45.9	46.2	48.3	50.1	51.9	53.2	54.1	55.3	56.4	57.0	55.8	54.9	56.3	59.7	63.0	65.2	65.8
American shad				0	0	0	0	0	0	0	0	1	2	3	17	113	239	200
Hickory shad																		
Blueback herring																		
Alewife																		
Gizzard shad				151	75	107	121	308	564	3,533	1,534	1,135	1,945	2,905	5,550	8,734	10,640	10,804
American eel																		
Sea lamprey															1			
Brown trout															1	1		
Rainbow trout					2			1	1									
Muskellunge																	1	
Carp															1	8	6	10
Quillback											1							
White sucker																		
Shorthead redhorse						2		8	11	7	29	4	1	18	55	86	36	99
Channel catfish						1			1		2	2						
Flathead catfish																		
Striped bass																		
Rock bass										1								
Redbreast sunfish																		
Green sunfish																		
Bluegill					1												1	
Smallmouth bass						4	2	10	25	18	73	6	2	38	167	60	95	187
Largemouth bass									1	1								
Yellow perch																		
Walleye				1					3		1	4				2	2	10
Tessellated darter																		
Tiger musky																		1
Banded darter																		
Totals	**0**	**0**	**0**	**152**	**78**	**114**	**123**	**327**	**606**	**3,560**	**1,640**	**1,152**	**1,950**	**2,964**	**5,792**	**9,004**	**11,020**	**11,311**

Table 7. (Continued)

DATE	5/7	5/8	5/9	5/10	5/11	5/12	5/13	5/14	5/15	5/16	5/17	5/18	5/19	5/20	5/21	5/22	5/23	5/24
Hours of Operation - Tailrace	9.8	9.7	9.8	9.8	9.6	9.7	9.7	9.4										
Number of Lifts - Tailrace	12	11	12	12	11	15	11	11										
Hours of Operation - Spillway	9.7	9.8	9.7	9.6	9.3	9.6	9.6	9.7										
Number of Lifts - Spillway	12	11	12	12	13	11	10	12										
Water Temperature (°F)	65.5	65.4	66.0	67.3	68.2	68.4	68.0	66.5	65.0	65.0	63.3	61.8	61.3	61.1	62.3	64.1	64.6	65.4
American shad	113	63	57	156	20	291	86	43										
Hickory shad																		
Blueback herring																		
Alewife																		
Gizzard shad	10,219	2,460	6,031	4,645	2752	15,422	11,051	10,459										
American eel																		
Sea lamprey				1			1											
Brown trout																		
Rainbow trout	1					2												
Muskellunge																		
Carp	18	15	4	11	11	2	10	11										
Quillback				1	1		34											
White sucker																		
Shorthead redhorse	35	12	13	2	26	30	34	19										
Channel catfish	2	1		15	1	7	9	24										
Flathead catfish																		
Striped bass																		
Rock bass				1			1											
Redbreast sunfish				1														
Green sunfish					1													
Bluegill						1												
Smallmouth bass	61	23	29	57	4	77	17	25										
Largemouth bass						1												
Yellow perch																		
Walleye		4	2	7	4	10	28	6										
Tessellated darter																		
Tiger musky																		
Banded darter																		
Totals	**10,449**	**2,578**	**6,136**	**4,897**	**2,820**	**15,843**	**11,271**	**10,587**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Table 7. (Continued)

DATE	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11
Hours of Operation - Tailrace		9.5	9.6	9.7	9.7	9.8	9.9	9.8	9.8	9.8	9.6	9.7	9.8	6.0	5.7	2.6	0	0
Number of Lifts - Tailrace		10	10	10	10	11	12	10	10	10	10	11	11	6	6	3	0	0
Hours of Operation - Spillway		9.4	9.7	9.8	9.8	9.8	9.8	9.8	9.7	9.7	9.7	9.7	9.9	6.0	5.8	5.8	5.8	5.7
Number of Lifts - Spillway		9	10	10	10	11	11	11	10	10	10	10	10	6	6	6	6	6
Water Temperature (°F)	65.3	68.4	70.4	66.2	67.7	69.8	71.2	73.1	73.3	73.9	73.5	72.0	70.5	70.1	70.8	71.3	72.0	72.2
American shad		3	0	3	1	3	1	10	3	8	14	6	2	3	22	0	0	0
Hickory shad																		
Blueback herring																		
Alewife																		
Gizzard shad		1,482	5,791	5,917	2,924	2,543	2,217	4,490	4,270	11,899	1,109	425	165	104	956	86	32	3
American eel			1															
Sea lamprey																		
Brown trout																		
Rainbow trout																		2
Muskellunge																		
Carp			1	5	1	8	16	3	11	52	40	29	25	4	4	4	7	3
Quillback				1		2				7	3							
White sucker															1			
Shorthead redhorse			1	1			5	2		2								
Channel catfish		4	8	25	21	29	48	8	58	30	40	34	16	6	7	17	35	43
Flathead catfish					1													
Striped bass								1										
Rock bass																	1	
Redbreast sunfish																		
Green sunfish																		
Bluegill								2				1						1
Smallmouth bass				3	3	5	10			4	7	1	1	3		2	2	
Largemouth bass																		
Yellow perch																		
Walleye			2		5	1	14	5	1	11	1	1	1	1	7	1	3	
Tessellated darter																		
Tiger musky																		
Banded darter																		
Totals	**0**	**1,489**	**5,804**	**5,955**	**2,956**	**2,591**	**2,311**	**4,521**	**4,343**	**12,013**	**1,214**	**497**	**210**	**121**	**997**	**110**	**80**	**52**

Table 7. (Continued)

DATE	6/12	6/13	6/14	6/15	6/16	6/17	6/18	6/19	6/20	6/21	6/22	6/23	6/24	6/25
Hours of Operation - Tailrace	0	0	0	0	0	0	0	5.6	5.7	5.7	5.6	5.8	5.8	5.8
Number of Lifts - Tailrace	0	0	0	0	0	0	0	6	6	6	6	6	6	6
Hours of Operation - Spillway	5.9	5.8	5.8	5.8	5.8	5.7	5.8	5.7	5.8	5.8	5.7	5.8	5.8	5.9
Number of Lifts - Spillway	6	6	8	6	6	6	6	6	6	5	6	6	6	6
Water Temperature (°F)	71.0	71.2	70.8	67.1	73.1	74.4	75.8	78.4	76.1	77.0	80.0	79.1	78.3	77.0
American shad	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hickory shad														
Blueback herring														
Alewife														
Gizzard shad	14	10	4	27	24	129	67	56	193	22	94	84	235	37
American eel														
Sea lamprey														
Brown trout														
Rainbow trout														
Muskellunge							1							
Carp	6	1	1	1		3		1						
Quillback														
White sucker														
Shorthead redhorse														
Channel catfish	4	16	6	1	2	24	4	2			10	30	46	13
Flathead catfish												1		
Striped bass														
Rock bass													1	
Redbreast sunfish														
Green sunfish											2			
Bluegill						1								
Smallmouth bass	1				1		1	1	3		6		3	
Largemouth bass											1			
Yellow perch														
Walleye			1	1	1	2	1				7		2	3
Tessellated darter														
Tiger musky														
Banded darter														
Totals	**25**	**27**	**12**	**30**	**28**	**159**	**74**	**60**	**196**	**22**	**120**	**115**	**287**	**53**

Table 7. (Continued)

DATE	6/26	6/27	6/28	6/29	6/30	**Season Total (Apr 2-June 30)**	**Res. Fish Passage Apr 2-29**	**Res. Fish Passage June 7-30**	**Res. Passage during Am. Shad season Apr. 30-June 6**
Hours of Operation - Tailrace	5.7	5.7	5.7	5.8	5.8	478.2	133.3	83.0	261.9
Number of Lifts - Tailrace	6	6	6	6	6	543	156	87	300
Hours of Operation - Spillway	5.6	5.6	5.8	5.8	5.6	513.9	113.8	138.6	261.5
Number of Lifts - Spillway	6	6	6	6	6	582	136	145	301
Water Temperature (°F)	76.0	74.4	77.0	76.2	78.7				
American shad	0	0	0	0	0	1,483	0	25	1,458
Hickory shad						0	0	0	0
Blueback herring						0	0	0	0
Alewife						0	0	0	0
Gizzard shad	42	9	24	15	7	157,310	7,052	2,274	147,984
American eel						1	0	0	1
Sea lamprey						3	0	0	3
Brown trout						2	0	0	2
Rainbow trout						9	4	2	3
Muskellunge						2	0	1	1
Carp	1		1		1	336	0	38	298
Quillback					2	52	1	2	49
White sucker						1	0	1	0
Shorthead redhorse						544	63	0	481
Channel catfish	1	2	3	8	2	668	4	282	382
Flathead catfish					1	3	0	2	1
Striped bass						1	0	0	1
Rock bass						6	2	2	2
Redbreast sunfish						1	0	0	1
Green sunfish						3	0	2	1
Bluegill						8	1	2	5
Smallmouth bass	1		4		1	1,083	172	29	882
Largemouth bass						4	2	1	1
Yellow perch						2	2	0	0
Walleye				1		162	10	31	121
Tessellated darter						1	1	0	0
Tiger musky						1	0	0	1
Banded darter						3	3	0	0
Totals	**45**	**11**	**32**	**24**	**14**	**161,689**	**7,317**	**2,694**	**151,678**

Table 8. Comparison of resident fish passage prior to, during, and after American Shad passage operations at Holtwood Dam, spring 2018

Total Resident Fish Passed (April 2-June 30)		Res. Fish passed in Am. Shad Season (Apr 30-June 6)		Total Resident Passage Season (April 2-29: June 7-30)		Resident Passage (April 2-29)		Resident Passage (June 7-30)	
Species	Total Passed	# Passed	% of Total Passed	# Passed	% of Total Passed	# Passed	% of Total Passed	# Passed	% of Total Passed
Smallmouth Bass	1,083	882	81.4%	201	18.6%	172	15.9%	29	2.7%
Walleye	162	121	74.7%	41	25.3%	10	6.2%	31	19.1%
Channel Catfish	668	382	57.2%	286	42.8%	4	0.6%	282	42.2%
Shorthead Redhorse	544	481	88.4%	63	11.6%	63	11.6%	0	0.0%
Quillback	52	49	94.2%	3	5.8%	1	1.9%	2	3.8%
Carp	336	298	88.7%	38	11.3%	0	0.0%	38	11.3%
Gizzard shad	157,310	147,984	94.1%	9,326	5.9%	7,052	4.5%	2,274	1.4%

Table 9. Summary of daily average river flow, water temperature, unit operation, fishway weir gate operation, and project water elevations during operation of the Holtwood fish passage facility in Fall, 2018 (Sept. 4, 5, 6, 7, 8, and 10). Fall season ended early due to persistent high river flows and Gate 9 mechanical failure.

Date	River Flow (cfs)	Ave. Water Temp. (°F)	Secchi (in)	Number of Units	Weir Gate Operation			Elevation (ft)		
					A	B	C	Tailrace	Spillway	Forebay
1-Sep	31,000									
2-Sep	25,500									
3-Sep	25,300									
4-Sep	23,100	80.3	16	3-5	X	X	X	111	118	168
5-Sep	21,500	79.3	14	3-4	X	X	X	111	118.5	169
6-Sep	21,100	81.1	14	4-6	X	X	X	110-113	118	169
7-Sep	20,900	82.1	12	6	X	X	X	112	119	169
8-Sep	21,700	82.7	12	3	X	X	X	111	119	169
9-Sep	27,100									
10-Sep	61,100	74.8	8	10	X	X	X	116.5	121	169.5

Table 10. Daily summary of resident fish passage at the Holtwood Fish Passage Facility in fall, 2018 (Sept. 4, 5, 6, 7, 8, and 10). Fall season ended early due to persistent high river flows and Gate 9 mechanical failure.

Date:	*1 Sep*	*2 Sep*	*3 Sep*	*4 Sep*	*5 Sep*	*6 Sep*	*7 Sep*	*8 Sep*	*9 Sep*	*10 Sep*	*11 Sep*	*TOTAL*
Hours of Operation - Tailrace:				5.7	5.6	5.7	5.6	5.6		5.8		34.0
Number of Lifts - Tailrace:				6	7	7	7	6		7		40
Hours of Operation - Spillway:				5.7	5.7	5.6	5.7	5.6		5.8		34.1
Number of Lifts - Spillway:				5	8	6	7	6		7		39
Water Temperature (°F):				79.7	80.4	82.1	82.4	84.2		77.7		
Gizzard shad				25	1		2			10		38
Carp				1			1			1		3
Comely Shiner				900								900
Channel Catfish				1	11	15	92	5		77		201
Bluegill				3	9	4	2	1				19
Smallmouth Bass				15	84	35	55	6		3		198
White Crappie					2							2
Black Crappie					1		1					2
Yellow Perch							1					1
Daily Total	**0**	**0**	**0**	**945**	**108**	**54**	**154**	**12**	**0**	**91**	**0**	**1,364**