SUMMARY OF OPERATIONS AT THE HOLTWOOD FISH PASSAGE FACILITY SPRING AND FALL, 2017

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EXECUTIVE SUMMARY

Per the settlement agreement for the Holtwood Redevelopment Project, 2017 marks the third year of fish passage operations for both resident and migratory fish species. The Holtwood fish passage facility commenced resident fish passage operations on April 13, 2017 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 conducted operating only the tailrace lift in 2017 due to extensive repairs to the spillway lift stemming from a malfunction of the spillway hopper/hoist system on May 24, 2017. The settlement agreement also allows Holtwood to suspend fish passage operations when river flows are ≥ 100,000 cfs during any fish passage season.

We were unable to start spring fish passage operations prior to April 13 due to river flows exceeding 100,000 cfs. We operated in resident fish passage mode from April 13 to 17, switching to migratory fish passage mode on April 18 due to the increased passage of American Shad at Conowingo (423 on April 17). Migratory fish passage operations were interrupted due to high river flows on April 24 and May 6 through 11. Migratory fish passage operations ended on June 7, 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 8 but were quickly suspended per Resource Agency request on June 9, (21 days before scheduled end date of June 30), due to the passage of a Northern snakehead at the Conowingo East Fish Lift into Conowingo Pond on May 20. Spillway lift operations were suspended on May 24 stemming from a malfunction of the hopper and hopper hoist which caused extensive damage to the hopper travel guide beams. The facility operated a total of 51 days between April 13 and June 9, 2017, (Tailrace = 51 days; Spillway = 35 days). Fall fish passage operation was conducted solely with the tailrace fish lift due to the extensive repairs resulting from the spillway malfunction listed previously. This fish passage season marks the twenty-first year of operation at Holtwood.

During the American Shad passage season (44 days of operation from April 18 to June 7), the lifts passed 162,843 fish of 23 taxa and 1 hybrid. Gizzard shad dominated the catch, and comprised 93% of the total fish collected and passed. American Shad and two (2) Alewife represented the *Alosa* species collected and passed at Holtwood in 2017. A total of 3,171 American Shad were passed by the Holtwood fishway in 2017 (3,169 during the "official" shad passage season, with 2 American Shad passed during resident fish passage operations).

The 2017 American Shad passage rate at Holtwood (19.5% of American Shad passing Conowingo passed Holtwood) was the seventh 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 functionality of tailrace entrance Gate A during the spring season.

During spring, 2017, resident fish passage operations were limited to 5 days in April due to high river flows during the first two weeks of the month and only 2 days in June due to the requested shutdown of the facility by the Resource Agencies. The facility operated 6 hours per day from 0900 to 1500 hrs per the settlement agreement. A total of 3,315 fish of 11 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, 2017, 96% 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 the tailrace fish lift only in 2017 due to the spillway fish lift equipment failures described previously. During 32 days of operation, a total of 17,038 fish comprised of 11 species were passed. Minnow species and gizzard shad accounted for nearly 99% of the total catch. It is anticipated that all repairs to the spillway fish lift will be completed before commencement of fish passage operations on April 1, 2018.

This year was the twenty-first 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.

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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 Energy Group) 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 and 2015. This year marked the twenty-first operational season.

Objectives of 2017 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 2017, all Obermeyer gates were operable. Operations began at the Holtwood Fish Lift facility on April 13, 2017 to initiate passage of resident fish species prior to passage of American Shad at Conowingo Dam (Table 1). We were unable to start operations on April 1 due to high river flows in excess of 100,000 cfs from April 1 through 12. American Shad passage operations at Holtwood (10-hr days) were initiated on April 18, one day after the Conowingo East fish lift passed 423 American Shad. River flows greater than 100,000 cfs occurred on April 24 and from May 6 through 11 during fish passage operations in 2017, 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 on 15 of the 51 days (29% of the season) this spring. In 2017, passage operations for migratory fish (American Shad, etc.) ended on June 7, with agency concurrence, due to increasing water temperatures and low American Shad passage. Spring passage operations for resident fish species ended on June 9 instead of the scheduled termination on June 30, due to a request from the Resource Agencies stemming from the passage of a Northern snakehead into Conowingo Pond by the Conowingo East Fish Lift on May 20. A major mechanical malfunction of the spillway hopper hoist system occurred on May 24, preventing continued use of the spillway lift for the remainder of the

spring and the entire fall resident fish passage season. Tailrace Entrance Gate A, which malfunctioned during preseason testing operations and was in the full-open position for most of the spring season, was repaired on June 1 and was functional for the remainder of the spring and entire fall resident fish passage season. Operations during the fall resident fish passage season were limited to the use of the tailrace fish lift only as the spillway lift was undergoing substantial repair work. We anticipate functionality of the entire Holtwood fish lift facility in spring, 2018.

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 2017, 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 were in the closed (up) position during fish passage operations excepting those times when the river flow approached and exceeded 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, 2017: entrances A, B, and C (2 days); entrances A and C (33 days); entrances A and B (10 days); entrance B only (5 days); and entrance A only (1 day).

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. During pre-season testing, entrance Gate A malfunctioned and fell to its lowermost position due to failure of the split nuts. Entrance Gate A remained in the full-open position for most of the season as consistent high river flow prevented the repair crew and dive team to initiate and

complete repairs until June 1. In 2017, Gate C was fully operational during the spring fish passage season.

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, 2017 commenced on April 13 and ended on June 9 (total days of operation = 51). The migratory fish passage season (based on presence of American Shad in the catch) ran from April 18 to June 7 (44 days of operation). Spillway and tailrace lift operations ended on May 24 and June 9, respectively due to two issues; a major mechanical failure of the spillway hopper hoist system and the Resource Agency request to terminate fish passage operations due to the passage of a Northern snakehead into Conowingo Pond by the Conowingo East Fish Lift on May 20.

During the spring fish passage season, the tailrace lift operated on 51 days while the spillway lift operated on 35 days. Resident fish passage operational hours were 0900 to 1500 hrs in spring, 2017, and we operated from 0800 to 1800 hrs during the migratory fish passage season per the redevelopment settlement agreement. Fall 2017 resident fish passage operations were conducted with only the use of the tailrace fish lift as extensive repairs were being conducted on the spillway lift to ensure availability of the entire fish passage facility in spring, 2018.

Operation of the Holtwood fishway followed methods established during the 1997 and 1998 spring fish migration seasons. A three person staff consisting of a lift operator, a supervising biologist, and biological technician manned the facility daily. 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 held 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 on-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 2017 migratory fish passage period (April 18 to June 7) is presented in Table 2. A total of 162,843 fish of 23 taxa plus one hybrid passed upstream into Lake Aldred. Gizzard shad (151,902), American Shad (3,169), smallmouth bass (2,888), shorthead redhorse (1,786), and walleye (1,564), comprised 99% of all fishes passed. Other abundant fishes passed included channel catfish (867), and carp (442). The peak one-day passage of all species occurred on May 1, when 12,034 fish were passed, comprised mostly of gizzard shad (11,136), shorthead redhorse (374), and smallmouth bass (279).

3.2 American Shad Passage

A total of 3,169 American Shad were passed in 44 days at Holtwood during the 2017 official migratory fish passage season (April 18 to June 7); 1,411 American Shad passed in the tailrace lift while the spillway lift accounted for 1,758 American Shad (Table 3). One (1) additional American Shad was passed prior to the start of the migratory fish passage season along with 1 shad passed after the migratory season for an overall passage total of 3,171 American Shad. Collection and passage of shad varied daily with 90% of the overall total shad (2,899) passed by May 27 (Figures 1 and 2). The highest daily American Shad catch occurred on May 21 when 377 shad moved upstream during 9.9 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 56.9°F to 71.5°F and river flows between 28,300 and 105,000 cfs. Spillage occurred on 9 days during the spring migratory season and on 15 of the 51 days that the facility operated in 2017. River water temperatures did not reach 70°F until May 24 and river flows were generally higher than the flows experienced in 2015 and 2016.

The capture of American Shad at the fishway in 2017 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 ft. to 119 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 ft. (Table 1). A Forebay elevation of 170 or higher was observed during migratory fish passage operations for nearly 30% of the season (13 of 44 days). Spillage was a common occurrence at Holtwood during the 2017 migratory fish passage season, particularly during early and mid-May, 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 (63) occurred from 1200 to 1259 hrs on May 24.

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, 1,413 and 1,758 shad were captured in the tailrace and spillway lifts over the total operating period in spring, 2017, 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 addition to the 3,171 American Shad passed in 2017, two alewife were also passed at Holtwood this season.

3.4 Maryland DNR tag-recapture

For most of the spring migratory fish passage season, water clarity was adequate, with visibility at the viewing window generally ranging from 18 to 24 inches. The viewing technicians identified 5 American Shad with attached Maryland DNR floy tags in 2017. Four of the 5 floy tags were yellow, from this year's tagging efforts downstream of Conowingo Dam, with 1 orange tag observed from tagging efforts in 2016. All floy tags were observed between April 29 and May 30.

3.5 American Shad Passage Evaluation

In spring 2017, 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. However, during preseason testing, the split nuts on entrance Gate A failed, and the gate fell to its lowermost position (full open). With Gate A in the full open position, we were unable to create an effective attraction flow. This situation, along with the higher river flows observed this spring, may have impacted the American Shad catch from the tailrace fish lift. Both spillway and tailrace lift operations ended prematurely on May 24 and June 9, respectively due to two issues; a major mechanical failure of the spillway hopper hoist system and the Resource Agency request to terminate fish passage operations due to the passage of a Northern snakehead into Conowingo Pond by the Conowingo East Fish Lift on May 20.

We were unable to start spring fish passage operations prior to April 13 due to river flows exceeding 100,000 cfs. We operated in resident fish passage mode from April 13 to 17, switching to migratory fish passage mode on April 18 due to the increased passage of American Shad at Conowingo (423 on April 17). Migratory fish passage operations were interrupted due to high river flows on April 24 and May 6 through 11. During the spring fish passage season, the tailrace lift operated on 51 days while the spillway lift operated on 35 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 48% of American Shad passed at river flows less than 40,000 cfs, with 45% passing at river flows greater than 40,000 cfs but less than 60,000 cfs. During migratory fish passage operations in 2017, river flows ranged from 28,300 cfs to 105,000 cfs; a much high range of flows than observed in 2015 and 2016.

The 2017 American Shad passage rate at Holtwood (19.5% of American Shad passing Conowingo passed Holtwood) was the seventh lowest rate observed since operations commenced in 1997 and well below the historical average 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 utilizing knowledge gained through these twenty one years of operation. Debugging of the fishway occurred as needed throughout the season, and operation was modified based on conditions encountered on a daily basis.

4.0 RESIDENT FISH PASSAGE

4.1 Spring

During spring, 2017, resident fish passage operations were limited to 5 days in April due to high river flows during the first two weeks of the month and only 2 days in June due to the requested shutdown of the facility by the Resource Agencies. The facility operated 6 hours per day from 0900 to 1500 hrs per the settlement agreement. A total of 3,315 fish of 11 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, 2017, 96% or more of the total resident fish observed were passed during the migratory fish passage season.

4.2 Fall

Fall resident fish passage operations were conducted using the tailrace fish lift only in 2017 due to the spillway fish lift equipment failures described previously (Table 9). During 32 days of operation, a total of 17,038 fish comprised of 11 species were passed (Table 10). Minnow species and gizzard shad accounted for nearly 99% of the total catch. It is anticipated that all repairs to the spillway fish lift will be completed before commencement of fish passage operations on April 1, 2018.

5.0 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) Operate the fishway at Holtwood Dam under annual operational guidelines developed and approved by the HFPTAC. Fishway operation should adhere to these guidelines; however, personnel must retain the ability to make “on-the-spot” modifications to maximize fishway performance.

3) 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.

4) Implement protocols/guidelines to spill trash through gates 7 and 9 or the Obermeyer gate adjacent to the fish trough exit. This should be done on an as needed basis prior to or after daily scheduled fishway operations.

6.0 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.

TABLES AND FIGURES