FINAL STUDY REPORT
DREISSENID MUSSEL MONITORING STUDY
RSP 3.24

CONOWINGO HYDROELECTRIC PROJECT

FERC PROJECT NUMBER 405

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EXECUTIVE SUMMARY

Exelon Generation Company, LLC has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt Conowingo Hydroelectric Project (Conowingo Project). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014. FERC issued the final study plan determination for the Project on February 4, 2010, approving the revised study plan with certain modifications. The final study plan determination required Exelon to conduct a Dreissenid Mussel Monitoring Study, which is the subject of this report. The objectives of this study are to: 1) determine the presence and abundance of Dreissenid mussels, particularly zebra mussels (*Dreissena polymorpha*) within the Project boundary and; 2) identify potential mitigation measures to minimize the impact of Dreissenid mussels to Project structures.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any, modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. An updated study report (USR) was filed on January 23, 2012 addressing comments from stakeholders received at the March ISR meeting, those comments addressed by Exelon in the May 27, 2011 responses to ISR comments, as well as editorial and minor text changes. This final study report is being filed with the Final License Application for the Project.

The zebra mussel is an exotic species of bivalve mollusks first introduced in North America in the mid 1980's. The mussel's initial release is believed to have occurred in the Great Lakes region (Lake St. Clair) via ballast water exchange from ships arriving from European freshwater ports. The occurrence and spread of the zebra mussel and its close relative, the quagga mussel (*Dreissena bugenis*), has been a nuisance to water users (e.g., utilities, municipalities, industries, agriculturists, and recreationists).

The detection and subsequent monitoring for Dreissenid mussels by Exelon at Peach Bottom Atomic Power Station and Conowingo Dam has occurred since 1991 and continued annually through 2008. With a one year lapse, the monitoring program at Conowingo Dam was initiated again in the spring of 2010. There are many factors ultimately involved in zebra mussel settlement and colonization, including water quality parameters and the presence of other shelled mollusks in flowing water conditions. The potential for Dreissenid mussel attachment and colonization in the lower Susquehanna River is good and no limiting concerns exist for the species. The investigation area for this study was at Conowingo Dam and surrounding Project waters. Zebra mussels have the potential to cause significant operational impacts at Conowingo Dam, including obstructions in water intakes at the dam and clogging of spillway gates.

For this study Exelon conducted veliger net sampling within Conowingo Dam. Artificial substrate inspections occurred at both the West Fish Lift (immediate tailrace) and in Conowingo Pond (six tube samplers). Natural substrate inspections were conducted at Shure's Landing Area (west shoreline 0.5 mi downstream of Conowingo Dam) for settled juveniles and adults. Three replicate samples were collected at each sampling event for microscopic analysis in the laboratory. Sampling for detection of settled juvenile mussels was accomplished using three PVC plates, one PVC tube with netting material inside and one scouring pad collector secured in the West Fish Lift tailrace. All pad samplers and veliger net samples were returned to the Normandeau office and examined microscopically (30-40X) for Dreissenid mussels and other organisms. Laboratory examinations were completed on live (unpreserved) samples, usually within 48 hours after collection, using the cross polarization technique.

Overall, no Dreissenid mussel veligers or settled juveniles were found in any of the collected net or substrate samples collected during the 2010 monitoring period at Conowingo Dam. Sampling frequency increased to weekly at Conowingo Dam in July after Dreissenid mussel veligers were observed in collected samples from the Peach Bottom Atomic Power Station intake area, located approximately six miles upstream of Conowingo Dam. The collection of a few adult zebra mussels downstream of Conowingo Dam by Maryland Department of Natural Resources Biologists conducting a darter survey suggests a widely distributed, low density population of adult zebra mussels is present in close proximity and downstream of Conowingo Dam. It is unclear whether this represents the start of a population explosion or the extent of the ability of zebra mussels to colonize this portion of the Susquehanna River below Conowingo Dam. Although zebra mussels were not collected at Conowingo Dam, the Asiatic clam (*Corbicula fluminea*), another biofouling organism, was routinely observed in samples taken at Conowingo Dam in June through November 2010. River temperatures during the monitoring period ranged from 9.0°C to 30.0°C (48.2°F to 86.0°F) in the Susquehanna River at Conowingo Dam. During the 2010 monitoring period, pH values in the Susquehanna River at the Conowingo Dam ranged from 7.3 to 8.5 standard units (su).

The Dreissenid mussel fouling prevention/control options considered most applicable for use at Conowingo Dam are listed within the initial study report. This general list was based on "potential" use, not actual feasibility, advantages, disadvantages, costs, or comparisons with other options. The purpose of this list is to provide a general starting point for Conowingo personnel to develop an effective mussel control program.

The impounded waters upstream of Conowingo Dam contain sufficient habitat and provide appropriate flow and environmental conditions throughout most of the year to allow establishment of viable mussel populations. Virtually any structure or system components in contact with raw river water at Conowingo Dam are susceptible to mussel settlement/fouling.

TABLE OF CONTENTS

1.0 INTRODUCTION **1**

2.0 BACKGROUND **3**

3.0 STUDY AREA **5**

4.0 METHODS **6**

5.0 RESULTS **8**

5.1 Zebra Mussels 8
5.2 Asiatic Clams 8
5.3 Other Organisms 9
5.4 Water Temperature 9
5.5 pH 9
5.6 Station Discharge during Sampling 9

6.0 DISCUSSION **11**

6.1 Potential for Settlement/Fouling at Conowingo Dam 11
6.2 Potential Prevention and Control Measures at Conowingo Dam 12

7.0 REFERENCES **14**

LIST OF TABLES

TABLE 2-1: POTENTIAL FOR ZEBRA/QUAGGA MUSSEL SETTLEMENT IN THE LOWER SUSQUEHANNA RIVER (VS. KEY WATER QUALITY AND OTHER PARAMETER CRITERIA FOR TEMPERATE SOURCE WATERS).. 15

TABLE 2-2: GENERAL COMPARISON OF EARLY LIFE STAGES OF THE ASIATIC CLAM, ZEBRA MUSSEL, AND QUAGGA MUSSEL. 16

TABLE 2-3: GENERAL COMPARISON OF CHARACTERISTICS FOR IDENTIFICATION OF EARLY AND ADULT LIFE STAGES OF THE ZEBRA MUSSEL AND ASIATIC CLAM. 17

TABLE 5.1-1: SUMMARY OF WATER QUALITY, OCCURRENCES OF ZEBRA MUSSELS, *CORBICULA* AND OTHER PRIMARY ORGANISMS COLLECTED/OBSERVED DURING DREISSENID MUSSEL MONITORING AT EXELON'S CONOWINGO GENERATING STATION ON THE LOWER SUSQUEHANNA RIVER, APRIL-NOVEMBER 2010. 18

TABLE 5.2-1: NUMBER OF *CORBICULA* LARVAE AND JUVENILES OBSERVED BY DATE DURING DREISSENID MUSSEL MONITORING AT EXELON'S CONOWINGO GENERATING STATION ON THE LOWER SUSQUEHANNA RIVER, APRIL THROUGH NOVEMBER 2010. 20

TABLE 6.1-1: A GENERAL LIST OF RAW WATER SYSTEMS/COMPONENTS SUSCEPTIBLE TO ZEBRA MUSSEL FOULING AT EXELON'S CONOWINGO GENERATING STATION. 21

TABLE 6.2-1: SUMMARY OF OPTIONS FOR PREVENTION/CONTROL OF ZEBRA/QUAGGA MUSSELS AT EXELON'S CONOWINGO GENERATING STATION. 22

LIST OF FIGURES

FIGURE 2-1: LOCATIONS OF POWER STATIONS IN THE LOWER SUSQUEHANNA RIVER 2010. 24

FIGURE 4-1: TOP PHOTO INDICATES THE RAW WATER TAP THAT WAS UTILIZED DURING SAMPLING EVENTS; BOTTOM PHOTO DEPICTS TYPICAL SET-UP FOR COLLECTING DREISSENID MUSSEL VELIGER THROUGH A 63µ MESH NET AT CONOWINGO DAM, APRIL THROUGH NOVEMBER, 2010.......... 25

FIGURE 4-2: TOP PHOTO SHOWS THE LOCATION OF THE ARTIFICIAL SUBSTRATE SAMPLERS (PVC PLATES, TUBES AND PAD) SECURED TO THE WEST FISH LIFT RAILING; BOTTOM PHOTO IS WHERE THE AMBIENT SUBSTRATE (SHURE'S LANDING) WAS INSPECTED FOR DREISSENID MUSSEL AT CONOWINGO DAM, APRIL THROUGH NOVEMBER, 2010. 26

FIGURE 4-3: DREISSENID MUSSEL TUBE SAMPLER LOCATIONS IN CONOWINGO POND, APRIL THROUGH NOVEMBER 2010.......... 27

LIST OF ABBREVIATIONS

C	Celsius, Centigrade
cfs	cubic feet per second
cm	centimeter
DO	Dissolved Oxygen
Exelon	Exelon Generation Company, LLC
F	Fahrenheit
fps	feet per second
FERC	Federal Energy Regulatory Commission
ILP	Integrated Licensing Process
ISR	Initial Study Report
KCFS	Thousand cubic feet per second
L	liter
MDNR	Maryland Department of Natural Resources
m	meter
µ	micro (prefix for one-millionth)
µg	microgram
mg	milligram
ml	milliliter
MW	megawatt
NOI	Notice of Intent
PAD	Pre-Application Document
PADEP	Pennsylvania Department of Environmental Protection
PASG	Pennsylvania Sea Grant
PBAPS	Peach Bottom Atomic Power Station
Project	Conowingo Hydroelectric Project
PSP	Proposed Study Plan
PVC	Polyvinyl Chloride
RSP	Revised Study Plan
su	standard units
USGS	United States Geological Survey
USR	Updated Study Report

1.0 INTRODUCTION

Exelon Generation Company, LLC (Exelon) has initiated with the Federal Energy Regulatory Commission (FERC) the process of relicensing the 573-megawatt (MW) Conowingo Hydroelectric Project (Project). Exelon is applying for a new license using the FERC's Integrated Licensing Process (ILP). The current license for the Conowingo Project was issued on August 14, 1980 and expires on September 1, 2014.

Exelon filed its Pre-Application Document (PAD) and Notice of Intent (NOI) with FERC on March 12, 2009. On June 11 and 12, 2009, a site visit and two scoping meetings were held at the Project for resource agencies and interested members of the public. Following these meetings, formal study requests were filed with FERC by several resource agencies. Many of these study requests were included in Exelon's Proposed Study Plan (PSP), which was filed on August 24, 2009. On September 22 and 23, 2009, Exelon held a meeting with resource agencies and interested members of the public to discuss the PSP.

Formal comments on the PSP were filed with FERC on November 22, 2009 by Commission staff and several resource agencies. Exelon filed a Revised Study Plan (RSP) for the Project on December 22, 2009. FERC issued the final study plan determination for the Project on February 4, 2010, approving the RSP with certain modifications.

The final study plan determination required Exelon to conduct a Dreissenid Mussel Monitoring Study, which is the subject of this report. The objectives of this study are to: 1) determine the presence and abundance of Dreissenid mussels, particularly zebra mussels (*Dreissena polymorpha*) within the Project boundary and; 2) determine potential mitigation measures to minimize the impacts of Dreissenid mussels to Project structures.

An initial study report (ISR) was filed on February 22, 2011, containing Exelon's 2010 study findings. An initial study report meeting was held on March 9, 10 and 11, 2011 with resource agencies and interested members of the public. Formal comments on the ISR including requested study plan modifications were filed with FERC on April 27, 2011 by Commission Staff, several resource agencies and interested members of the public. Exelon filed responses to the ISR comments with FERC on May 27, 2011. On June 24, 2011, FERC issued a study plan modification determination order. The order specified what, if any, modifications to the ISRs should be made. For this study, FERC's June 24, 2011 order required no modifications to the original study plan. An updated study report (USR) was filed on January 23, 2012 addressing comments from stakeholders received at the March ISR meeting, those comments addressed by Exelon in the May 27, 2011 responses to ISR comments, as well as editorial and minor text changes. This final study report is being filed with the Final License Application for the Project.

2.0 BACKGROUND

The zebra mussel, *Dreissena polymorpha*, is an exotic species of bivalve mollusks first introduced in North America in the mid 1980s. The mussel's initial release is believed to have occurred in the Great Lakes region (Lake St. Clair) via ballast water exchange from ships arriving from European freshwater ports. Since its introduction, the mussel has rapidly spread throughout the Great Lakes (particularly lakes Erie, Ontario, and Michigan) and into major inland waterways including navigable portions of the Mississippi River drainage to New Orleans, as well as into the Ohio, Missouri, Illinois, Tennessee, Arkansas, Cumberland, St. Lawrence, and Hudson Rivers, the Finger Lakes, and numerous smaller inland waters north, south, and west of lakes Erie and Ontario.

In the early 1990's a few Dreissenid veligers were found in the upper mainstem of the Susquehanna River near Johnson City, New York. In 2000, Biologists from State University of New York discovered Dreissenid mussels in Eaton Brook Reservoir, at the northern tip of the watershed. In May of 2007 Dreissenid mussels were discovered during routine monitoring at Cowanesque Lake, near the New York state line. The lake is on the Cowanesque River, which flows into the Susquehanna River (Chesapeake Bay Journal, 2007). However, the potential for a Dreissenid mussel invasion is evident in the Susquehanna River with adult populations of Dreissenid mussels established in New York in close proximity to the upper Susquehanna River (via the Finger Lakes, Eaton Brook Reservoir, and Cowanesque Lake). Also, adult Dreissenid mussel populations have been confirmed in the Ohio, Allegheny, and Monongahela Rivers near Pittsburgh in the western part of Pennsylvania. The occurrence and spread of the zebra mussel, and its close relative, the quagga mussel (*Dreissena bugenis*), has been an economic disaster for water users (e.g., utilities, municipalities, industries, agriculturalists, and recreationists). Costs to these users in lost services, production, and remedial and control measures could approach billions.

Exelon has conducted biomonitoring for an Asiatic clam (*Corbicula fluminea*) control program in Conowingo Pond for the Peach Bottom Atomic Power Station (PBAPS) since 1981. The detection and subsequent monitoring for Dreissenid mussels by Exelon at PBAPS and Conowingo Dam has occurred since 1991 and continued annually through 2008. With a one year lapse, the monitoring program at Conowingo Dam was initiated again in the spring of 2010.

The Susquehanna River in the Project area was free of Dreissenid mussels until fall 2008, when a few adult zebra mussels were located at Conowingo Dam, Glen Cove Marina (located near Conowingo Dam), and Muddy Run Reservoir (Exelon 2009). One dead adult zebra mussel was collected from a strainer sample at Conowingo Dam, one dead adult zebra mussel was found attached to a boat motor that was removed for winter storage at Glen Cove Marina upstream of Conowingo Dam. Also, four dead adult zebra mussels (shells only) were found along shore of the Muddy Run Reservoir during a low elevation level (Figure 2-1 and Figure 4-3). Subsequently, zebra mussel veligers were documented during 2009 in the intake canal at PBAPS. Biomonitoring at Conowingo Dam did not occur in 2009.

With the presence of zebra mussels in Conowingo Pond, the potential for actual mussel colonization is inevitable but to what extent is still unknown. There are many factors ultimately involved in zebra mussel attachment, settlement and colonization, including water quality parameters and the presence of other shelled mollusks in flowing water conditions. Generally speaking, if a given river system supports a thriving population of clams or other bivalve mollusks, a zebra mussel population most likely will thrive as well. Based on the parameter criteria listed in Table 2-1, the suitability of the Susquehanna River (from Harrisburg, PA downstream) for mussel settlement was determined. Results of this assessment (also shown in Table 2-1) were based on the following general classifications for each parameter/condition evaluated:

- **GOOD** – condition not limiting, will support mussel settlement, massive infestation likely (particularly under enhanced parameter conditions).
- **POOR** – condition marginal, limited chance for settlement, massive colonization unlikely.
- **NONE** – extreme condition, no survival/settlement expected.

In summary, the potential for Dreissenid mussel attachment, settlement and colonization in the lower Susquehanna River is **Good** and no limiting concerns exist for the species. General comparisons of early life stages of the Asiatic clam, zebra mussel, and quagga mussel are provided in Table 2-2. Comparisons of the adult life stage for Asiatic clam and zebra mussels are provided in Table 2-3.

3.0 STUDY AREA

The Conowingo Project uses limited active storage within Conowingo Pond for generation purposes. Maximum hydraulic capacity of the Conowingo powerhouse is 86,000 cfs. The Susquehanna River below Conowingo Dam flows approximately 10 miles before entering Chesapeake Bay. The non-tidal portion of the Susquehanna River encompasses approximately 4 miles of river length, from Conowingo Dam downstream to the mouth of Deer Creek (a tributary).

The investigation area for this study was Conowingo Pond and the Susquehanna River at Conowingo Dam. Zebra mussels have the potential to cause significant operational impacts at Conowingo Dam, including obstructions in water intakes at the dam and clogging of spillway gates. Additionally, presence of colonized zebra mussels could cause ecological impacts in the impoundment and downstream into the Chesapeake Bay.

4.0 METHODS

For this study Exelon conducted veliger net sampling within Conowingo Dam. Artificial substrate inspections occurred at both the West Fish Lift (immediate tailrace) and at six tube samplers in Conowingo Pond. Natural substrate inspections were conducted at Shure's Landing Area (west shoreline 0.5 mi downstream of Conowingo Dam) for settled juveniles and adults. The monitoring program initially consisted of twice-monthly sampling for Dreissenid mussel veligers from river water supplied by a tap in the filter room area within Conowingo Dam. Once Dreissenid veligers were detected in and near Project waters (as part of a separate study being conducted at PBAPS), the sampling frequency increased to weekly until the sampling events subsided in November. The initial sampling event was conducted on April 7, 2010. Sampling continued through mid-November until the ambient river temperature approached 8°C. Mussel spawning activity occurs during this period and typically peaks between 15 and 18°C (59 and 64°F).

The veliger net sampling was conducted at a raw river water tap from the filter plant area inside the facility (Figure 4-1). A garden hose was attached to the raw water tap and a known volume of raw river water (usually 1000 liters) filtered through the 63-micron (μ) mesh plankton net. The filtered residue was then examined for mussel veligers with a polarized microscope in the laboratory. Three replicate samples were collected each sampling event for microscopic analysis in the laboratory.

Visual inspections were made of artificial substrates that were secured in the tailrace at the West Fish Lift. Juvenile and adult mussels will attach to any hard substrate, including PVC, cement, wood, rocks, and various metals, as well as to other mussel/clam shells and aquatic grasses. Settled mussels are sampled via artificial substrates (PVC plates, PVC tube and scouring pad collectors) and inspection of available natural habitat (i.e. rocks, debris along shore) and man-made (steel, concrete, wood, etc.) substrates. Sampling for detection of settled juvenile mussels was accomplished using three PVC plates, one PVC tube with netting material inside and one scouring pad collector secured to the West Fish Lift railing (Figure 4-2). The PVC plates and PVC tube were examined with a magnifying glass or naked eye. The scouring pad collector was removed and replaced with a new, clean one during each sampling event. The removed pad sampler was placed in a Ziploc® bag and brought back to the lab. At the lab, the pad collector was rinsed at the sink into a fine meshed (53μ) sieve. The rinsed residue was then examined under a polarized microscope for the presence of juvenile mussels. The total surface area of a PVC plate (both sides) available for mussel settlement was 220 in^2 (0.142 m^2), while the PVC tube and pad sampler provided a surface area of 255 in^2 (0.165 m^2) and 36 in^2 (0.023 m^2), respectively.

All pad samplers and veliger net samples were returned to the Normandeau office and examined microscopically (30-40X) for Dreissenid mussels and other organisms. Laboratory examinations were completed on live (unpreserved) samples, usually within 48 hours after collection, using the cross polarization technique. When applicable, collected samples were refrigerated prior to examination in the lab.

During each sampling event, temperature and pH of the Conowingo Pond water were recorded along with results of inspections of shoreline substrates at Shure's Landing (Figure 4-2) for settled mussels and station discharge data from the Conowingo tailrace USGS gage. Monitoring results were recorded on Pennsylvania Sea Grant (PASG) report forms and reported to Exelon, MDNR, PADEP, and PASG on a monthly basis.

In addition, six tube samplers were located within Conowingo Pond in the vicinity of boat access areas and Conowingo Dam marker buoys (Figure 4-3). One tube sampler each was suspended by rope approximately 2-3 meters below Conowingo Dam marker buoys positioned upstream (≈0.25 mi) of the spillway and powerhouse. The other four tube samplers were attached by rope to a structure (concrete, tree, boulder) at a depth of approximately 2-3 meters. They were located near Conowingo Creek, Broad Creek, Glen Cove Marina and a tower near Mt Johnson Island. These six tube samplers were visually inspected for settled Dreissenid mussels once a month in conjunction with the concurrent weekly water quality sampling events.

5.0 RESULTS

5.1 Zebra Mussels

At Conowingo Dam (water tap, West Fish Lift, Shure's Landing Area), no Dreissenid mussel veligers or settled juveniles were found in any of the net or substrate samples collected during the 2010 monitoring period (Table 5.1-1). Also, no settled Dreissenid mussels were observed during the monthly inspections of the six tube samplers in Conowingo Pond. Sampling frequency increased to weekly at Conowingo Dam in July after Dreissenid mussel veligers were observed in collected samples from the PBAPS intake area (as part of a separate study effort), located approximately 6 miles upstream of Conowingo Dam. In addition, 11 adult zebra mussels (8-alive and 3-dead) were collected and preserved from the lower Susquehanna River near Robert and Spencer islands and off the mouth of Octoraro Creek during the week of July 5-9, 2010 by Maryland Department of Natural Resources' (MDNR) Monitoring and Non-tidal Assessment Division biologists. The MDNR biologists were conducting a snorkeling survey looking for the federally-endangered Maryland darter (*Etheostoma sellare*) and also noting the occurrences of fishes, native mussels and snails when they found the zebra mussels. The mussels were attached to the downstream sides of large boulders and bedrock outcrops and widely separated. The zebra mussel shell lengths ranged from 23 to 38 mm (mean = 31 mm), and were probably 2-4 years of age (MDNR press release, July 15, 2010). On August 3, 2010, MDNR biologists collected and preserved an additional three adult zebra mussels (2-alive and 1-dead) found in the lower Susquehanna below Conowingo, bringing the total number of adult zebra mussels collected downstream from the Conowingo Dam in 2010 to 14 (10-alive and 4-dead).

5.2 Asiatic Clams

Although zebra mussels were not detected at Conowingo Dam, the Asiatic clam (*Corbicula fluminea*), another biofouling organism, was routinely observed in samples taken at Conowingo Dam in May through November 2010 (Table 5.2-1). During this period, the total number of clam larvae collected was highest in September (284) followed by July (49), October (36), and August and November (19 each). Juvenile clams were only present in small numbers (<10) and during sampling events in July, September, and November; no clams were observed in April. Larvae and early juveniles were observed in both the net and pad samples, indicating the relative availability of these life stages via water column transport in the source waters. Most of the juvenile clams were found in the pad and tube samplers.

Based on the occurrence of larvae collected in the samples, *Corbicula* spawning was continuous from May through November with larval production the greatest in July and September (Table 5.2-1).

5.3 Other Organisms

Other organisms observed in net and substrate samples collected at Conowingo Dam in 2010 included rotifers, ostracods, cladocerans, copepods, bryozoans, worms (round and flatworms), snails, midge and caddis larvae, scuds, freshwater sponges, damselfly nymphs, and algae (Table 5.1-1).

5.4 Water Temperature

Ambient river temperatures during the monitoring period ranged from 9.0°C to 30.0°C (48.2°F to 86.0°F) at Conowingo Dam (Table 5.1-1). Overall, river temperatures at Conowingo Dam varied during the sampling period with the peak values occurring in August and the low value in November.

5.5 pH

During the 2010 monitoring period, pH values in the Susquehanna River at the Conowingo Dam ranged from 7.3 to 8.5 su (Table 5.1.1).

5.6 Station Discharge during Sampling

During the 2010 monitoring period, station discharge measured at the Conowingo USGS gage in the Susquehanna River ranged from 3,650 to 65,700 cfs during individual sampling events. Station discharge measured at the Conowingo USGS gage ranged from 3,580 to 141,000 cfs for the duration of the Dreissenid mussel sampling season (April 7 through November 17, 2010). The minimum station discharge was measured on September 29, 2010 and the maximum station discharge was measured during spillage on October 3, 2010. The station discharge measured at the Conowingo USGS gage was less than 10,000 cfs for part of everyday from May through the end of November except for a two week period in October. Most of September, the station discharge never exceeded 10,000 cfs during any part of the day. There was also a week to ten day period in August when the station discharge never exceeded 10,000 cfs. Exelon believes that when zebra mussels spawn in the upper Conowingo Pond, they would have the potential to settle out of the water column and attach to a substrate before passing through Conowingo Dam with river flows less than 10,000 cfs. The Conowingo station discharge is not a measure of the ambient river flow for the Susquehanna River. Marietta USGS gage is the lower most gage that represents natural river flow. River flow for the 2010 monitoring period measured at the Marietta USGS gage in the Susquehanna River ranged from 4,130 to 120,000 cfs for the period April 7 through November 17, 2010. The minimum ambient river flow was measured on September 22, 2010 and the maximum river flow was measured on April 2, 2010. The incoming river flow from Marietta USGS gage was less than 10,000 cfs for extended periods of time beginning in late June and continuing through late September. There were a few short periods within this timeframe when the flow was greater than 10,000 cfs and reached 20,000 cfs.

6.0 DISCUSSION

6.1 Potential for Settlement/Fouling at Conowingo Dam

No Dreissenid mussels were reported or observed on structures around or within Conowingo Dam during the 2010 monitoring period. Dreissenid mussel sampling was also conducted approximately six miles upstream of Conowingo Dam at PBAPS during 2010 from April through November as part of separate proceeding. Dreissenid mussel veligers were identified in collected samples at PBAPS in extremely low densities (<0.1/L) beginning in late July and at least once monthly through early October. The peak Dreissenid mussel veliger density of 0.093/L was collected during the August 18, 2010 sampling event. Although Dreissenid mussels have been identified and considered established (first observed in 2008) within Conowingo Pond, the population is either very widely distributed or at very low densities. Therefore, while a widely distributed and low density population of adult zebra mussels does seem to be present upstream and downstream of Conowingo Dam, it is unclear whether this represents the start of a population explosion or the extent of the ability of zebra mussels to colonize this portion of the Susquehanna River.

At present, adult Dreissenid mussels continue to flourish in the Allegheny, Ohio and Monongahela Rivers in the vicinity of Pittsburgh and in the lower Hudson River in New York. These areas are similar to the impoundments found upstream of Conowingo Dam. The impounded waters upstream of Conowingo Dam contain sufficient habitat and provide appropriate flow and environmental conditions throughout most of the year to allow establishment of viable Dreissenid mussel populations (Normandeau Associates, 1995 and 2002). Colonization and infestation will impact hydroelectric dams and municipal and industrial water intakes. Zebra mussel settlement at Conowingo Dam will occur from veligers spawned in upstream impoundments/areas of the river. Suspended zebra mussel veligers typically settle out of the water column within four to five weeks. In a separate Dreissenid mussel monitoring study at PBAPS in 2010, the majority of the Dreissenid mussel veligers were collected in the net samples at the outer screen building when river flows were less than 10,000 cfs. Generally speaking, Dreissenid mussel veligers could remain in Conowingo Pond and not be passed through Conowingo Dam during river flow periods of less than 10,000 cfs. When river flows are consistently >10,000cfs, most locally spawned veligers should pass the dam and settle out downstream of Conowingo Dam, but, if extended periods of low flow (<10,000cfs) are experienced from spring through fall, veligers from Conowingo Pond could form a settled population at Conowingo Dam. During 2010, extended river flow periods of less than 10,000 cfs occurred in parts of June and July, most of August and all of September at Marietta. With this being the case, Dreissenid mussel veligers should have been identified in collected samples during sampling events at Conowingo Dam. As of November 2010, no Dreissenid mussels were identified at Conowingo Dam, thus the low density established population of Dreissenid mussels located upstream of Conowingo Dam has not had a direct impact to Conowingo Dam.

Virtually any structure or system components in contact with raw river water at Conowingo Dam are susceptible to mussel settlement/fouling (Table 6.1-1). With water velocities through operating units being too fast for mussels to settle, the potential for settlement on trash racks/bars, scroll cases, wicket gates, etc, would be during periods when the units are off-line. They also could affect the operation of wicket gates and other moveable components, and block cooling and other service water openings within the intake structure. The operation of regulation and spill gates could be impacted with attached Dreissenid mussels. Head gates and trash racks could be difficult to replace with Dreissenid mussels attached to and in their grooves/slots. Also, this could occur at draft tube areas, stop logs and slots for turbines not utilized during low river flow periods (e.g., summer months).

Zebra mussel settlement could also occur within the station. In-line strainers, filters, small diameter piping for raw water cooling (thrust bearings, lube oil, transformers), fire protection, and instrument gauging could all become affected by mussel attachment over time. The fouling potentials briefly described above may occur in varying degrees at Conowingo Dam following establishment of a spawning population of mussels located in upstream areas.

6.2 Potential Prevention and Control Measures at Conowingo Dam

Of the many available Dreissenid mussel fouling prevention/control options, those considered most applicable for use at Conowingo Dam are listed in Table 6.2-1. Selection of an option from this general list was based on its "potential" for use, not on actual feasibility, advantages, disadvantages, costs, or comparisons with other options. However, since it is beyond the scope of this report to identify all raw river water components at Conowingo Dam (or the extent to which each will become fouled), treatment options were chosen based on a categorization of components generic to hydropower dams. The component categories and corresponding options for mussel control are provided in Table 6.2-1 (Normandeau Associates, 1995). Most of the generic components listed in the table would apply to Conowingo Dam, and are useful for providing a starting point to develop an effective mussel control program. In addition, new and improved technologies are continually being tested for controlling Dreissenid mussels as more populations have become established within the United States.

Post colonization monitoring (i.e., mussel spawning rates and periodicity, settlement/colonization rates, preferred settlement areas, etc.) will be needed to develop an effective plant-wide control program. Although chemical treatments will play an important role in controlling mussel colonization in raw water systems, other feasible control techniques (e.g., coatings, disposable substrates, mechanical/physical removal, etc.), will be needed to prevent and remediate mussel fouling at other Conowingo locations (trash racks, head gates and slots, strainers, stop logs, spill gates, etc.). The use and timing of chemical treatments and other controls depends upon the ability to characterize and define spawning, settlement, and colonization habits of the indigenous population.

7.0 REFERENCES

Chesapeake Bay Journal, 2007. Zebra mussels found in Pennsylvania lake on Cowanesque River near New York, September 2007, Volume 17, No. 6.

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MD Department of Natural Resources Press Release titled "Zebra Mussels Now Established in Susquehanna River Below Conowingo Dam", July 15, 2010.

Normandeau Associates, 2002. Zebra Mussel Detection Monitoring at PPL's Hydro and Fossil-Fuel Generating Stations, 2001 Summary. Report prepared for PPL, Inc. Allentown, PA.

Normandeau Associates, 1995. Zebra Mussels and Conowingo Hydro Station: A Summary of Fouling Potentials and Control Options. Report prepared for Conowingo Hydro Station. Darlington, MD.

Zebra Mussel Research Technical Notes. Free source materials, periodically updated, dealing with mussel fouling and control research by the U.S. Army COE, particularly at hydraulic facilities. Available from the Waterways Experiment Station (WES), Vicksburg, MS. Contact Ms. Pat Humphries or Ms. Paula Rockett at (601)634-2571 for materials and to get on the mailing list.

Dreissena. Newsletter published six times annually by the Zebra Mussel Clearinghouse, a project of the New York Sea Grant - editor Charles R. O'Neill. Subscription is $60/year and includes newsletter, synopsis of on-going research/controls, and several other important services - most worthwhile, highly recommended. Contact the Clearinghouse (800)285-2285 or (716)395-2729 (fax).

Practical Manual for Zebra Mussel Monitoring and Control. Authored by Renata Claudi and Gerald L. Mackie. Excellent reference book, easy reading, provides "soup to nuts" information - highly recommended. Available from CRC Press, Inc.; 2000 Corporate Boulevard, N.W.; Boca Raton, Florida 33431 - Order Catalog Number L985. Cost is $59.95.

Proceedings of the 7th International Zebra Mussel Conference. Proceedings from conference held in New Orleans in January 1997. Contains 37 presentations, over 600 pages. Available from Renata Claudi at Ontario Hydro (see address above). Cost is ~$50.00.

Electric Power Research Institute Publications. Various zebra mussel conference proceedings and other seminar/workshop materials and publications are available at no cost to EPRI member utilities. Contact the EPRI Distribution Center; 207 Coggins Drive, P.O. Box 23205; Pleasant Hill, CA 94523; (510)934-4212 for a list and/or copies of relevant publications.

TABLE 2-1: POTENTIAL FOR ZEBRA/QUAGGA MUSSEL SETTLEMENT IN THE LOWER SUSQUEHANNA RIVER (VS. KEY WATER QUALITY AND OTHER PARAMETER CRITERIA FOR TEMPERATE SOURCE WATERS).

Settlement Potential				
Parameter	**Good**	**Poor**	**None**	**Susquehanna River Assessment**
Flow Velocity (ft/sec)	0.5-3.5	4-6.5	>7	Good
Temperature Range (^{o}C)	0-30	-2; >30	<-2; >40	Good
Oxygen Saturation (%)	>60	Chronic periods <50	<6.0; >9.0	Good
pH (su)	>7.0; <9.0	6.4-7.0	<6.0; >9.0	Good
Calcium (mg/l)	>12	4-12	<4	Good
Alkalinity (mg/l CaCO3)	>35	15-35	<15	Good
Hardness (mg/l CaCo3)	>35	20-35	<20	Good
Potassium (mg/l)	<20	20-30	>30	Good
Shelled Mollusks (e.g., clams, river mussels, snails, other)	Established populations present	Few to no mussels present	No shelled mollusks present	Good
Recreational Use (boating, fishing, etc.)	High use, people attracted from a wide area	Low use or limited to local use	No use	Good
Commercial Use (shipping, fishing)	Inter-basin use or transfer	Intra-basin use only	No use	None**
Proximity to Mussel Infested Waters	In-basin or adjacent basin, <500 miles away	Out of basin>1,000 miles away	N/A	Good

* Based on data from various literature sources

** The Potential for inter-basin transfer exists only in the navigable freshwater portion of the lower Susquehanna River downstream of Conowingo Dam.

TABLE 2-2: GENERAL COMPARISON OF EARLY LIFE STAGES OF THE ASIATIC CLAM, ZEBRA MUSSEL, AND QUAGGA MUSSEL.

General Life Stage	Asiatic Clam	Zebra Mussel	Quagga Mussel
Straight-Hinged or D-larvae	≥200 µm SL Foot present Velum present short time then sheds Uses foot to move Does not swim	80-100 µm SL Shell longer than tall height = 80% of SL Hinge length >50% of SL Velum readily visible, with dark crescent melanophores Foot not yet developed Swims in circular motion	40-80 µm SL More rounded than ZM height = 90% of SL Hinge length <50% SL Velum readily visible, with dark crescent melanophores Foot not yet developed Swims in circular motion
Early Umbonal Larvae	>280 µm SL Foot present Siphon present Umbos of equal height Shell rather rounded Does not swim Uses foot to move	110-230 µm SL Velum still present Shell still longer than tall Umbos of equal height Hinge length >50% of SL Velum readily visible, with dark crescent melanophores Foot not yet developed Swims in circular motion	60-100 µm SL Velum still present More rounded than ZM height = 90% of SL Hinge length <50% of SL Velum readily visible, with dark crescent melanophores Foot not yet developed Swims in circular motion
Older Umbonal Larvae	Same as above for the Early umbonal veligers	140-350 µm SL Umbos of equal height Valve margins do not overlap Shell appears round Velum still present Swims in circular motion	120-220 µm SL Umbos height not equal Overlapping shell margins limited to below shoulders Right umbo extends upward more than left umbo Velum still present Swims in circular motion
Pediveligers	>500 µm SL Shell opaque and robust Umbos very prominent Umbos of equal height Foot well developed Siphon present	230-460 µm SL;clam-shaped Shell more opaque & thicker Umbos developed and prominent Umbos of equal height Valve margins do not overlap Foot present, used to crawl Velum used for swimming	150-230 µm SL; clam-shaped Shell more opaque & thicker Umbos developed and prominent Umbos height not equal Overlapping shall margins Right umbo extends up more than left; umbos not equal Foot present; used to crawl Velum used for swimming
Plantigrade	None, the later stages thru adults maintain the shape and form of the pediveligers	>340 µm SL Shell begins the switch from clam-like to elongated shape Valve margins do not overlap Umbos pronounced and equal in height Foot present; velum is gone Cannot swim; crawls only	220-410 µm SL Shell begins the switch from clam-like to elongated shape Overlapping shell margins Right umbo extends up more than left, umbos not equal Foot present, velum is gone Cannot swim, crawls only

Compiled from USACOE and other sources and Normandeau's experience

TABLE 2-3: GENERAL COMPARISON OF CHARACTERISTICS FOR IDENTIFICATION OF EARLY AND ADULT LIFE STAGES OF THE ZEBRA MUSSEL AND ASIATIC CLAM.

Stage	Zebra Mussel	Asiatic Clam
Pre-Straight Hinged, or D-larvae state (i.e. *Trochophores*)	Ciliated protozoan-like in appearance; displays spinning action due to cilia 50-90 microns in size. Readily available in the plankton (water column)	Ciliated protozoan-like' displays spinning action 100-160 microns in size. An extremely rare find in the water column; survival outside adult unlikely (brood in adult gills)
Straight-hinged or D-larvae stage	Thin, transparent shell present; growth lines not apparent on shell Ciliated velum usually evident; food not well developed 80-100 µm shell length (SL). Readily available in the water column	Shell more defined and robust; more translucent than transparent; growth lines usually evident Ciliated velum not readily apparent; foot is relatively well developed 200-300 µm SL. Not readily available in the water column, but can be suspended in the bottom by high flow
Post-veliger (mussels) Early Juvenile (clams) stage	Clam-like shape Thin, well developed shell generally transparent; growth lines not apparent Umbonal area (valve "hump") more pronounced Large post-veligers generally smaller than smallest clam early juveniles Readily available in the water column	Clam-like shape Thicker (heavier), well developed shell with tannish tint, generally translucent; growth lines apparent Umbonal area (valve "hump") less pronounced Smallest early juveniles generally larger than largest mussel post-veligers Not readily available in water column, but can be suspended off the bottom by increased flow
Late Juvenile Adult stage	Elongated in shape, the umbone is acute and lies anteriorly, shell often darkly striped Relatively thin, well developed shell, growth rings not apparent, attachment threads evident ventrally Typically attached to any hard surface, often on the sides of pipe, cement, wood walls and rocks	Clam-like shape, the umbone is rounded and lies in the dorsal position; shell olive-brown to brown-black in color Heavy, thick robust shell, with heavy & evenly spaced growth ridges; no byssal attachment threads present Not attached, live in or on bottom substrates, move about by well developed foot

TABLE 5.1-1: SUMMARY OF WATER QUALITY, OCCURRENCES OF ZEBRA MUSSELS, *CORBICULA* AND OTHER PRIMARY ORGANISMS COLLECTED/OBSERVED DURING DREISSENID MUSSEL MONITORING AT EXELON'S CONOWINGO GENERATING STATION ON THE LOWER SUSQUEHANNA RIVER, APRIL-NOVEMBER 2010.

Date Sampled	Water Temp (°C)	pH (su)	Occurrences of: Mussels	Corbicula*	Other primary organisms collected/observed	Substrates sampled
25-Mar-10	11.0	N/A	N/A	N/A	Initial deployment of artificial substrates during sampling events	
07-Apr-10	14.5	7.4	No	No	Rotifers, ostracods, copepods, misc. worms, algae, midge larvae, and a few flatworms	PVC plates and tube, pad sampler and Shure's Landing
21-Apr-10	15.5	8.4	No	No	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge larvae, scuds, and a few flatworms	PVC plates and tube, pad sampler and Shure's Landing
05-May-10	18.5	8.5	No	No	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae midge larvae, scuds, snails, and a few flatworms	PVC plates and tube, pad sampler and Shure's Landing
19-May-10	17.0	7.6	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
02-Jun-10	24.0	7.6	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
16-Jun-10	24.5	7.5	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
07-Jul-10	29.5	7.8	No	L & J	Rotifers, ostracods, copepods, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
21-Jun-10	28.5	7.9	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
28-Jul-10	28.0	7.7	No	L & J	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
04-Aug-10	27.5	7.6	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
11-Aug-10	30.0	7.8	No	No	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
18-Aug-10	29.5	7.4	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
25-Aug-10	25.0	7.8	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
01-Sep-10	25.5	7.8	No	L & J	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
07-Sep-10	27.5	7.7	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
15-Sep-10	24.5	7.6	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
22-Sep-10	24.0	7.4	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
29-Sep-10	22.5	7.7	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, midge and caddis larvae, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
06-Oct-10	19.0	7.4	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, damselfly nymph, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
13-Oct-10	16.5	7.3	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, flatworms, leeches, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing

20-Oct-10	15.0	7.3	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, flatworms, scuds, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
27-Oct-10	15.0	7.4	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, freshwater sponges, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
03-Novt-10	12.5	7.6	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, freshwater sponges, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
10-Nov-10	10.0	7.5	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, freshwater sponges, snails, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing
17-Nov-10	9.0	8.5	No	L	Rotifers, ostracods, copepods, cladocerans, misc. worms, algae, freshwater sponges, scuds, and bryozoans	PVC plates and tube, pad sampler and Shure's Landing

* L= one or more corbicula larvae observed; J= one or more juvenile corbicula observed; No= no veligers or settled juveniles (see Table 5 for numbers observed)

TABLE 5.2-1: NUMBER OF *CORBICULA* LARVAE AND JUVENILES OBSERVED BY DATE DURING DREISSENID MUSSEL MONITORING AT EXELON'S CONOWINGO GENERATING STATION ON THE LOWER SUSQUEHANNA RIVER, APRIL THROUGH NOVEMBER 2010.

Date Sampled	Number of Corbicula collected/observed*			Shell Length In microns (40X)
	Larvae	Juveniles	Total	
7-Apr	0	0	0	N/A
21-Apr	0	0	0	N/A
5-May	0	0	0	N/A
19-May	1	0	1	Not measured
2-Jun	6	0	6	150-216 µ
16-Jun	1	0	1	216 µ
7-Jul	3	3	6	144-816 µ
21-Jul	43	0	43	264-408 µ
28-Jul	3	10	13	144-180 µ;1-3 mm
4-Aug	1	0	1	264 µ
11-Aug	0	0	0	N/A
18-Aug	2	0	2	168-216 µ
25-Aug	16	0	16	192-264 µ
1-Sep	3	1	4	264-288 µ;600µ-3mm
7-Sep	24	0	24	192-288 µ
15-Sep	157	0	157	216-312 µ
22-Sep	47	0	47	192-240 µ
29-Sep	53	0	53	192-312 µ
6-Oct	4	0	4	192-264 µ
13-Oct	9	0	9	132-264 µ
20-Oct	5	0	5	192-240 µ
27-Oct	18	0	18	216-240 µ
3-Nov	8	0	8	192-264 µ
10-Nov	1	0	1	264 µ
17-Nov	10	1	11	216-264 µ; 528 µ
Totals	**415**	**15**	**430**	

*Most *Corbicula* larvae were observed in net collections from the raw water line, most juvenile *Corbicula* were observed in the pad and tube samplers

TABLE 6.1-1: A GENERAL LIST OF RAW WATER SYSTEMS/COMPONENTS SUSCEPTIBLE TO ZEBRA MUSSEL FOULING AT EXELON'S CONOWINGO GENERATING STATION.

Headworks/Intakes
Concrete superstructure
Trash racks/bars
Headgates and slots
Trash rake grooves
Stoplogs
Intake walls
Butterfly valves
Scroll case
Wicket gates*
Cooling/other raw water intake portals
Superstructure drains
Turbines
Runners*
Draft tube
Exposed venting system components*
Generator thrust bearing and other cooling lines
Screens, strainers, and applicable filtration systems
Pyzometer and other raw water gauges
Water cooled coolers, heat exchangers, compressors, lube oil
Transformer cooling lines
Other
Fire protection lines and applicable storage tanks**
Trash and regulation gates*
Flood/crest gates*
East & West Fish Passage Facilities (superstructure, gates channels, other submerged components)
DO compliance monitoring system

* The weight and thickness of mussel encrustations may prevent operability, or result in a loss of unit efficiency/power output, as applicable.

** If domestic water is used, it is important that no cross-ties to raw source water exist or, if present, not used during testing of fire protection system.

TABLE 6.2-1: SUMMARY OF OPTIONS FOR PREVENTION/CONTROL OF ZEBRA/QUAGGA MUSSELS AT EXELON'S CONOWINGO GENERATING STATION.

Chemical Option	Option Approach		Technology vs Mussels	Effectiveness of Technology	Comments
	Proactive	Reactive			
Oxidizing Biocides					
Chlorine (Cl_2)	X	X	Proven	Wide	Effective continuous or semi-continuous, may require dechlorination, best used to prevent settlement, Trihalomethanes byproducts
Non-oxidizing Molluscicides					
Betz Clam Trol (CT-1, CT-2, CT-4)	X	X	Proven	Wide	Very effective, 12-24 hr. doses, detox required if no dilution, on-line use, expensive, no potable water use
Calgon H130	X	X	Proven	Wide	See Betz comment
Buckman Bulab	X		Limited	Limited	See Betz comment
ElfAtochem TD2335	X	X	Emerging	Testing	Similar to Betz and Calgon
Other Non-oxidizers					
Cu/Al floc	X		Emerging	Limited	On-line system, low maintenance costs, effective Cu conc. Is less than receiving water standards, unit on-lie at NYSEG
Non-Chemical Options					
Manual cleaning/removal		X	Proven	Wide	Labor intensive, may involve extensive down-time
Pigging		X	Proven	Wide	Labor intensive, down-time could be long pending system
High pressure water jetting		X	Proven	Wide	Labor intensive, effective where access available
Strainers and Traps	X	X	Proven	Wide	Effective in-line, component specific, dual/auto systems best
Filtration	X		Emerging	Limited	Effective for low capacity systems, clogging, component specific
Thermal treatment	X		Proven	Wide	Highly effective on or off-line, system wide or component specific

Chemical Option	Option Approach		Technology vs Mussels	Effectiveness of Technology	Comments
	Proactive	Reactive			
Antifouling coatings/materials	X		Proven	Limited	Effective, durability questionable, very expensive
Desiccation/freezing		X	Emerging	Limited	Effective for de-watered & redundant systems, impoundments
Hypoxia/Anoxia	X	X	Emerging	Limited	Effective at temp. >20^{o}C, requires stagnant conditions
Disposable substrates	X		Emerging	Limited	Not cost effective if down-time required for installation/retrievation
Other Controls					
System modification	X		Proven	Limited	Effective, system specific, could be capital intensive

FIGURE 2-1: LOCATIONS OF POWER STATIONS IN THE LOWER SUSQUEHANNA RIVER 2010.

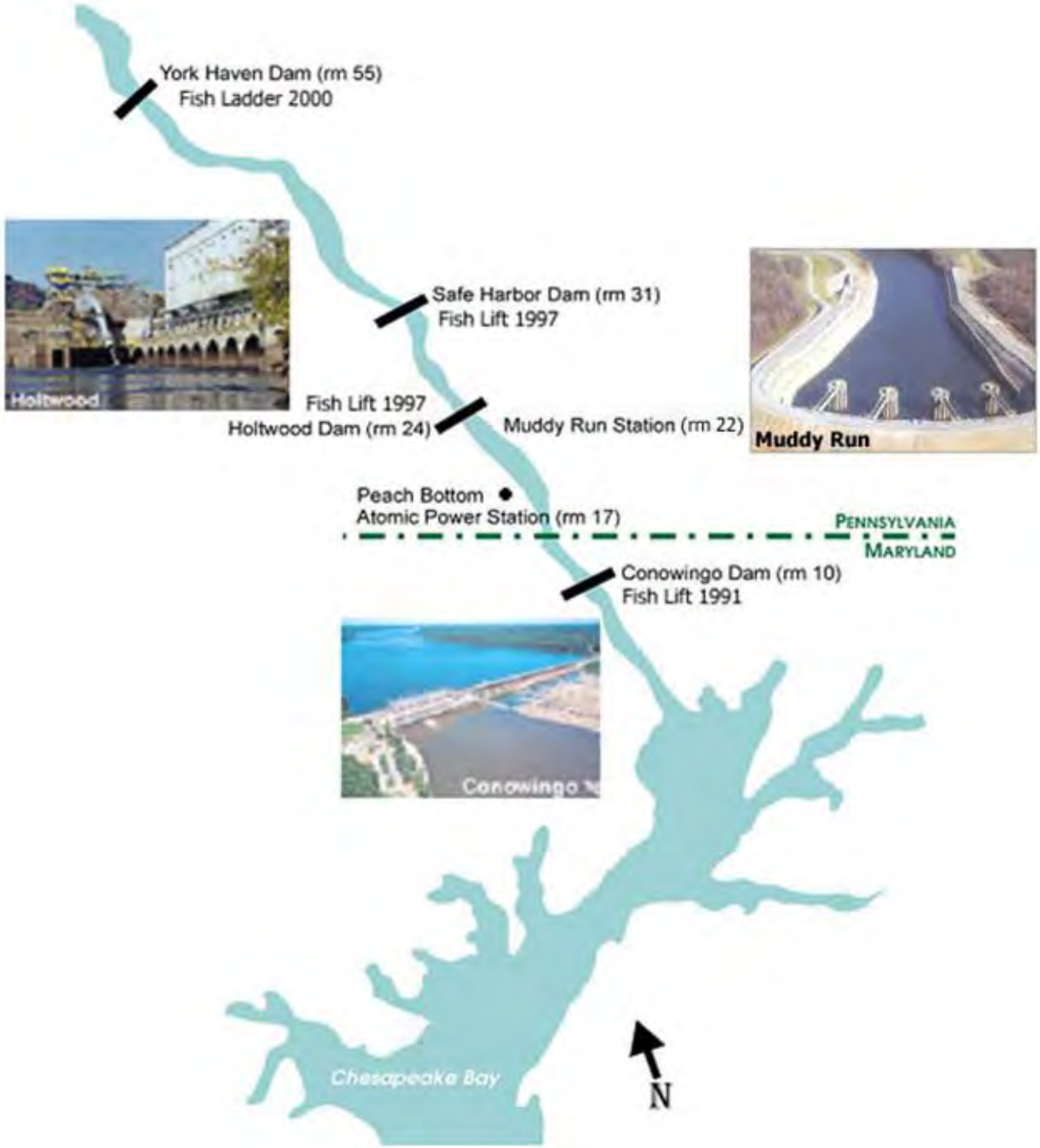
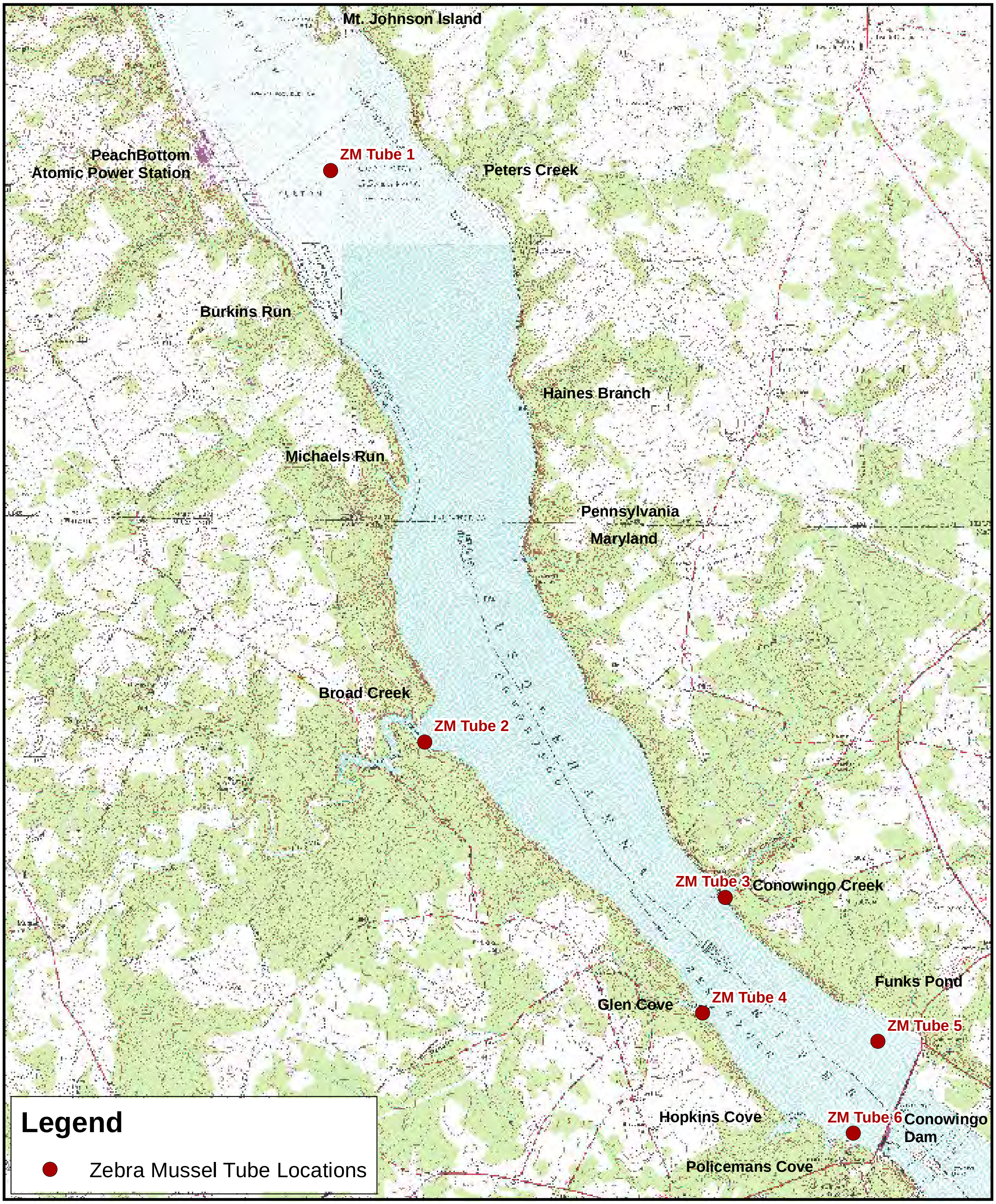


FIGURE 4-1: TOP PHOTO INDICATES THE RAW WATER TAP THAT WAS UTILIZED DURING SAMPLING EVENTS; BOTTOM PHOTO DEPICTS TYPICAL SET-UP FOR COLLECTING DREISSENID MUSSEL VELIGER THROUGH A 63µ MESH NET AT CONOWINGO DAM, APRIL THROUGH NOVEMBER, 2010.

FIGURE 4-2: TOP PHOTO SHOWS THE LOCATION OF THE ARTIFICIAL SUBSTRATE SAMPLERS (PVC PLATES, TUBES AND PAD) SECURED TO THE WEST FISH LIFT RAILING; BOTTOM PHOTO IS WHERE THE AMBIENT SUBSTRATE (SHURE'S LANDING) WAS INSPECTED FOR DREISSENID MUSSEL AT CONOWINGO DAM, APRIL THROUGH NOVEMBER, 2010.



EXELON GENERATION COMPANY, LLC

Exelon.

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RSP STUDY 3.24
CONOWINGO HYDROELECTRIC PROJECT
PROJECT NO. 405

1 inch = 1 miles

0 0.5 1 2 Miles

Figure 4-3
Figure Title: Dreissenid mussel tube sampler locations in Conowingo Pond, April through November 2010.