ENGINEERING RESPONSE SUPPLEMENT TO UNITED STATES ENVIRONMENTAL PROTECTION AGENCY CWA §308 LETTER

PSNH SCHILLER STATION PORTSMOUTH, NEW HAMPSHIRE

Prepared for
Public Service of New Hampshire

Prepared by:

Enercon Services, Inc.
500 TownPark Lane
Kennesaw, GA 30144
October 2014

TABLE OF CONTENTS

1 Introduction 3
1.1 Background 3
1.2 Executive Summary 3
2 Clean Water Act Section 316(b) 7
2.1 Impingement Compliance 7
2.2 Entrainment Compliance 11
2.3 Compliance for Schiller Station 12
3 Engineering Update 17
3.1 Changes in Impingement-Reducing Intake Technologies 17
3.2 Changes to Schiller Station 20
3.3 Intake Flow Operational Data 21
3.4 Variable Speed Pumps 21
3.5 2008 Cost Estimate Updates 23
4 Cooling Tower Drift 24
4.1 Water Salinity at Schiller 24
4.2 General Impacts of Drift 24
4.3 Air Emissions 25
4.4 Drift Eliminators 26
4.5 Summary 26
5 Wide-Slot Wedgewire Screens 28
5.1 Conceptual Design Summary 28
5.2 Structural / Construction Considerations 30
5.3 Structural Design Environmental Conditions 32
5.4 Construction Methodology 33
5.5 Hydraulic Considerations 36
5.6 Air Burst System 38
5.7 Revised Cost Estimate 38
6 Barrier Impingement Nets 40
6.1 Conceptual Design Summary 40
6.2 Civil / Structural Design Considerations 41
6.3 Hydraulic Design Considerations 44
6.4 Debris and Biological Fouling 45
6.5 Construction Methodology 45
6.6 Cost Estimate 46
7 Summary and Conclusions 48
8 References 49

LIST OF ATTACHMENTS

Attachment 1: Capital Cost Assessments — 4 pages

Attachment 2: Conceptual Drawings — 7 pages

Attachment 3: Normandeau Attachment — 24 pages

1 Introduction

1.1 Background

Public Service of New Hampshire's (PSNH's) Schiller Station (or simply, the "Station") in Portsmouth, New Hampshire is seeking a renewal of its existing National Pollutant Discharge Elimination System permit (NPDES Permit NH0001473). To support development of the Station's NPDES permit renewal, on October 31, 2007 the United States Environmental Protection Agency (EPA) issued an information request letter to PSNH under Section 308 of the Clean Water Act (CWA) regarding the Station's compliance with CWA §316(b), 33 U.S.C. §1326(b) (§308 Letter). In the §308 Letter, EPA requested certain technology information from PSNH to support EPA's development of the new permit for Schiller Station. In October 2008, PSNH submitted a response (2008 Response) prepared by Enercon Services, Inc. (ENERCON) and Normandeau Associates, Inc. (Normandeau). The 2008 Response evaluated the engineering feasibility of certain cooling water intake structure (CWIS) technologies and operational measures that would be generally expected to reduce impingement (being pinned against CWISs) and/or entrainment (being drawn into CWISs) mortality of aquatic organisms at Schiller Station.

EPA issued follow-up information requests in support of NPDES permit development. PSNH submitted separate responses to these follow-up information requests, most recently the August 2013 Response that was prepared by ENERCON.

Given the regulatory and technological changes in the time since the 2008 Response was issued, and given the operational changes at Schiller Station since the 2008 Response, PSNH seeks to update a portion of the information contained in the 2008 Response to reflect these changes prior to re-issuance to EPA. ENERCON and Normandeau have worked together to issue this Supplement to the original 2008 Response, which provides updates to necessary information.

This supplement does not seek to re-evaluate every item from the 2008 Response, but focuses on technological and biological changes that may affect the determination of Best Technology Available (BTA) for Schiller Station under the recent 316(b) rule published in the Code of Federal Regulations (CFR). This supplement provides conceptual designs for wide-slot wedgewire screens and a barrier net for Schiller Station to support development of cost estimates for these technologies. A more detailed description of the contents of this report is provided in Section 1.2 below.

1.2 Executive Summary

This report serves as a supplement, or addendum, to the 2008 Response and provides additional updates and information as described above. Information from the August 2013 Request for Information Response is also cited, where applicable. The list below provides a summary of the findings contained within this supplement.

- Changes in the regulatory environment since the 2008 Response have been reviewed. Most significantly, the new CWA Section 316(b) rule was published in the CFR on August 15, 2014. The rule contains seven different compliance alternatives for meeting the BTA standard for impingement mortality, and contains several entrainment characterization requirements for facilities that have an actual intake flow (AIF) of 125 million gallons per day (MGD) or greater. Because Schiller Station has an AIF of well below 125 MGD, submittal of entrainment characterization information is not required.

Several different compliance alternatives are discussed. Compliance is possible using wedgewire screens or a barrier net to reduce the design intake through-screen velocity to 0.5 feet per second (fps) or less. Compliance is also possible for Unit 4 by returning the retired-in-place Unit 3 intake channels to service, thus reducing the actual intake through-screen velocity to 0.5 fps or less for that Unit. Other potential candidate technologies for compliance include modified Ristroph screens with an upgraded fish handling and return system (FHRS), or meeting the 24 percent impingement mortality rate.

- Impingement mortality was estimated from the latent survival observations for the existing traveling screens and fish return systems at Schiller Station (Units 4, 5 and 6 combined) for the fragile and non-fragile fish species and macro-crustaceans impinged during the 2006-2007 Study. The observed latent mortality was 100 percent for the fragile fish species present in the impingement collections at Schiller Station (Rainbow Smelt, Atlantic Menhaden, Atlantic Herring, Blueback Herring, and Alewife), while non-fragile fish species (predominantly White Hake, Cunner, Northern Pipefish, Cunner and Grubby) exhibited an overall latent mortality of 74.2 percent. Macro-crustaceans (Green Crab, Rock Crab, American Lobster, Horseshoe Crab and Jonah Crab) impinged on the existing traveling screens at Schiller Station Units 4, 5, and 6 combined were hardy compared to the fragile and non-fragile fish species, exhibiting a latent impingement mortality of 32.9 percent.
- Annual impingement abundance and mortality for Schiller Station were estimated for comparison with the new §316(b) regulations to determine if the existing CWIS at each Unit achieved the specified impingement mortality performance standard of 24 percent under §125.94(c)(7). The comparison was made by applying the observed mortality rates of non-fragile fish and macro-crustaceans from the 2006-2007 Study to the annual impingement abundance estimated using the actual intake flows observed for the three most recent years of operation of Schiller Station Units 4, 5 and 6 (2011 through 2013). Latent mortality values of 74.2 percent for non-fragile fish and 32.9 percent for macro-crustaceans for all three Units combined did not achieve the impingement mortality standard of 24 percent at Schiller Station. If the survival data were weighted by the annual total impingement abundance of non-fragile fish or macro-crustaceans and not in proportion to their abundance in the survival samples, the latent mortality was 71.6 percent for non-fragile fish and was 32.3 percent for macro-crustaceans from all three Units combined at Schiller Station.
- The previous 2008 Response estimates of impingement abundance were also used to estimate latent impingement mortality for comparison to the design intake flows, the actual 2006-2007 intake flows, and the current 2011-2013 intake flows for each Unit and for all three Units combined. The percent mortality achieved by the existing

CWIS configuration of traveling screens and return systems was estimated as 44.5 percent for 2011-2013. Although the annual number of fish and macro-crustaceans impinged at Schiller Station (all three Units combined) was reduced by 47.5 percent due to flow reductions mostly at Units 4 and 6, relatively high abundance and survival of hardy macro-crustaceans impinged at Schiller Station were offset by relatively low survival of non-fragile fish species to produce this result.

- Technologies that were not discussed in the 2008 Response, such as parallel condensing systems and drum screens, would provide significant benefits if installed. However, they are infeasible from an engineering perspective for a retrofit installation at Schiller Station. Additionally, there have been recent advancements in acoustic fish deterrent systems (FDSs) technology and reliability. However, as noted in the 2008 Response, it is not believed that acoustic FDSs would provide significant benefit at Schiller Station.
- There have been no significant changes to the configuration of Schiller Station since 2008. Operational intake flow data for each of the Units was reviewed for the past three years, showing that Units 4 and 6 have been operating at particularly low capacity factors. The result of this reduced capacity factor is that the AIF is much lower than the design intake flow (DIF). The potential of reducing the intake flows during plant operation using variable speed pumps (VSPs) is revisited. Minimal reductions in intake flows are possible, but further analysis is required to precisely determine the limitations under which VSPs would be required to operate, and to quantify other impacts of using VSPs including reduced efficiency of the Station.
- Cooling tower operation, which aims to break water into small droplets for increased heat transfer, results in drift. Drift is defined as the small liquid water droplets that become entrained in the flow of air, leaving the top of the tower as small liquid droplets. Fine particulate matter can result from drift particles that originate from a salt water cooling tower. This has detrimental effects to the nearby environment and can result in the cooling tower being considered a point source emitter.
- A preliminary design and cost estimate for wide-slot wedgewire screens at Schiller Station is provided. The wedgewire screens are half-screens due to the relatively shallow water depths present in front of each intake. The half-screens are half of a cylinder, with the flat side pointing towards the river bottom. Screen House #1 (Unit 4 and the retired-in-place Unit 3) would require two 78-in. diameter screens, while Screen House #2 (Units 5 and 6) would require three 84-in. diameter screens. Three layers of defense-in-depth are provided to alleviate concerns related to potential blockage of the wedgewire screens. Each Screen House would be equipped with an air burst system (ABS), which would periodically provide a "burst" of compressed air into the center of the wedgewire screen, dislodging potential blockage sources. The fast-moving currents of the Piscataqua River can be used to allow dislodged objects to be easily swept away (based on when the ABS is operated within the tidal cycle). Additionally, the screens are slightly oversized from a hydraulic standpoint to provide an allowance for blockage on the screens while still meeting the 0.5 fps through-screen

velocity criteria for compliance under 40 CFR 125.94(c)(2). A biological evaluation and compliance monitoring of wide-slot wedgewire screen performance at Schiller Station is not required because the design, through screen velocity is less than 0.5 fps. Finally, each of the Screen Houses would be provided with an "emergency" intake capability using the existing traveling water screens that would prevent a plant outage in the event of excessive wedgewire screen blockage.

- A preliminary design and cost estimate for a barrier net system at Schiller Station is provided. The barrier net would be large enough to encompass both the Screen House #1 offshore and Screen House #2 onshore intakes. This large surface area would provide sufficiently low through-screen velocities to achieve compliance under 40 CFR 125.94(c)(2), even with significant debris blockage. A biological evaluation and compliance monitoring of barrier net performance at Schiller Station is not required because the design, through mesh velocity is less than 0.5 fps. The net would be made of ultra-high-molecular-weight polyethylene, also known as Dyneema. Operating experience and discussions with the manufacturer have shown that this material can provide good performance if cleaned several times per year using a pressure washer. However, operating experience has also shown that frequent inspections are required to monitor for breaks and tears in the net, in addition to net blockage. It is anticipated that frequent repairs would be needed, especially due to the high water velocities in the Piscataqua River. This results in higher operation and maintenance costs relative to the wedgewire screens. Exact river velocities in this area were not available, and detailed information regarding debris loading and ice floes were also not available. As such, additional impacts to cost and net reliability are possible based on these uncertainties. To this end, a study is recommended to retrieve more detailed information.
- Revised cost estimates are provided. New construction cost estimates are provided for the barrier net and wedgewire screen designs. Other construction and engineering costs from Attachment 4 of the 2008 Response are updated to 2014 dollars.
- The use of mechanical draft cooling towers in a closed-cycle cooling configuration is possible, but is much more expensive than other comparable technologies. Given the low capacity factor and DIFs of the Station, the ongoing operational cost burden associated with closed-cycle cooling is not deemed a reasonable compliance option.

2 Clean Water Act Section 316(b)

As it relates to the renewal of the NPDES permit for Schiller Station, there are two recent regulatory developments that have the potential to affect NPDES permit renewal at Schiller Station.

Firstly, EPA and the United States Army Corps of Engineers (USACE) have proposed a joint rule to clarify the types of waters that are considered "waters of the United States" under the CWA. The proposed rule was published in the Federal Register on April 21, 2014. The Piscataqua River remains a water of the United States under the revised definition. Therefore, this new rule does not have significant impact to Schiller Station, so it is not discussed further in this Report. The final regulations are still pending and are subject to change; however, the Piscataqua River is expected to remain in the waters of the United States.

The most significant regulatory change that has occurred since the 2008 Response is the finalizing of the CWA Section 316(b) rules for existing facilities. The new 316(b) rule (referred to hereafter as "the rule") was pre-published by EPA on May 19, 2014, with final publication in the Federal Register occurring on August 15, 2014.

Clean Water Act Section 316(b) requires that NPDES permits for facilities with CWISs ensure that the location, design, construction, and capacity of the structures reflect the BTA to minimize harmful impacts to the environment. Existing large electric-generating facilities were addressed in the 2004 Phase II rule, but this was subsequently remanded on January 25, 2007. Several alterations have been made to the rule since the 2008 Response that may impact the technology assessment for Schiller Station as a part of the NPDES permit renewal process. This is because the new final CWA 316(b) rule contains changes to the way in which facilities will meet the impingement and entrainment mortality standards.

The remainder of this section includes information taken from the 316(b) rule; citations are not provided after each sentence or paragraph for brevity. This Section provides a summary-level discussion on the new rule. For exact language and further detail, 40 CFR Parts 122 and 125 of the Federal Register should be consulted. Note that, for example, 40 CFR Part 122 and §122 are used interchangeably in this report for brevity.

2.1 Impingement Compliance

Existing power generating facilities that are designed to withdraw greater than 2 MGD of water from waters of the United States, and that use at least 25 percent of this water exclusively for cooling purposes, are subject to the BTA standard for impingement mortality. Compliance with the BTA standard for impingement mortality may be achieved using any one of seven options delineated in the rule, as described below.

2.1.1 Compliance Options

Option #1 – §125.94(c)(1): Operate a closed-cycle recirculating system as defined at §125.92. This is essentially a pre-approved technology requiring no demonstration, or only a minimal demonstration, that the flow reduction and control measures function as EPA envisions. Submittal of the information delineated in §122.21(r)(2) through (r)(6) and §122.21(r)(8) is required as a part of the permit application process. The monitoring required must include measuring cooling water withdrawals, make-up water flows, and blowdown flows. The facility is required to monitor actual intake flows (the average volume of water withdrawn on an annual basis) and cycles of concentration to allow the NPDES Permit Director (referred to hereafter as "the Director") to determine that make-up and blowdown flows have been minimized. Biological compliance monitoring is not required.

Option #2 – §125.94(c)(2): Operate a CWIS that has a maximum through-screen design intake velocity of 0.5 fps. This is a pre-approved technology requiring no demonstration, or only a minimal demonstration, that the flow reduction and control measures function as EPA envisions. Submittal of the information delineated in §122.21(r)(2) through (r)(6) and §122.21(r)(8) is required as a part of the permit application process. The facility must submit information demonstrating that the maximum design intake velocity passing through the screens cannot exceed 0.5 fps. This maximum water velocity must be achieved during all conditions, including periods of minimum water source elevations and during periods of maximum head loss across the screens. Biological compliance monitoring is not required.

Option #3 – §125.94(c)(3): Operate a CWIS that has a maximum through-screen intake velocity of 0.5 fps. The facility must submit information to the Director that demonstrates that the maximum intake velocity as water passes perpendicularly through the screen does not exceed 0.5 fps. Submittal of the information delineated in §122.21(r)(2) through (r)(6) and §122.21(r)(8) is required as a part of the permit application process. This method is similar to Option #2 (*design* velocity) except that the intake's maximum design velocity can exceed 0.5 fps as long as the intake is operated in a manner such that the actual, measured velocity does not. One example given in the rule is a facility that was originally designed with an intake velocity of 1.0 fps, but has achieved an actual intake velocity 0.5 fps by retiring a portion of the plant. Monitoring of the velocity at the screen face or immediately adjacent to the screen face (not the approach velocity) must be conducted daily, or a calculation must be performed demonstrating this. Additionally, the facility may be granted permission to exceed the low velocity compliance alternative for brief periods of time, such as during backwashing or back-flushing. Biological compliance monitoring is not required.

Option #4 – §125.94(c)(4): Operate an offshore velocity cap as defined in §125.92 that is installed before the effective date of the rule. This is a pre-approved technology requiring no demonstration, or only a minimal demonstration, that the control measures function as EPA envisions. Submittal of the information delineated in §122.21(r)(2) through (r)(6) and §122.21(r)(8) is required as a part of the permit application process. The velocity cap must be located a minimum of 800 ft offshore, and must contain devices such as bar racks to exclude marine animals. Additionally, the velocity cap must be designed to change the direction of the water withdrawn from vertical to horizontal, and intake flow must be monitored daily. Biological compliance monitoring is not required. If facilities choose to construct a velocity cap at an offshore location after the effective date of the rule, they would be utilizing compliance options #6 or #7 below.

Option #5 – §125.94(c)(5): Operate a modified traveling screen that the Director determines meets the definition at §125.92(s) and that the Director determines is the BTA for impingement reduction. The definition requires those features of a traveling water screen that provide an appropriate level of fish protection including:

- Collection buckets that minimize turbulence;
- Guard rails or barriers to prevent loss of fish from the collection system;
- Smooth or soft screen panel materials that protect fish from descaling;
- Continuous or near-continuous rotation of screens and operation of collection equipment to recover impinged fish as soon as practical;
- Low-pressure wash or vacuum to remove collected organisms from the screen; and
- A fish handling and return system with sufficient water flow to return fish directly to the source waterbody in a manner that does not promote re-impingement of the fish, or a large vertical drop.

For this option, the facility is required to submit a site-specific impingement technology performance optimization study that includes two years of biological sampling. The study must demonstrate that the operation of the modified traveling screens has been optimized to minimize impingement mortality. EPA notes in the rule that modified traveling screens include, but are not limited to modified Ristroph screens with a FHRS, dual flow screens with smooth mesh, and rotary screens with fish returns or vacuum returns. Submittal of the information delineated in §122.21(r)(2) through (r)(6), §122.21(r)(6)(i), and §122.21(r)(8) is required as a part of the permit application process.

Option #6 – §125.94(c)(6): Operate any systems of technologies, best management practices, and/or operational measures that the Director determines is the BTA for impingement reduction. This option allows the facility to choose the technologies, practices, and operational measures that it believes will meet the impingement mortality standard. The facility is required to submit a site-specific impingement study including two years of biological data collection demonstrating that the operation of the system of technologies, operational measures and best management practices has been optimized to minimize impingement mortality. The estimated reductions in impingement must be based on comparison of the system to a once-through cooling system with a traveling screen whose point of withdrawal from the surface of the water is located at the shoreline of the source waterbody. Submittal of the information delineated in §122.21(r)(2) through (r)(6), §122.21(r)(6)(ii), and §122.21(r)(8) is required as a part of the permit application process.

Option #7 – §125.94(c)(7): Achieve the specified impingement mortality standard. This option requires that the facility achieve a 12-month impingement mortality performance of all life stages of fish and shellfish of no more than 24 percent mortality, including latent mortality, for all non-fragile species. The rule contains specific requirements relating to how impingement shall be calculated. Compliance may be demonstrated for either the entire facility or for each individual CWIS. Submittal of the information delineated in

§122.21(r)(2) through (r)(6), and §122.21(r)(8) is required as a part of the permit application process.

In addition to the compliance options discussed above, a case can also be made for some facilities that the existing levels of impingement mortality is *de minimis* based on impingement abundance numbers or age 1 equivalent[1] abundance in relation to mean annual intake flows. The acceptance of a *de minimis* demonstration is at the discretion of the USEPA Director.

2.1.2 Information Submittals

The items below are required to be submitted to EPA as a part of the permit renewal process based on the impingement compliance alternative selected by the facility. Note that the descriptions below are summary-level only; the rule itself should be consulted for more detailed information regarding the compliance requirements.

- <u>§122.21(r)(2) Source Water Physical Data:</u> This submission is required to characterize the facility and evaluate the type of waterbody that is potentially affected by the CWIS. Information including size and shape of the water body, depth, salinity and temperature regimes, and other documentation is listed in the rule as being potentially applicable data to be included in this submission.
- <u>§122.21(r)(3) Cooling Water Intake Structure Data:</u> This submission is used to characterize the CWIS and evaluate the potential for impingement and entrainment of aquatic organisms. The submission should include a description of the configuration of each cooling water intake structure, DIFs, daily hours of operation, months of operation, and engineering drawings of the intake structure, and other information related to the cooling water intake system.
- <u>§122.21(r)(4) Source Water Baseline Biological Characterization Data:</u> Facilities are required to characterize the biological community in the vicinity of the CWIS and to characterize the operation of the CWIS.
- <u>§122.21(r)(5) Cooling Water System Data:</u> This submission should describe operation of the cooling water system(s) and its relationship to the CWIS (including the use of helper towers), the proportion of design flow that is used for each purpose, description of reductions in total water withdrawal, the number of days the system is in operation, any seasonal changes in the operation of the system, and a description of any existing impingement and entrainment technologies along with their performance.

[1] Age-1 equivalents are defined in the rule as the number of individual organisms of different ages impinged and entrained by facility intakes, standardized to equivalent numbers of 1-year old fish. A conversion rate between all life history stages and age 1 is calculated using species-specific survival tables based on the life history schedule and age-specific mortality rates.

- §122.21(r)(6) Chosen Method of Compliance with Impingement Mortality Standard: The facility must identify which compliance alternative it has chosen to meet the impingement mortality standard. Facilities choosing to comply by operating a modified traveling screen (under Option #5) must submit an impingement technology performance optimization study under § 122.21(r)(6)(i). Similarly, facilities choosing to comply by operating a system of technologies (under Option #6) that will achieve the impingement mortality standard must submit a impingement technology performance optimization study under §122.21(r)(6)(ii). A case can also be made for some facilities that the existing levels of impingement mortality is *de minimis* based on impingement abundance numbers or age 1 equivalent abundance in relation to mean annual intake flows. The acceptance of a *de minimis* demonstration or an exemption due to low capacity utilization factor is at the discretion of the USEPA Director.
- §122.21(r)(7) is addressed under Section 2.2, Entrainment Compliance.
- §122.21(r)(8) Operational Status: The facility must provide descriptions of each unit's operating status includes age of the unit, capacity utilization for the previous five years, any major upgrades completed in the past 15 years, a description of any completed or scheduled uprates, Nuclear Regulatory Commission (NRC) re-licensing status for nuclear facilities, plans or schedules for decommissioning or replacement of units, and a description of future production schedules for manufacturing facilities.

2.2 Entrainment Compliance

For entrainment compliance, the rule does not prescribe a single nationally applicable entrainment performance standard, but instead requires that the Director must establish the BTA entrainment requirement on a site-specific basis.

All existing facilities must submit §122.21(r)(7) and §122.21(r)(8) to EPA. Facilities that have an AIF of 125 MGD or greater must submit §122.21(r)(9) through (r)(13) to EPA as described below to aid in determination of BTA for entrainment. The Director may waive the requirement on a site-specific basis to submit §122.21(r)(9) through §122.21(r)(13).

The list of items below are required to be submitted to EPA as a part of the permit renewal process based on the requirements listed above. The rule does not require that any of the information in this Section be submitted by facilities that have an AIF of 125 MGD or less. Note that the descriptions below are summary-level only; the rule itself should be consulted for more detailed information regarding the compliance requirements.

- §122.21(r)(7) Entrainment Performance Studies: The permit applicant must submit a description of any entrainment-related biological studies conducted at the facility and provide a summary of any conclusions or results. Studies that are older than 10 years or conducted at other facilities must contain an explanation of why the data are still relevant and representative of conditions at the facility. New studies are not required to fulfill this requirement.

- §122.21(r)(9) Entrainment Characterization Study: A two-year entrainment data collection study is required, including complete documentation of the data collection period and the frequency of entrainment characterization, and an identification of the organisms sampled.
- §122.21(r)(10) Comprehensive Technical Feasibility and Cost Evaluation Study: The facility must submit an engineering study of the technical feasibility and incremental costs of candidate entrainment control technologies. The study must include an evaluation of the technical feasibility of closed-cycle cooling, fine-mesh screens with a mesh size of 2 mm or smaller, reuse of water or alternate sources of cooling water, and any other entrainment reduction technologies identified by the applicant or requested by the Director.
- §122.21(r)(11) Benefits Valuation Study: The facility must submit a detailed discussion on the benefits of the candidate entrainment reduction technologies evaluated in (r)(10) using data from the Entrainment Characterization Study in (r)(9). Benefits should be quantified in physical or biological units and monetized using appropriate economic valuation methods.
- §122.21(r)(12) Non-Water Quality Environmental and Other Impacts Assessment: The facility must submit a detailed discussion of the changes in non-water quality environmental and other factors attributed to the technologies, operational measures, or both, as applicable. These changes may include impacts such as additional energy consumption, air pollutant emissions, noise, safety concerns, potential for plumes, icing, availability of emergency cooling water, grid reliability, etc.
- §122.21(r)(13) Peer Review: The facility must provide for a peer review of the permit application studies required under §122.21(r)(10) through §122.21(r)(12).

2.3 Compliance for Schiller Station

There are likely several alternatives through which Schiller Station can achieve compliance with Section 316(b) of the CWA. This section will evaluate the different compliance scenarios, and discuss the Station modifications that would be required. This section relies upon information from the 2008 Response, the August 2013 Request for Information (Ref. 8.23), and this report.

As discussed in Section 2.2, the new rule does not require submittal of any information related to entrainment for facilities with an AIF less than 125 MGD. As discussed in Section 3.3 of this report, the AIF for Schiller Station is well below 125 MGD; therefore, compliance with Section 316(b) of the CWA for Schiller Station will be focused on meeting the impingement BTA standard.

2.3.1 Option #1 – Closed-Cycle Cooling

As discussed in the 2008 Response, a closed-cycle cooling configuration using mechanical draft cooling towers was determined to be feasible from an engineering perspective at Schiller Station. The initial and ongoing costs are significantly higher than that of other technologies and operational measures considered for reduction in impingement mortality. Conversion of existing operating power plants from once-through to closed-cycle cooling is largely unprecedented. Additional parasitic losses, plume, icing, noise, lost generating capacity during implementation, environmental impacts, and visual impact are all negative consequences that would occur from implementation of this alternative as discussed in the 2008 Response. Therefore, based on these impacts, the relative cost of this technology, and Schiller Station's low capacity factor, conversion of Schiller Station to closed-cycle cooling is not considered a practical compliance scenario.

2.3.2 Option #2 – Design Through-Screen Velocity of 0.5 fps

Compliance under Option #2 would require Schiller Station to operate an intake such that the design intake through-screen velocity does not exceed 0.5 fps at any time. This could be accomplished in a number of ways, some of which are more practical than others.

As discussed in the August 2013 Response to follow-up information requests from EPA, the installation of MultiDisc screens would increase the through-screen velocities at Schiller Station without other modifications to expand the intakes. Installation of W Intake Protection (WIP) Screens would also increase the through-screen velocity without other modifications to expand the intakes. The installation of dual flow traveling water screens may be possible such that the through-screen velocity is reduced to 0.5 fps; however, as discussed in the August 2013 Response, the approach velocity through the side entrance openings would be greatly increased (Ref. 8.23), potentially limiting the ability of fish to swim away from the intake. These technologies likely do not represent good candidate technologies for this compliance scenario.

As discussed in Section 5 of this report, wide-slot wedgewire screens can be installed at Schiller Station in a manner that reduces the through-screen velocity to less than 0.5 fps. It is expected that the ABS would prevent excessive blockage from occurring at the screens. However, in the event that significant blockage does occur, both Screen Houses contain backup "emergency" intakes that would prevent a plant outage. During these emergency scenarios, the intake velocity would exceed the 0.5 fps; however, this is expected to be a rare occurrence.

As discussed in Section 6 of this report, a barrier net with a 3/8-in. mesh size could be installed around both intakes at Schiller Station such that a through-screen velocity of less than 0.5 fps is achieved during all scenarios. It is expected that, even with heavy debris loading on the net, the velocity attributed to the CWIS would be maintained under the limit of 0.5 fps due to the amount of netting required to span around both intakes. Ambient currents may increase or decrease the actual velocity of water passing through the screen or net.

2.3.3 Option #3 – Actual Through-Screen Velocity of 0.5 fps

As noted in Section 2.1, this compliance scenario differs from Option #2 in that the design intake velocity may exceed 0.5 fps, however, the intake must be operated in a manner such that the actual intake velocity is 0.5 fps or less. The example cited in the rule is an intake that was originally designed for 1.0 fps, but now operates at a lower intake velocity due to retiring of a portion of the plant. Given that Units 3 and 4 share the same intake (Screen House #1), and that Unit 3 was retired in 1991, this is an option that may be available for Unit 4 as discussed in Section 6.1.1 of the 2008 Response. As discussed in that Section, this modification would result in an actual intake velocity of 0.46 fps in Screen House #1 at mean low water (MLW), satisfying the criteria. As also discussed in the 2008 Response, this would require installation of new traveling water screens, installation of a common FHRS trough, and any structural modifications required to the intake structure building to accommodate new equipment. However, as noted above, compliance under this scenario is only possible for Unit 4, as Units 5 and 6 currently utilize all of the available intake bays in Screen House #2.

2.3.4 Option #4 – Offshore Velocity Cap

As discussed in the 2008 Response, Unit 4 uses an offshore bulkhead intake with bar racks, and Units 5 and 6 use a conventional shoreline intake. Compliance under this scenario would have required Schiller Station to have an offshore velocity cap that meets the definition in the rule (located a minimum of 800 ft offshore) before the effective date of the rule. Because Schiller Station does not currently have an offshore velocity cap, compliance under this scenario is not possible. As noted in the rule, even if Schiller Station were to install an offshore velocity cap that meets the definition, compliance would be pursued under either Option #6 or #7.

2.3.5 Option #5 – Modified Travelling Water Screen

Compliance under Option #5 would require installation of modified traveling water screens and a FHRS that meets the definition as described in Section 2.1 of this report. Modified coarse-mesh Ristroph screens with a modified FHRS is a candidate technology for compliance under this scenario. For this compliance option, the site would need to conduct an impingement technology performance optimization study as discussed in Section 2.1 of this report.

2.3.6 Option #6 – System of Technologies

Compliance under this option requires Schiller Station to utilize any systems of technologies, best management practices, and operational measures that the Director determines is the BTA for impingement reduction. Schiller Station would be required to submit a two-year, site-specific study concluding that the operation of the systems of technologies, operational measures and best management practices have been optimized to minimize impingement mortality.

The systems of technologies may take credit for reductions in impingement mortality already obtained at the facility. Additionally, reductions in AIF below the DIF may be credited. As discussed in Section 3.3 of this report, the AIF of Schiller Station is well below the DIF, especially for Units 4 and 6. The DIF for the Station is approximately 125.8 MGD as discussed in Section 2.3.2.3.2 of the 2008 Response, however the AIF determined in Section 3.3 of this report from 2011 – May 2014 is approximately 74 MGD.

It is noted that Schiller Station cannot take credit for the closure of Unit 3 as a part of its system of technologies and operational measures to reduce intake flow. The rule clarifies that credit can only be taken for a 10-year window following closure of a portion of the facility. As stated in the 2008 Response, Unit 3 was retired in 1991.

Compliance under this scenario would begin with the crediting of the reduced intake flows as part of a system of technologies and operational measures. Based on whether this technology and operational measure is deemed BTA for Schiller Station on a site-specific basis by EPA, additional supplemental technologies or operational measures could be proposed to operate in tandem with those already employed. However, because of the historic variability associated with the capacity factor, crediting of low capacity factors for BTA compliance is not considered further in this report. Compliance using a combination of technologies, such as a barrier net for one Screen House and wedgewire screens for another, may be possible as well.

2.3.7 Option #7 – Achieve the Specified Impingement Mortality Standard

Compliance under this option would require Schiller Station to achieve a 12-month impingement mortality performance of all life stages of fish and shellfish of not more than 24 percent mortality, including latent mortality, for all non-fragile species. Many of the technologies described above are potential candidate technologies for compliance under this scenario, including wide-slot wedgewire screens, barrier nets, and modified Ristroph screens with a FHRS. Annual impingement abundance and mortality for Schiller Station were estimated in Attachment 3 for comparison with the new §316(b) regulations to determine if the existing CWIS at each Unit achieved the specified impingement mortality performance standard of 24 percent specified under §125.94(c)(7). The comparison was made by applying the observed mortality rates of non-fragile fish and macro-crustaceans from the 2006-2007 Study to the annual impingement abundance estimated using the actual intake flows observed for the three most recent years of operation of Schiller Station Units 4, 5 and 6 (2011 through 2013). Latent mortality values of 74.2 percent for non-fragile fish and 32.9 percent for macro-crustaceans for all three Units combined did not achieve the impingement mortality standard of 24 percent at Schiller Station. If the survival data were weighted by the annual total impingement abundance of non-fragile fish or macro-crustaceans and not in proportion to their abundance in the survival samples, the latent mortality was 71.6 percent for non-fragile fish and was 32.3 percent for macro-crustaceans from all three Units combined at Schiller Station.

The previous 2008 Response estimates of impingement abundance were also used to estimate latent impingement mortality for comparison to the design intake flows, the actual 2006-2007 intake flows, and the current 2011-2013 intake flows for each Unit and for all three Units combined (see Attachment 3). The percent mortality achieved by the existing CWIS configuration of traveling screens and return systems was estimated as 44.5 percent for 2011-2013. Although the annual number of fish and macro-crustaceans impinged at Schiller Station (all three Units combined) was reduced by 47.5 percent due to flow reductions mostly at Units 4 and 6, relatively high abundance and survival of hardy macro-crustaceans impinged at Schiller Station were offset by relatively low survival of non-fragile fish species to produce this result.

2.3.8 Summary

In summary, many of the technologies evaluated in the 2008 Report were evaluated using impingement survivability and impingement reduction as a measure. Therefore, this information is not repeated here. However, note that changes have occurred since 2008 in the way that impingement mortality is determined; these changes are discussed in Attachment 3.

One of the more cost-effective options discussed in the 2008 Response was installation of modified Ristroph screens with an upgraded FHRS. This was estimated to provide impingement survival rates of 75.5, 73.5, and 75.3 percent for Units 4, 5, and 6, respectively, based on 2008 figures and methodology. It is noted, however, that this would be similar to achieving compliance under Option #5, however with different §122.21 subsection submittals provided to EPA during the NPDES permit application process.

3 Engineering Update

3.1 Changes in Impingement-Reducing Intake Technologies

Since the issuance of the 2008 Response, several updates and changes in impingement-reducing intake technologies have occurred. There are several relevant technologies that were not addressed in the 2008 Response. This section provides a summary of several technological advancements and other technologies relevant to the 2008 Response.

In June 2010, the Environment Agency (United Kingdom, or UK) published a report called "Cooling Water Options for the New Generation of Nuclear Power Stations in the UK" (Ref. 8.1). The purpose of the study was to ensure that new nuclear power stations built in the UK meet high standards of safety, security, and environmental protection. A specific focus was placed on cooling water options, and evaluation of environmental impact that is equally applicable to other power plants and facilities with large cooling water intakes in general.

3.1.1 Parallel Condensing System

One technology evaluated in the Environment Agency Report is the Parallel Condensing System™ (PAC), which is a patented GEA Group concept in which the exhaust steam from the turbine is split into two variable streams (Ref. 8.1). One stream goes to a typical water-cooled condenser with a wet cooling tower, the other stream goes to an air-cooled condenser. This is different from a hybrid cooling tower that uses wet and dry cooling in either a parallel or series arrangement to cool one condenser. In the PAC, one of the two condensers is an air-cooled heat exchanger in itself. The advantages of an air-cooled heat exchanger are that no water is evaporated. The disadvantage is that only sensible heat transfer can occur due to no water being evaporated. This leads to reduced heat transfer efficiencies, especially during warmer weather. On hot days, the PAC would likely rely mostly on the wet condenser, however the dry section can reject a portion of the overall heat load, thereby reducing peak water usage. During the cooler months, if so designed, the heat rejected by the dry unit can be increased up to 100 percent, with no evaporative losses. The plume can be reduced or eliminated entirely when danger of icing exists, simply by shutting down the wet section (Ref. 8.1). An illustration of this system is shown in Figure 1.

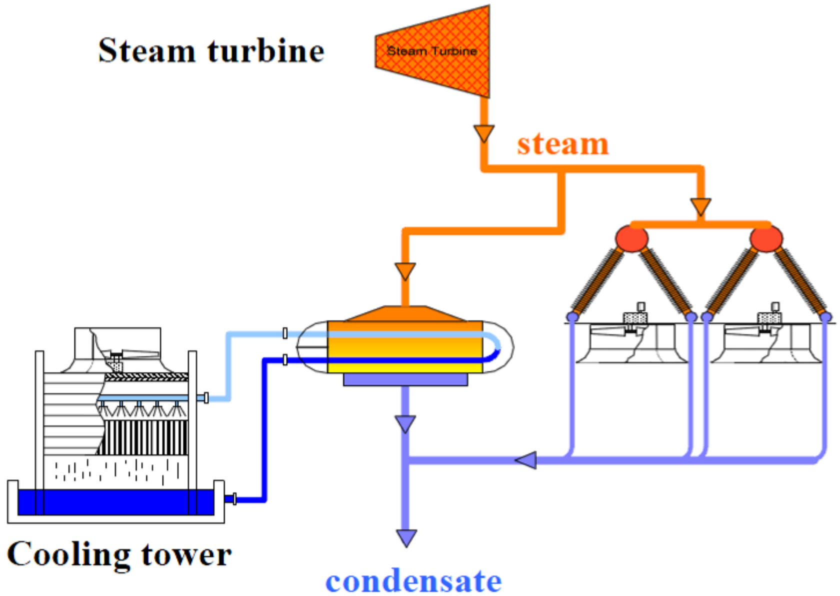

Figure 1: Parallel Condensing System™ illustration (Ref. 8.2)

This system has been installed at Comanche III, a 750-MW coal-fired plant in Pueblo, CO (Ref. 8.2). This system has also been installed at Ryehouse, UK, a 720-MW combined-cycle power plant, and at Astoria Energy in Queens, NY, a 500-MW combined-cycle power plant (Ref. 8.3). This technology, while showing promise to reduce intake flows for new facilities, is clearly not feasible from an engineering perspective for a retrofit at Schiller Station, as installation of this technology would require a significant re-design and re-build of the power conversion cycle and plant cooling water systems.

3.1.2 Drum Screens

Drum screens are simpler in construction than conventional traveling water screens, and are comprised of a slowly revolving mesh cylinder through which water is passed. The revolving cylinder is essentially the only moving part, although a motor is required to turn the cylinder, and screen wash pumps are also required. Drum screens are widely used throughout Europe, Asia, and South America in power plants and other large water intakes (Ref. 8.26). The civil costs and the initial price of a drum screen installation may be higher than that of a traveling water screen installation. However, because of the design simplicity, the maintenance and operating costs of a drum screen installation are usually less than those of a traveling water screen. Variations related to the configuration exist, such as single and double-entry drum screens.

For double-entry drum screens, raw water enters the two open ends of the drum screen and flow through the wire mesh panels. Water flows from the inside to the outside of the drum. Debris is retained on the inside surface of the wire mesh panels and elevated out of the flow as the drum rotates. Debris retention is aided by lifting shelves that are fitted to the inside of the drum at regular intervals. The debris is removed from the mesh into a debris trough at the top of the drum by a high-pressure spray wash system (Ref. 8.26). A double-entry drum screen is shown in Figure 2.

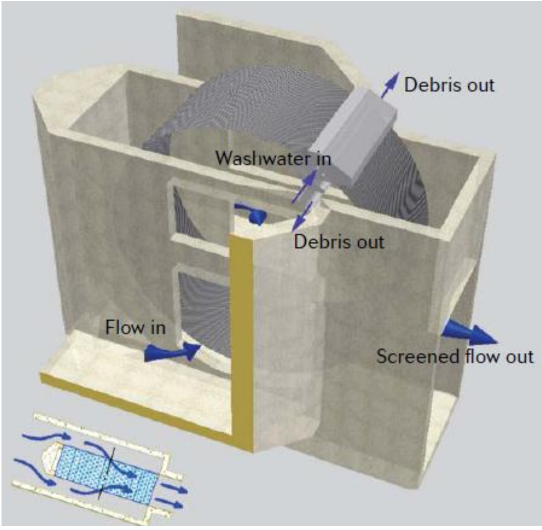

Figure 2: Double-entry drum screen (Ref. 8.27)

Single-entry drum screens are similar to the larger double-entry drum screens. The major difference is that they are not oriented in line with the flow, and that the downstream end of the drum is closed with a full-diameter backplate. Flow enters the drum through its open end and exits outward through the wire mesh mounted on the screens periphery. Debris is retained on the inside surface of the wire mesh panels and is elevated out of the flow as the drum rotates. Similar to the double-entry drum screens, the debris is removed by a high-pressure spray wash system (Ref. 8.26). A single-entry drum screen is shown in Figure 3.

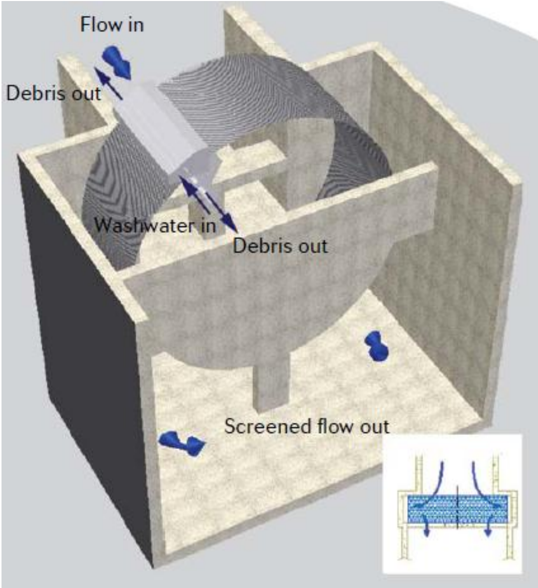

Figure 3: Single-entry drum screen (Ref. 8.27)

Drum screening systems are being installed at intake structure facilities all over the world, including installations in France, Holland, Belgium, China, and others. Due to the current configuration of Screen Houses #1 and #2 at Schiller Station, which were designed for traveling water screens, installation of drum screens would require extensive structural modifications to the intake structures.

3.1.3 Acoustic Fish Deterrent Systems

An example of advancements in long term reliability of acoustic fish deterrent systems (FDSs) is the development of the sound projector array (SPA). SPA systems can be designed to allow access to the projectors without divers. Required maintenance is conducted on projectors one at a time on 12-month intervals without a loss of barrier integrity. SPA systems are currently installed at Doel Nuclear, Hartlepool Nuclear, Great Yarmouth, among others. To ensure redundancy, sound projector numbers are typically over-specified by 100 percent. A test conducted at Doel Nuclear showed that 15 out of 20 projectors had to fail before the fish deflection efficiency dropped significantly (Ref. 8.4). However, as concluded in the 2008 Response, an acoustic FDS installed at Schiller Station would not significantly reduce impingement and a technological evaluation of FDS feasibility is not warranted.

3.2 Changes to Schiller Station

The only major change to the way that Schiller Station has operated since submittal of the 2008 Response has been a lower capacity or utilization factor. This is reflected in the intake flow operational data in Section 3.3. Otherwise, there have been no major changes to plant configuration or equipment since 2008 that would affect intake flows, discharges, or impingement and entrainment.

3.3 Intake Flow Operational Data

Recent intake flow data was supplied by the Station to characterize the utilization factor and AIF rates over the past several years for each Unit. Data was supplied from 2011 through 2013 to account for the last three full years of data. The AIF for each year was determined by averaging the daily intake volumes over each year for each Unit. Table 1 below shows the AIF for each operating Unit at Schiller Station in MGD.

Table 1: Actual intake flows for Schiller Station from 2011 – 2013, MGD

	Unit 4	Unit 5	Unit 6	TOTAL
2011	23.37	36.13	24.93	84.43
2012	12.62	39.10	13.16	64.87
2013	16.88	39.15	15.85	71.88
Average	**17.62**	**38.13**	**17.98**	**73.73**
DIF	42.2	41.8	41.8	125.8

From Table 1 above, the AIF from the time period of January 1, 2011 – December 31, 2013 for Schiller Station was calculated to be approximately 74 MGD. There was considerable variability from year-to-year, with the AIF being as low as approximately 65 MGD in 2012, and as high as approximately 84 MGD so far in 2011. Therefore, Schiller Station, as it is operated currently, should be considered to have an AIF well below the 125 MGD threshold discussed in Section 2.2. The DIFs are taken from Section 2.3.2.3.2 of the 2008 Response. Note that the AIFs for Units 4 and 6 are significantly below their DIF, representing existing operational measures to reduce intake flows. If Schiller Station were to operate continuously, at full capacity for three consecutive years, the AIF would reach 125.8 MGD, which is just above the threshold discussed in Section 2.2.

3.4 Variable Speed Pumps

The 2008 Response evaluated the use of VSPs to reduce the intake flow by Schiller Station under the assumption that a reduction of intake flow yields a proportional reduction in entrainment and impingement mortality. Reduction of intake flow using VSPs reduces cooling to the condenser, which impacts plant operation, and increases the Station's discharge temperature, which potentially impacts NPDES permit compliance.

Two separate plant operating restrictions were discussed in the 2008 Response. Firstly, a minimum flow velocity of 3 fps is required through the condenser to build up enough flow resistance within the condenser to ensure uniform quality of water throughout all the tubes. Under the design flow conditions as Schiller Station, each Unit operates with a condenser tube velocity of 3.5 fps. Therefore, this restriction bounds the available flow reduction to no greater than 14 percent. Secondly, as discussed in the 2008 Response, the condenser for each Unit has a design pressure limit of 1.5 in-Hg. Operation beyond this limit results in increased fuel consumption and may potentially reduce the reliability of plant equipment. Table 6.5 of the 2008 Response estimated the monthly available flow reduction based on this limitation using empirical operational flow data from 2000 – 2007.

The 2008 Response provided the design through-screen velocities for each of the Units at Schiller Station based on the design intake capacity, MLW level, and screening dimensions. Based on these inputs, the through-screen velocity for Unit 4 is 1.38 fps at MLW, and the through-screen velocity for Units 5 and 6 is 0.68 fps at MLW. If VSPs were used to reduce the intake flows for each of the Units, there would be a proportional decrease in the average through-screen velocity. Table 2 below provides the estimated average through-screen velocities based on the available flow reduction estimates provided in the 2008 Response.

Table 2: Estimated average through-screen velocities based on estimated allowable flow reductions from Table 6.5 of 2008 Response

Month	Unit 4	Unit 5	Unit 6
January	1.19	0.58	0.58
February	1.19	0.58	0.58
March	1.19	0.58	0.58
April	1.19	0.58	0.59
May	1.19	0.61	0.59
June	1.34	0.68	0.66
July	1.38	0.68	0.68
August	1.38	0.68	0.68
September	1.36	0.68	0.67
October	1.21	0.64	0.60
November	1.19	0.58	0.58
December	1.19	0.58	0.58

From Table 2 above, slight reductions in through-screen velocity would result from the use of VSPs to reduce impingement. However, the through-screen velocities are estimated to remain above 0.5 fps. Additionally, the flow reductions presented in Table 6.5 of the 2008 report, which form the basis of Table 2 above, are estimates based on empirical data. These flow reductions do not provide a buffer or any operating margin against the two limits described above. In reality, a buffer would exist to prevent these limitations from being exceeded during unexpected plant conditions or transients. Therefore, the buffer would prevent the through-screen velocities from being reduced to the amounts shown in Table 2 above. Additionally, these flow reductions are based on estimates and have not been precisely calculated using rigorous analysis.

Detailed thermal analyses of the plant heat balances has not been performed. Because VSPs would reduce the amount of cooling water provided to the plant condensers, a higher discharge water temperature is required to maintain the heat cycle. This has several impacts, including higher thermal discharge temperature to the Piscataqua River. Additionally, due to the reduced condenser cooling efficiency, higher condenser pressures and condensate temperatures would result. This reduces the thermal efficiency of the power conversion cycle, requiring more fuel to be consumed to produce the same power output. The impact to Station thermal efficiency cannot be precisely determined without detailed modeling of the plant power conversion system using a software program such as Performance Evaluation of Power

System Efficiency (PEPSE). This would allow for precise characterization of the limitations of VSPs due to the plant heat cycle and condenser limitations.

Additionally, as noted above, reduction of flow using VSPs results in increased discharge temperature. Based on the 2000 – 2007 empirical operating data, the increased discharge temperature based on decreasing flows can be estimated. The median temperature differential between incoming and discharge cooling water at full flow conditions was 21.1°F for Unit 4, 21.6°F for Unit 5, and 22.1°F for Unit 6. The median temperature observation was used to reduce the impact of erroneous readings from the estimate. Based on a 1 percent reduction in cooling water intake flow, the Unit 4 discharge temperature would be expected to increase by 0.21°F, while the Units 5 and 6 discharge temperatures would be expected to increase by 0.22°F. This, however, is an estimate that would require detailed modeling to determine a precise impact.

As shown in Table 6.8 of the 2008 Response, during certain months the thermal discharge limitations associated with the Station's NPDES permit are more limiting than the Station's operating parameters. Flow cannot be reduced as significantly because the temperature differential limitation and/or maximum discharge temperature limitation would be exceeded. In general, the allowable flow reductions from VSPs are limited by the NPDES permit temperature differential limit of 25°F during the cooler months, and are limited by the condenser operating limits during the warmer months. The available flow reductions per the 95°F maximum discharge temperature limitation is generally bounded by the available flow reductions per the condenser limitations in the warmer months. However, the extent to which flow can be reduced as a result of condenser limitations has only been estimated to this point and has not been precisely determined. Additionally, all of the VSP analysis has been based on estimates from empirical data; therefore, considerable uncertainty exists within these conclusions.

3.5 2008 Cost Estimate Updates

The project engineering and construction cost estimates that were previously provided in Attachment 4 of the 2008 Response are reviewed and updated to current 2014 dollars using construction cost index estimation factors. It is recognized that the cost for certain materials and proprietary technologies may scale differently than what the cost indices will capture; however, given that these are Class 5 cost estimates per ASTM E2516-11 (Ref. 8.10), general cost index estimation factors are typically used.

All projects listed in sections of Attachment 4 of the 2008 report are updated except for Section 4, Fine Mesh Wedgewire Screens. This estimate was omitted from this update because the design has been refined (discussed in Section 5 of this report) and a new cost estimate provided in Attachment 1, Section 1. See Attachment 1, Section 3 of this report for all other 2008 Cost Estimate Updates described in this section.

4 Cooling Tower Drift

Cooling towers are designed to promote close contact between air and water within the fill to improve heat transfer, and ultimately, performance of the cooling tower. As a byproduct of this facet of cooling tower design, small water droplets become entrained in the air stream leaving the tower. Cooling tower drift is defined as the circulating water that is lost from a cooling tower as liquid droplets become entrained in the exhaust air stream (Ref. 8.5).

Cooling tower drift was mentioned briefly in the 2008 Response; however, more information is provided in this Supplement due to the increased attention on cooling tower drift in recent years. Drift is comprised of liquid water droplets, and should not be confused with the water vapor that has saturated the air stream leaving the top of the tower due to evaporation of water within the tower. Drift should not be confused with the very small water droplets that form when saturated water vapor leaves the top of the tower and condense out of the air due to a drop in temperature (i.e., the plume). The composition of the water that comprises drift is the same as that of the circulating water passing through the tower. This can become problematic based on the water quality characteristics.

4.1 Water Salinity at Schiller

As discussed in the 2008 Response, Schiller Station is located on the Piscataqua River in a coastal region that is influenced by tidal variations in the Atlantic Ocean. The salt content of the river near Schiller Station is typical of coastal waters an average of 72 percent of the time (Ref. 8.6). During the flood tide, salinities typical of coastal waters occur 86.5 percent of the time; during ebb tide, coastal salinities typical of coastal waters occur 57 percent of the time. The salinities are more typical of estuarine conditions only during the spring freshet (i.e. the freshwater runoff resulting from snow and ice melt) or the fall secondary runoff periods (Ref. 8.6). Therefore, the water that would be used for a potential cooling tower at Schiller Station would likely be typical of coastal waters a majority of the time.

The use of salt water has many implications for the design and operation of cooling towers. The modified properties of salt water include: reduced vapor pressure, higher surface tension, higher dynamic viscosity, lower thermal conductivity, and higher density relative to freshwater (Ref. 8.11). Other than the higher surface tension, these changes in properties act to reduce the performance of the cooling tower and may require use of a larger tower. The higher surface tension aids in the breakup of water within the fill, leading to smaller water droplets and potentially increased performance of the tower. In theory, this would lead to slightly improved performance for drift eliminators (which are discussed in more detail in Section 4.4), and subsequently lower drift rates. However, discussions with drift eliminator vendors have indicated that the performance of drift eliminators is essentially the same with salt water (Ref. 8.11). The performance of drift eliminators using salt water becomes important due to the dissolved solids within the droplets.

4.2 General Impacts of Drift

Impacts associated with cooling tower drift contacting nearby equipment and the environment are typically limited to the region immediately surrounding the cooling tower. Large drift droplets settle out of the tower exhaust air stream and deposit near the tower. This process can lead to wetting, icing, salt deposition, and other related problems such as damage to equipment or to vegetation (Ref. 8.7).

Special considerations reducing drift may be required because of the sensitivity of the natural vegetation or the crops in the vicinity of the site to damage from airborne salt particles. When siting a tower, the vulnerability of existing facilities in the vicinity of the cooling tower to corrosion from drift should be considered. Not only are the amount, direction, and distance of the drift from the cooling system important, but the salt concentration above the natural background salt deposition at the site is also important in assessing drift effects. The environmental effects of salt drift are most severe where saline water or water with high mineral content is used for condenser cooling (Ref. 8.8).

Reference 8.11 conducted an operating experience survey of facilities that operate cooling towers using salt water or brackish water. Plants visited include: St. Johns River Power Park, Jacksonville, Florida; Plant Smith, Lynn Haven, Florida; Plant Crist, Pensacola, Florida; and Plant Watson, Gulfport, Mississippi. Additionally, telephone interviews were conducted for several other facilities, including the following: Pittsburg Power Plant, Pittsburg, California; Palo Verde Nuclear Generating Station, Palo Verde, Arizona; and GEA Integrated Cooling Technologies, Lakewood, Colorado. One of the primary conclusions was the following (Ref. 8.11):

> *Nearly all plants with high-salinity cooling towers, both natural and mechanical draft, have encountered accelerated corrosion on unprotected metal surfaces on buildings and equipment at the plant site near the towers.*

Additionally, it was noted in the study that both mechanical and natural draft towers constructed of concrete have experienced varying degrees of deterioration from exposure to salt water. In some cases, very extensive repairs had been required (Ref. 8.11). In addition to the added operations and maintenance costs associated with operating a cooling tower system, additional costs should be expected as a result of degradation of equipment near the tower.

4.3 Air Emissions

With drift droplets that have higher salinity, the mass emissions of salt increase even if the drift volume itself remains essentially the same. This has the effect of introducing fine particulate matter into the atmosphere. Particles with a mean aerodynamic diameter of less than or equal to 10 microns or 2.5 microns are classified within the National Ambient Air Quality Standards (NAAQS) as PM10 or PM2.5, respectively (Ref. 8.11).

If it is assumed that a typical wet cooling tower using seawater operates at 1.5 cycles of concentration (i.e., drift salinity of 52,500 ppm) and has a flow rate of 250,000 gpm, the tower would generate PM10 emissions of approximately 4,700 tons per year (Ref. 8.11). Contrasting this to a tower that operates using freshwater, if the makeup source has a total dissolved solids (TDS) concentration of 500 ppm, and operated at 10 cycles of concentration, the drift salinity would only be 5,000 ppm. This would constitute less than 1/10th of the salinity of the salt water tower, even with the increased cycles of concentration (Ref. 8.11).

Drift rates are a function of the quality of installation and state of repair of the drift eliminators, and can be higher or lower depending upon installation-specific and site-specific circumstances. The drop size spectrum can change with different drift eliminator designs, as well as with age and condition of the drift eliminators. Some fraction of the drift will fall to the ground or surrounding structures, and the dissolved material in those drops will not be released into the atmosphere (Ref. 8.11). This would be expected to vary based on local geography, proximity of other structures, height of the tower, as well as typical wind velocities and directions.

In summary, operating a cooling tower using salt water can lead to significant air emissions in the form of fine particulate matter. There is significant uncertainty in the rate of expected air emissions that would result from a salt water cooling tower. The design, installation, and state of repair of the tower all play a significant role in the emissions rate, as well as the local environment immediately surrounding the tower.

4.4 Drift Eliminators

Drift eliminators remove a portion of the entrained water from the discharge air by causing it to make sudden changes in direction. The resulting centrifugal force separates the drops of water from the air, depositing them on the eliminator surface, from which they flow back to the tower. Concern related to the possible environmental impacts related to cooling tower drift stimulated considerable research and development in the fields of drift eliminators. Currently, the anticipated drift levels in smaller, more compact towers will seldom exceed 0.008 percent of the circulating water flow rate (Ref. 8.5). In larger towers, which afford more room and opportunity for drift-eliminating techniques, drift rates will normally be in the region of 0.001 percent (Ref. 8.5).

One negative byproduct of drift eliminators is increased air pressure losses through the tower, potentially resulting in increased fan horsepower requirements. Pressure loss can be beneficial in small amounts because it evenly distributes air flow within the tower; however, drift eliminator design typically attempts to reduce pressure losses as much as possible because there is already sufficient pressure loss in the tower. Typically, they are classified by the number of directional changes or “passes”, with an increase in the number of passes usually resulting in increased pressure drop (Ref. 8.5). SPX Cooling Technologies specifically designs drift eliminators for crossflow towers with turning vanes to reduce pressure losses (Ref. 8.17).

Drift eliminators can come in several different configurations. They may consist of several slats positioned within frames, or they may be molded into a cellular configuration with labyrinth passages. Towers that use film fill may have drift eliminators molded integrally with the fill sheets (Ref. 8.5).

4.5 Summary

In summary, there are many considerations for designing and citing a cooling tower. Several of the primary considerations include the ambient weather conditions, design heat load, flow rates, cooling tower type, and available space. Operating a cooling tower creates a negative environmental impact to the surrounding region, potentially including noise, plume, icing, fogging, and drift. Drift is the result of liquid water droplets that become entrained in the air flow exiting the tower. Due to the water salinity at Schiller Station, drift is an especially important consideration that may detrimentally affect the surrounding environment if a cooling tower were to be installed.

5 Wide-Slot Wedgewire Screens

Wedgewire screens are large, permanent intake screens installed in a waterbody that exclude aquatic organisms and allow a large screening area in support of low through-screen intake velocities. Wedgewire screens can be designed such that a through-screen velocity of 0.5 fps would be achieved, making wedgewire screens a candidate technology for compliance of Section 316(b) of the CWA under §125.94(c)(2). Many wedgewire screen systems are equipped with an air burst system (ABS), which uses periodic bursts of compressed air to blow accumulated objects from the screens, preventing blockage that can lead to higher capture velocities and pressure drops. By selecting this option, evaluating the biological efficacy of these proposed wide-slot wedgewire screens is not required under the final §316(b) regulations, although they may offer some entrainment reduction benefits in addition to impingement mortality BTA compliance (Attachment 3).

Wedgewire screens have been successfully installed in plant water intakes as a method of minimizing impact to aquatic life, while providing sufficient water for plant operations. Wedgewire screens were installed at the Oak Creek Power Plant intake on Lake Michigan, near Milwaukee, Wisconsin in 2009. This intake system uses 24 Z-Alloy cylindrical wedgewire screens, with a 3/8-in. slot size (Ref. 8.20). Z-Alloy (a proprietary copper-nickel alloy) has been shown to substantially reduce bio-fouling compared with stainless steel, while providing excellent corrosion resistance in underwater environments.

As stated in the 2008 Response, narrow-slot wedgewire screens would provide increased entrainment performance relative to wide-slot screens due to the smaller opening size; however, wide-slot screens are re-evaluated in this report as a means to achieve the 0.5 fps maximum design velocity and satisfy the rule. This section provides a conceptual design for wide-slot wedgewire screens in support of providing a Class 5 cost estimate per ASTM E2516-11 (Ref. 8.10). This design incorporates more recent lessons learned that were not available at the time of the 2008 Response.

5.1 Conceptual Design Summary

5.1.1 Unit 4 (Screen House #1)

As described in the 2008 Response, Unit 4 uses an offshore intake that provides cooling water into Screen House #1. Within Screen House #1, there is one traveling water screen and intake bay that are currently utilized for Unit 4 operation. Screen House #1 contains two retired-in-place intake bays that were once used for Unit 3.

The Unit 4 conceptual design utilizes one of the retired-in-place Unit 3 intake conduits, on the north side. Two Johnson Screens Model T-78HC half-screens with a slot width of 3/8 in. would be connected to the northern most intake pipe (i.e. retired Unit 3 intake pipe). Drawings of these screens are provided in Attachment 2. Each screen would be 18.25 ft long and have a diameter of 78 in. Half-screens were selected because the distance between the full screen and the water surface at low water level is less than the required half-diameter of the screen (i.e. 3.25 ft) as identified in the Johnson Screens Application

Guide (Ref. 8.21). Increasing the distance between the screen and the water surface is recommended if site conditions are subject to icing.

The screens were selected to maintain head loss at approximately 1 ft H_2O or less at the required flow rate, and therefore the maximum through-screen velocity would 0.33 fps, which is less than the 0.5 fps design intake velocity required to be considered a candidate technology under §125.94(c)(2). This reduced through-screen velocity provides operating margin and allowance for some blockage on the screens. The pressure drop associated with the screens would be approximately 0.33 psi at full flow.

Outlet pipes from the screens would be 30-in. 316L stainless steel. Pipe size was based on AWWA standard steel-ring flanges, class B (86 psi pressure rating). The diameter of the flange would need to be smaller than the diameter of the screen plus the baseplate, so that the flange does not interfere with the placement of the screen on the concrete pad. The radius of the T-78HC screen would be 39 in. and the baseplate has a thickness of 0.5 in.; therefore a 38.75-in. AWWA class B flange would meet the dimensional requirements. Per Table 2 of Reference 8.22, the nominal pipe size for this flange is 30 in. Pressure drop through this piping would be small.

The intake from Unit 3 would be cross-connected to Unit 4 using the existing cross-tie between the Units. A valve exists between the Unit 3 and Unit 4 intakes that can be opened to permit this cross-flow. No additional changes to Screen House #1 would be required. As discussed in the 2008 report, the circulating water pumps for Unit 4 are not located within Screen House #1; therefore, the sudden turn in flow would not cause vortexing concerns at the Unit 4 circulating water pumps since they are sufficiently far downstream.

During normal operation, the Unit 4 stop log would be lowered, the Unit 4 traveling water screen would be off, and the cross-tie between Units would be open. Because the wedgewire screens are connected to the northern most Unit 3 intake, no traveling water screens are required to be installed in Unit 3 for normal operation. In an emergency situation where blockage of the wedgewire screens occurs, the Unit 4 stop log would be raised and the traveling water screen would be turned on. In this arrangement, the Unit 4 intake would operate similar to its current configuration. The cross-tie between units can remain open or closed as needed for maintenance/repair functions.

5.1.2 Units 5 and 6 (Screen House #2)

As described in the 2008 Response, Units 5 and 6 receive their cooling water from Screen House #2, which contains a conventional shoreline bulkhead intake. There are four intake bays, two for Unit 5 and two for Unit 6, each equipped with bar racks and traveling water screens. Each of the intake bays are separated by partition walls. Unlike Unit 4, the circulating water pumps for Units 5 and 6 are located in the Screen House.

For the Units 5 and 6 (Screen House #2) conceptual design, three Johnson Screens Model T-84HC half-screens with a slot width of 3/8 in. would be connected to a new intake plenum box. Drawings of these screens are provided in Attachment 2. Based on the similar water depth conditions, half-screens were also selected for Screen House #2. Each screen would be 20.75 ft long and has a width/diameter of 84 in. Outlet pipes from the screens would be 32-in. 316L stainless steel. As discussed above, screens were selected to maintain head loss at 1 ft H_2O or less at the design flow rate. The maximum through-screen velocity would be 0.37 fps, which is less than the 0.5 fps design intake velocity required to be considered a candidate technology under §125.94(c)(2). The pressure drop associated with the screens would be approximately 0.32 psi at full flow.

Pipe size was based on AWWA standard steel-ring flanges, class B (86 psi pressure rating). The outlet flange would need to be smaller than the radius of the screen (42 in.) plus the baseplate (0.5) so as to not interfere with the placement of the screen on the concrete pad. A 41.75-in AWWA class B flange would meet the dimensional requirements. Per Table 2 of Reference 8.22, this corresponds to a 32-in. pipe size. The pressure drop associated with the new piping would be small.

During normal operation, water would enter the wedgewire screens and enter the plenum, where the flows would converge before entering the intakes for Units 5 and 6 as it does currently. In an emergency situation where blockage of the wedgewire screens occurs, the two sluice gates on the front side of the plenum would be opened, allowing water to enter the plenum directly. Operation of the traveling water screens in Screen House #2 would only be required during this off-normal operation.

5.2 Structural / Construction Considerations

5.2.1 Structural System Descriptions

The locations of the proposed wedgewire screens systems are shown on drawing PSNH009-C-001 (Attachment 2). The wedgewire screens and associated concrete structures would be located on the east side of each screen house. A precast structural system would be used to minimize construction schedule, limit underwater construction, and limit/completely avoid plant outage during the construction.

<u>Wedgewire screen system for Screen House #1</u>

The wedgewire screen system for Screen House #1 (Unit 4) would be composed of wedgewire screens and a precast concrete pad. Two half-screen type wedgewire screens (Johnson Screens, model T-78HC) would be attached to the top of a precast concrete pad with embedded stainless steel headed studs. The 30-in. diameter stainless steel pipe would be connected to the existing offshore intake bar rack. The northern most existing Unit 3 intake bar rack would be replaced with a new stainless steel plate, which has a flanged pipe stub for tie-in. The other existing intake bar rack for Unit 3 would be replaced with a new stainless plate, and sealed to completely block off the intake flow. The Unit 4 existing offshore intake bar rack would remain in place, and the onshore stop log would be lowered into place during normal operation as outlined in Section 5.1. See PSNH009-C-002 (Attachment 2) for the detailed configuration.

Wedgewire screen system for Screen House #2

The wedgewire screen system for Screen House #2 (Units 5 and 6) would be composed of wedgewire screens, a precast pad for the wedgewire screens, and a precast concrete plenum. Three half-screen type wedgewire screens (Johnson Screens, model T-84HC) would be attached to the top of a precast concrete pad with embedded stainless steel headed studs. For constructability, the precast concrete plenum would be designed as two segments (i.e., walls and pad), and would be assembled on site during construction, potentially on a construction barge. The precast wall segment would have multiple circular hollow cores in it. During construction, pre-assembled reinforcing steel cages (vertical bars and spiral ties) would be placed in the circular voids, and infill concrete would be poured and cured to form internal circular columns to structurally combine the segments (slab and walls). The 32-in. diameter stainless steel pipe would connect the outlet pipe of the wedgewire screen and the embedded pipe in the precast wall segment of the plenum. The wall would have two emergency bypass openings (5.75'W x 11.0'H) with stainless steel sluice gates on the river side (east side) to provide an alternative source of circulating water should the wedgewire screens become blocked. The top of the precast concrete portion of the plenum would be open to the water below. The opening would be covered with stainless steel grating with stainless steel support beams to provide working space, coverage of the intake plenum void, and access to the sluice gate system. See PSNH009-C-003 (Attachment 2) for the detailed configuration.

Common Items for Both Screen Houses

The selection of material for the sluice gates, intake piping and submerged ABS piping was based on material availability, durability and cost considerations. For this conceptual design and associated cost estimate (Section 5.7), stainless steel 316L was considered based on availability of 30-in., 32-in., and 6-in. nominal pipe sizes as well as structural plate and typical structural members. Detailed design considerations should include an allowance in pipe and member sizes to account for corrosion. More durable materials, such as duplex 2205 stainless steel, recommended for water with a chloride concentration above 1000 ppm, or super-duplex 2507 stainless steel, recommended for water with a chloride concentration above 4000 ppm, should also be considered during detailed design based on a detailed salinity assessment and cost-benefit analysis that considers material availability and design life. Higher grade stainless steels can be used to extend the life of submerged structures and reduce maintenance issues.

Each wedgewire screen requires installation of 6-in. diameter ABS piping, which would be connected to the ABS compressor equipment. Typical pipe supports composed of stainless steel channel struts and concrete expansion anchor bolts would be installed along the ABS piping route. For the wedgewire screen intake piping, additional supports are not expected because the span between the outlet of the wedgewire screens and the existing intake piping would be relatively short. However, if detailed design efforts identify that supports are required, concrete ballast blocks can be used.

5.3 Structural Design Environmental Conditions

The structural design of wedgewire screens and associated structures would be governed by the design loads per ASCE 7-10 (Ref. 8.12) and additional industry standards for underwater design considerations and construction practices. Because the wedgewire screen support structures are marine structures, the following additional loads should be also considered.

5.3.1 Tidal Condition

Schiller Station is located on the southwestern shore of Piscataqua River, approximately 5 miles from the mouth of the river. This section of river is tidally-influenced and tidal current is considered in the design. According to the recent survey performed by NOAA, the maximum tidal current velocity is conservatively 250 cm/s (≈ 8 fps), and the tidal current direction is generally in the north/south direction and varies based on the tidal cycle (Ref. 8.13). Hydrodynamic loads associated with the current are considered, in addition to the hydrostatic loads based on the river condition.

Water elevations are as follows:

- Extreme high water: EL. 8.3 ft (Ref. 8.25)
- Max high tide: EL. 8.0 ft (Ref. 8.24)
- Mean high water: EL. 3.67 ft (Ref. 8.25)
- Mean low water: EL. -3.67 ft (Ref. 8.25)
- Min low tide: EL. -7.0 ft (Ref. 8.24)
- Extreme low water: EL. -8.75 ft (Ref. 8.25)

5.3.2 Flood Loads

The site may experience flood conditions; therefore, the flood effects should be considered during detailed design. Design flood load cases should consider hydrostatic load, hydrodynamic load, wave load, and impact load. The plant extreme high water level of 8.3 ft (Section 5.3.1) should be considered during detailed design.

Flood loads would be determined during detailed design based on these design parameters according to ASCE 7-10 Section 5 and other industry standards.

Piscataqua River is subject to floating debris. The debris can present an impact hazard to underwater components of the proposed wedgewire screen system. According to ASCE 7-10, the impact load can be categorized into three categories; (1) normal impact load, (2) special impact load, (3) extreme impact load. The wedgewire screens are installed on the bottom of the river, and the probability of direct impact from the floating debris is low. Therefore, the ‘normal impact’ case would be considered during detailed design. Previous project experience has also shown that impact of debris on wedgewire screens at water velocities similar to this case results in localized damage of the wedgewire screens, but not complete failure.

5.3.3 Geotechnical Conditions

Based on review of existing drawings (Refs. 8.14 and 8.15), the existing intake structures are generally supported directly on bedrock. New structures for the wedgewire screen system would be constructed near these existing intake structures; therefore, pile foundations are not expected. The bottom of the proposed precast concrete pads would require proper preparation (i.e., gravel course with tremie concrete, as required) to place the precast concrete pads.

During detailed design, a stability check of the plenum structure for Screen House #2 is necessary. Considering the weight of the structure, a pile foundation is not expected. However, if additional capacity is required for stability, either anchoring the foundation to the bedrock or tying the plenum to the existing intake structure is recommended. The cost estimate (Section 5.7) does not include the cost of either concept due to the potential that anchorage is not required and due to the relatively minimal additional cost.

5.4 Construction Methodology

Marine construction introduces additional complexity, challenges, and risk beyond those typically encountered during more traditional onshore construction projects. Thus, the design of marine structures is based substantially on constructability. Construction techniques deemed efficient on land are often considered inappropriate for marine construction. A typical rule of thumb is that, where structures are required at the bottom of the water body, installing a fewer number of large components is generally more efficient than a large number of small components. The components should be large enough to ensure efficient underwater installation and reduce underwater joining, but not so large that they are unmanageable.

In terms of the construction method for installation of prefabricated structural modules, in-the-wet construction can be generally categorized into ‘float-in’ and ‘lift-in’ methods. The ‘lift-in’ method is generally more efficient than ‘float-in’ method when river flow velocity is high and where several prefabricated modules have to be assembled on site. The ‘lift-in’ method should be employed for this project considering the river environmental condition. Construction considerations for the conceptual design are discussed below.

5.4.1 Prefabrication of Structures

The concrete structures would be cast on the deck of a barge. After the concrete structures are cured, the wedgewire screens would be installed on the top of the precast pads. Two sluice gates would be installed to the plenum wall precast segment for Screen House #2. To minimize the traveling distance to the project site and to provide better access during prefabrication, it is recommended to select the location of the barge as close as possible to the project site, such as near current Schiller Station Dock at east-south side of Screen Houses.

5.4.2 Transportation of Prefabricated Structures

The prefabricated structures would be transported to the project site by barge (with tug boat). A crane barge with sufficient lifting capacity would also be transported to the project site. During transportation, a typical barge requires less than 5 ft of draft, allowing the barge to travel through the inland waterway route. Overall height restrictions are not significant because the crane can be fully erected at the project site.

The maximum weight of the precast segments is expected to be less than 200 tons. Derrick crane barges up to 500-ton capacity are readily available for lease in the United States, although the lead-time required for leasing may run up to 6 months. Therefore, the lead-time should be considered as an important factor in project scheduling.

5.4.3 Installation of the Prefabricated Structures

Prefabricated segments would be installed underwater using a large crane barge (i.e., Derrick crane barge). A Derrick crane barge has excellent control in positioning precast components, because it is able to quickly reach any point in 3D space with one set of controls.

The prefabricated structure would be slowly lowered to the prepared ground at the bottom of the river. The day of the operation should be selected with mild winds not exceeding 15 knots from any direction.

Before positioning a crane barge for lift-in operations, a mooring/anchoring system should be installed on site. A proper mooring plan should include the operation position as well as the standoff position procedure. An 8-point mooring system is often needed to provide adequate control of the crane barge position.

As an alternative, a jack-up crane barge can be used. A jack-up barge is usually towed to the project site, moored with a spread mooring, and then jacked free of water. Stability would be provided by spuds (vertical support piles) pushed or driven into the river bed. The barge can mechanically “climb” on the spud piles and firmly lock itself to the supporting legs. A jack-up barge has proven to be very effective for heavy-lift in turbulent or swift current. Due to the inherent stability, jack-up crane barge can achieve much a tighter tolerance (Ref. 8.16).

Environmental factors such as river flow velocity and allowable work window affect the lift-in operation. Thus, the river conditions during installation must be considered. Installation of these prefabricated segments would be largely independent of water level, but, somewhat constrained by river flow velocity. The ideal condition for the lift-in installation would be in a slack tide in which the river flow velocity is less than 2.0 fps.

During lift-in installation of the structures, monitoring should be continuously performed to check important parameters, including:

- Environmental conditions – the current and wind condition at the time of installation
- Orientation, positioning, and leveling of the structures
- Exact elevation of the segment above river bed or prepared gravel foundation
- Nearby navigation traffic and construction activities

- Hook loads on the lift-in structure

The prefabricated segments should be lowered in a gradual and fully controlled manner. Any sudden and large motion during the set-down process is to be avoided. The lowering speed generally does not exceed 5 ft/min. When the segment reaches approximately 1 ft above the touchdown position, the lowering would be halted and surveyed to verify the position. The final position of the prefabricated segments would be adjusted as necessary.

General installation process for the two wedgewire screen assemblies (for Screen Houses #1 and #2) is summarized below.

5.4.4 Installation Process of the Wedgewire Screen System for Screen House #1 (Unit 4)

- Replace two existing intake barriers in the offshore intake structure with new stainless steel plates (one with pipe stub-out).
- Seal the gap between the new stainless steel plates and the existing steel channels.
- Before placement of the precast concrete pad, prepare the ground and provide gravel at the proposed location. Add tremie concrete as required.
- Place the wedgewire screen assembly (i.e., precast pad with two wedgewire screens) on the top of the gravel course.
- Place backfill (rip rap) around the precast pad.
- Install 30 in. diameter stainless steel pipe (connect between the outlet of the wedgewire screen and the stainless pipe which would be pre-installed on the new stainless steel plate at the entrance of the intake pipe)
- Tie-in the ABS pipe from the wedgewire screen assembly to the ABS compressor equipment.

The installation of the Unit 4 wedgewire screen system can be performed with the Unit online. See PSNH009-C-002 (Attachment 2) for more details.

5.4.5 Installation Process of the Wedgewire Screen System for Screen House #2 (Units 5 and 6)

- Before placement of the precast concrete pad, prepare the ground and provide gravel at the proposed location. Add tremie concrete as required.
- Place the wedgewire screen assembly (i.e., precast pad with three wedgewire screens) on the top of the gravel course.
- Place the foundation portion of the plenum on top of the prepared ground (Units offline).
- Place the precast wall portion of the plenum on the top of the precast pad portion of the plenum (Units offline).

- Insert the prefabricated reinforcing steel cage into the hollow cores in the precast wall (Units offline).
- Place infill concrete into the inside of the hollow cores and cure (Units offline).
- Place backfill (rip rap) around the precast pad.
- Tie-in the intake pipe from the wedgewire screen assembly to the intake pipe embedded in the plenum wall.
- Tie-in the ABS pipe from the wedgewire screen assembly to the ABS compressor equipment.
- Seal the gap between the new plenum structure wall and existing intake structure.
- Install beams and gratings on the top of the plenum.

The design of the prefabricated components and the proposed construction sequence limits the amount of construction that must be performed with the Units offline. However, during certain portions of the construction sequence (as noted above) the Units will need to be offline. The time required to perform these construction operations are short enough such that they can be performed during planned outages thereby not affecting the plant's generating output. See PSNH009-C-003 (Attachment 2) for more details.

5.5 Hydraulic Considerations

5.5.1 Unit 4 (Screen House #1)

The pressure drop through the wedgewire screens at full flow would be approximately 0.33 psi. Based on the flow rate and size of the pipe, the pressure drop associated with the new piping would be approximately 0.2 psi per 100 ft of pipe. Assuming that 30 ft of new pipe would be required to connect the screens to the existing intake pipe, the additional head loss due to screens and piping is:

0.33 psi + (0.2 psi /100 ft) x 30 ft = 0.39 psi, or about 0.90 ft H_2O

As shown above, additional head loss due to installation of screens and piping would be slightly less than 1 ft of water. As a result, the water level within the Screen House #1 intake bay would be expected to drop by this amount due to the extra hydraulic resistance along the intake flow path. Drops in intake bay level require consideration of impacts to the circulating water pumps. Lower levels in the intake bay would reduce the submergence of the circulating water pumps, potentially creating concerns for vortexing or air intrusion. A hydraulic model study is recommended to ensure that the circulating water pumps can reliably operate under these new conditions. Another result of lower intake bay levels would be the increased hydraulic head across the circulating water pumps. The increased hydraulic head would result in the pumps operating at a lower point on the curve, potentially reducing flow or increasing power consumption.

The additional head loss of 0.9 ft is calculated under the assumption that the wedgewire screens are completely clean and free of blockage. Based on the maximum design through-screen velocity of 0.33 fps, blockage of approximately one-third of the screen could occur before a 0.5 fps through-screen velocity occurs at the screen. However, the water level drawdown (i.e., head loss into the intake structure) in the intake structure bay may be too significant to allow this condition to develop.

To protect the circulating water pumps, an appropriate minimum water level within the intake structure bay would need to be determined and administratively controlled. Procedural actions would be required to raise the Unit 4 stop log, thereby opening the emergency direct flow path, when the water level reaches a certain set point. A hydraulic model study is recommended to determine appropriate water levels to prevent vortexing and air intrusion at the Unit 4 circulating water pumps. The procedural action to raise the Unit 4 stop log would occur at a water level slightly higher than the minimum level determined by the model study, to provide some margin in protection of the pumps. During the use of the emergency intake path, the through-screen velocity through the traveling water screen may be greater than 0.5 fps.

5.5.2 Units 5 and 6 (Screen House #2)

The pressure drop through the wedgewire screens at full flow would be approximately 0.32 psi. Based on the flow rate and size of the pipe, the pressure drop associated with the new pipe would be approximately 0.2 psi per 100 ft of pipe. Assuming that 30 ft of new pipe would be required to connect the screens to the new plenum box, the additional head loss due to installation of new screens and piping is:

0.32 psi + (0.2 psi / 100 ft) x 30 ft = 0.38 psi, or 0.88 ft H_2O

As shown above, additional head loss due to installation of screens and piping would be slightly less than 1 ft of water. Similar effects as Screen House #1 are anticipated; therefore a hydraulic model study is recommended. Similar to Screen House #1, the additional drawdown calculation is based on the wedgewire screens being completely clean and free of blockage. Based on the maximum design through-screen velocity of 0.37 fps, blockage of approximately one-third of the screen could occur before a 0.5 fps through-screen velocity occurs at the screen. However, the water level drawdown (i.e., head loss into the intake structure) in the intake structure bay may be too significant to allow this condition to develop. For the same reasons as for Screen House #1, a hydraulic model study is recommended to determine the minimum water level in the intake bay before vortexing and air intrusion occurs at the Units 5 and 6 circulating water pumps. This would allow an appropriate set point for raising the sluice gates and opening the emergency flow path.

In the emergency situation, two sluice gates on the face of the plenum (i.e. east side) would be opened to allow water directly into the plenum box. Gates were sized for a maximum flow velocity of 1 fps during the emergency condition. Based on the flow rate (58,000 gpm) and desired flow velocity, the required area of the gates was found to be 64.6 ft^2. Since the low water level (7 ft below MSL) is the limiting dimension, the gates are each 11 ft tall by 5.75 ft wide.

5.6 Air Burst System

Both sets of screens (for Unit 4, and for Units 5 and 6) would be equipped with an ABS and provided with 6-in. nominal sized connections. The ABS would be used to periodically clean the screen by releasing compressed air inside the screen. As the air expands and passes through the screen surface, it dislodges accumulated objects. Any objects that are dislodged from the screens are expected to be easily carried away by the Piscataqua River current due to the high flow velocity (in excess of 5 fps).

The ABS for each Screen House would consist of four components: a compressor, air receiver, release valve, and interconnecting piping. Monitoring and control equipment can also be incorporated into the system to provide automation. Operating the system involves charging of the ABS receiver tank to the operating pressure and opening the release valve to release the stored volume of compressed air to a single screen during each air burst. This process forces water accumulated in the ABS piping out of the pipe, through the screen, followed by the compressed air burst. Both the water and the compressed air backwash each screen in turn. Each ABS compressor would be connected to the inlet air connection on each wedgewire screen by 6-in. nominal 316L stainless steel piping.

It is assumed in this preliminary design that the onshore ABS equipment would be located within each of the Screen Houses where space is available. If space is not available to locate these pieces of equipment, engineering feasibility would not be impacted; however, an increase in cost may occur.

Johnson Screens, a leading wedgewire screen manufacturer, states in their Surface Water Intake Screens Application Guide that performance of marine intakes is subject to a wide variety of site conditions and is difficult to predict. It recommends that, for marine installations, consideration should be given to installing and monitoring a small test screen early in the design process. This evaluation would aid in determining cleaning cycles and redundancy levels for screen equipment (Ref. 8.21). While the levels of redundancy have already been discussed, frequency for diver cleaning and inspection would be determined based on either a small scale study or through operating experience. Regardless of the effectiveness of the ABS or presence of screen blockage, occasional diver inspections would be required to verify the integrity and functionality of the wedgewire screen system.

5.7 Revised Cost Estimate

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

6 Barrier Impingement Nets

Aquatic microfiltration barrier systems were evaluated in the 2008 Response as being technologically infeasible due to space limitations. However, a barrier net containing a larger opening size will have a greater flow capacity per square foot. As a result, the required net length is decreased and can be designed within the space constraints at Schiller Station. A stationary net that is deployed around a CWIS to reduce the intake velocity to an appropriate value, while preventing organisms that can pass through a 3/8-in. mesh from entering the CWIS, is referred to as a barrier net in this report. Barrier nets have been effectively applied at several power plant cooling water systems, as well as a number of hydroelectric projects. The ability of barrier nets to exclude fish from a water intake depends on the fish species and size to be protected, near-field hydraulic conditions, and the amount of debris present (Ref. 8.18).

Barrier nets are currently in use at over a dozen facilities in the United States. Facilities that have installed barrier nets include: Bowline Point Generating Station (located in a marine environment), Hudson River; J.P. Pulliam Power Plant, Lake Michigan; Chalk Point Station, Patuxent River; Dallman Generating Station; J.R. Whiting Plant, Lake Erie; Ludington Pumped Storage, Lake Michigan (discussed further in Section 6.1); D.E. Karn Plant, Lake Michigan; and Pine Hydroelectric Plant, Pine River (Ref. 8.18).

This section provides a conceptual design for a barrier net in support of providing a Class 5 cost estimate per ASTM E2516-11 (Ref. 8.10). This design is based on the use of barrier nets as an impingement-reducing technology, and incorporates lessons learned from industry operating experience.

6.1 Conceptual Design Summary

Barrier nets provide an option to meet the BTA standard for impingement mortality as a candidate technology for 316(b) compliance under §125.94(c)(2). By selecting this option, evaluating the biological efficacy of the proposed barrier net is not required under the final §316(b) regulations (Attachment 3).

Conceptual design of the Schiller barrier net is based upon consideration of total cost, structural feasibility, constructability, and effective impingement reduction. In order to effectively address impingement mortality as defined in the rule, the mesh size of the barrier net is selected to be 3/8 in. The primary hydraulic consideration for effective impingement reduction is maintenance of a through-mesh velocity of 0.5 fps or less. The through-mesh velocity is a function of the open area available through the net and the distance from the intake. This is discussed further in Section 6.3.

The proposed conceptual layout of the barrier net is provided in Drawing PSNH009-C-004 (Attachment 2). The layout of the barrier net provides a complete barrier for the intake structures, with the enclosed area separated from the discharge. Since the site geology consists of fairly shallow rock, the proposed piers for the barrier net system would be drilled shafts that extend into the rock. Spacing of the drilled shafts is based on minimizing the tributary area that contributes to the current load on each pile, which minimizes the total number of piles, and maximizes accessibility to the area via boat or barge. The span of barrier net along the existing Schiller Station Dock would be attached to the existing concrete piers and should be aligned with the spacing of the existing piers.

The barrier net material is proposed to be Dyneema® high strength, high-modulus polyethylene fiber, which is a very strong fiber made of ultra-high molecular weight polyethylene. The tensile strength and elastic modulus of Dyneema are in the range of 320-580 ksi, which makes it suitable for use in a number of applications such as personnel and vehicle armor, ropes and lines for mooring and tugging, and netting. This material is used for the largest barrier net currently deployed – the 2.4 miles long Ludington Pumped Storage Plant netting on Lake Michigan. The Dyneema fiber is essentially inert which makes it suitable for deployment in saltwater/brackish water such as the Piscataqua River. Due to the relatively high strength and modulus of the fibers, the nets do not elongate appreciably and can withstand significant forces. The mesh size of 3/8 in. and the surface smoothness of Dyneema are selected to prevent debris and larger fish from becoming entangled.

Based on the conceptual layout of the barrier net, anchor points for the Dyneema net would be provided by the new drilled shafts, the existing Schiller Station Dock piers, and the new retaining walls (at the shore). Dyneema has a specific gravity less than water (0.98); therefore, in order to anchor the net along the river bottom, metal chains should be attached along the entire bottom edge of the Dyneema net. The required chain weight and the need for any additional anchoring along the base of the net does not significantly impact the cost and would be evaluated during detailed design. The elevation of the top of the barrier net is required to be higher than the extreme high water elevation of +8.3 ft.

6.2 Civil / Structural Design Considerations

Structural design of the barrier net is required to consider stresses on all system components: the Dyneema net, the drilled shafts, the existing Schiller Station Dock piers, and the shore retaining walls. Elongation of the net is also a primary consideration. Elongation impacts structural design as well as general layout of the net.

6.2.1 Current Load on the Net

The dominant load on the barrier net system is the drag force on the net itself due to the current load. The drag force on the net is based on various parameters, as depicted in the simplified drag equation (Ref. 8.28, Eq. 7-13):

$$D = \frac{1}{2}\rho V^2 C_d A$$

Where:

ρ is the density of the fluid (water in this case);
V is the fluid velocity;
A is the cross sectional area; and
C_d is the drag coefficient.

The drag coefficient is dependent upon the shape of the object and friction between the object surface and the fluid. For the purpose of conceptual design, the applied drag coefficient is taken to be that for a cable, equal to 1.2. Consideration of the velocity and cross-sectional area and its impact on the barrier net design are discussed below.

The projected-normal component of the velocity is a function of the current speed and direction. As discussed in Section 5.3.1, the Piscataqua River current is tidally-influenced with a maximum tidal current speed of approximately 250 cm/s (≈ 8 fps). While the current velocity decreases with depth, the maximum velocity near the surface is applied for all depths in conceptual design.

The direction of the Piscataqua River current varies with the tidal cycle, as measured and documented in Reference 8.13. The direction of the current compared to the span of the net impacts the fluid flow perpendicular to the net. For conceptual design, the angle between the direction of current and the nets is approximated based upon the measured direction in Reference 8.13 and the conceptual layout of the nets. For the netting with 35 ft. spans south of Screen House #2 (see layout drawing PSNH009-C-004, Attachment 2), the angle between the current velocity and the net span is taken to be 90 degrees (meaning the flow is perpendicular to the net). For the netting with 50 to 75 ft. spans north of the Schiller Station dock, the angle between the current velocity and the net spans is taken to be 35 degrees.

The total drag force is proportional to the square of the normal component of the velocity; therefore, the speed and direction of the current has a significant impact on the total forces in the system. The available data in Reference 8.13 is based on measured parameters near the center of the river. These parameters could vary significantly close to the shore at the proposed barrier net location, especially considering the features in the water (mainly the piles associated with the Schiller Station Dock) which would impact flow through the nets. Therefore, additional studies regarding the current velocity and direction should be considered during detailed design.

The cross-sectional area upon which the current load would be acting is a function of the span between anchor points, the water surface elevation subject to tidal fluctuation, the depth of the river, and the percent of closed area of the net. The span between anchor points is selected for conceptual design as discussed in Section 6.1. The tidally influenced water surface and the depth of the river both contribute to the height of net subject to drag. The tidal water elevations are discussed in Section 5.3.1. The maximum high tide elevation of 8.0 ft. is conservatively applied concurrent with the maximum current velocity for conceptual design. The extreme high water elevation from Section 5.3.1 was not considered because off how infrequent the event occurs, but should be reconsidered during detailed design. The depth of the river is estimated based on the excavation plan shown in Reference 8.15; however, more accurate and detailed bathymetry in the vicinity of the proposed barrier net would be needed as part of detailed design. In order to approximate the maximum drag force, height of net causing drag is taken as the river depth plus the maximum high tide water elevation.

The percent closed area is based on the net dimensional parameters as well as any fouling or debris built-up on the net. According to Pacific Netting Products, netting with 3/8-in. mesh size has an open area of approximately 63 percent, meaning the cross-sectional area of the barrier net itself is roughly 37 percent of the total area. To account for fouling and debris build-up, it was assumed that 50 percent of the open area of the net (or half of 63 percent) is blocked. Therefore, the percent closed area is taken to be 68.5 percent. Additional studies regarding fouling and debris build-up should be considered during detailed design. Periodic cleaning or replacement of the net may be required to maintain an acceptable open area.

6.2.2 Capacity of the Barrier Net System

Since the net only resists axial tension, it behaves like a cable. For conceptual design, the net is idealized as being loaded perpendicular to the span, hence, the horizontal component of axial tension in the net is constant. The axial tension at any point along the span of the net is equal to:

$$T = \frac{H}{cos\theta}$$

Where:

- H is the horizontal component of axial tension; and
- θ is the angle between horizontal and the direction of the tension, as depicted in Figure 2 below.

The maximum angle θ, and thus the maximum net tension, is a function of the total deflection and elongation of the net. Therefore, the maximum load on the barrier net system is a function of the elastic modulus of the netting.

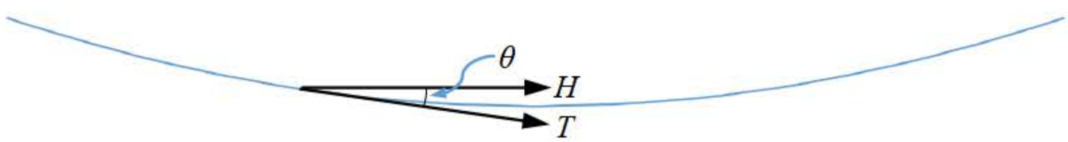

Figure 2: Forces on the net idealized as a cable loaded perpendicular to the span

As discussed above, the net material is selected to be Dyneema high-strength, high-modulus polyethylene fiber. This material provides significantly greater strength and stiffness compared to nylon. As the material elastic modulus increases, the total deflection of the net is minimized, which helps maintain acceptable separation between the net and the intake. However, as the elastic modulus increases and the total deflection decreases, the maximum axial tension on the net increases. For conceptual design, the maximum load on the netting and drilled shafts is balanced with the netting total deflection and proximity to the intake. In order to size the drilled shafts and provide a proposed layout for the conceptual barrier net system, the elastic modulus of the Dyneema material is used. However, the elastic modulus for the net is based on the material parameter for Dyneema fiber as well as the stretching of the woven net chords. Neglecting the added elasticity of the woven chords is conservative for the maximum load on the barrier net system, but non-conservative for the total deflection. For detailed design, a range in net elasticity should be considered.

For conceptual design, the proposed drilled shafts for the barrier net system as shown in Drawing PSNH009-C-004 (Attachment 2) are sized for the current load based on the parameters and assumptions discussed above. The proposed drilled shafts based on the conceptual layout should be roughly 48" in diameter. During detailed design, the capacity of the existing concrete piers should be evaluated for the increased load due to the barrier net current load.

6.3 Hydraulic Design Considerations

Achieving a through-screen velocity of 0.5 fps is a requirement for Section 316(b) compliance as discussed in Section 6.1. The netting would have to be installed such that it provides a complete barrier for the intake structures, but also such that there would be sufficient screening area to achieve the 0.5 fps through-screen velocity resulting from the plant intake.

The design cooling water intake flow rate through the netting is obtained from summing the flow rates for Unit 4 (29,150 gpm) and Units 5 & 6 (58,000 gpm).[2] The total maximum flow rate is 87,150 gpm or 194.2 ft^3/s. At this flow, the open area required to achieve 0.5 fps from the plant intake is approximately 388.4 ft^2. According to Pacific Netting Products, netting with 3/8-in. mesh size has an open area of approximately 63 percent. Therefore the total required netting area would be approximately 616.5 ft^2.

The net would have to be long enough and configured in such a way to provide a barrier to both intake structures. Drawing PSNH0009-C-004 provides a preliminary configuration for the barrier netting. This configuration requires approximately 245 ft of netting. Since the netting would have to be tall enough to prevent any fish from swimming over the top of the net during high water, the net would have to be approximately 27 ft tall. Using the above dimensions, the total area of the netting would be 6615 ft^2, which would be 10 times more than the necessary surface area for a 0.5 fps through-screen velocity attributed to the plant intake. At low water level, i.e. when average river depth is approximately 11 ft, the available netting area is 2,695 ft^2, which provides more than four times more screening area than is necessary for achieving a 0.5 fps through-screen velocity. Due to the large surface area required to surround both intakes, a significant margin would be available to mitigate issues associated with fouling and blockage of the net.

Assuming significant debris that causes blockage of 50 percent of the open area of the net, there would still be sufficient open area to achieve a through-screen velocity of approximately 0.25 fps at the low water level.[3] Note that the ambient currents regularly exceed 5 fps in this vicinity of the Piscataqua River.

---

[2] Note that screen wash flow rates are not included in this number; it assumed that they would not be needed regularly if a barrier net system were deployed.

[3] Through-screen velocity is defined as the velocity of water passing perpendicularly through the screen or net that results from plant intake flow. Ambient currents may increase or decrease the actual velocity of water passing through the screen or net.

6.4 Debris and Biological Fouling

Operating experience associated with Dyneema netting has shown that cleaning can occur using spray wash techniques from either a barge or using divers. The Ludington Pumped Storage Plant on Lake Michigan reported in 2005 that their Dyneema barrier net was cleaned four times that year using divers with spray wands. The netting was sprayed to clear the net of algae and zebra mussels. A Dyneema barrier net is used at the Highline Irrigation Canal on Highline Lake in Colorado. Cleaning was reported to have been done twice per year. It was also reported that cleaning the top 6 – 8 ft of the net is possible by using a barge and winch, and cleaning the net with a pressure washer system. Cleaning the remainder of the net requires using divers and a high-pressure cleaning system. It is noted for many of these installations that weekly or, in some cases daily, inspection of the net occurs. Underwater inspection using divers tends to occur less frequently (Ref. 8.19). In the event that significant blockage does occur, as discussed in Section 6.3, the through-screen velocity would be expected to remain well below 0.5 fps.

Based on this operating experience, it is expected that frequent inspection of the netting material would be required to verify that tears or breaks in the net have not occurred. Given that this was required at other sites, and given the generally high current velocities in the Piscataqua River, repairs to the net are anticipated to be needed regularly. This would likely be accentuated for the small section of net that is not generally parallel to the prevailing current directions (see PSNH009-C-004 in Attachment 2). Specific current velocities in front of the intakes are not known; however it is known that the general velocities in the river are high. Ice floes occur during the spring months; however, sufficient information is not available on their size and frequency distribution to ascertain the reliability impacts to the net due to impact from floating ice at potentially high velocities. Further study with regard to both the velocities and ice floes is needed to determine whether protective measures are required to protect the barrier net structure.

It is expected that cleaning of the netting using a pressure washing system would be required several times per year. This may require use of divers depending upon the capability of the spray system that is utilized. Therefore, the operations and maintenance costs associated with the barrier net system are expected to be relatively high compared to wedgewire screens. In summary, the reliability of a barrier net system would be expected to be lower than that of wedgewire screens. A pilot test or study is recommended to ensure that debris loading, the local velocity, and frequency and size distribution of ice floes do not require additional preventive measures to protect the net.

6.5 Construction Methodology

Construction of the Schiller barrier net includes excavation and installation of two shore retaining walls, drilling and pouring three drilled shafts, and attaching the net to the anchor points (retaining walls, drilled shafts, and existing Schiller Station Dock piers). The construction methods are fairly routine; however, they are complicated by the shallow bedrock and the additional requirements for marine construction (such as river current velocity).

For installation of the shore retaining walls, the area around the proposed wall location should be excavated. The strength characteristics of the soil as well as the elevation of bedrock would dictate the volume of excavation required. For shallower bedrock elevations, the excavation would be minimized, but rock removal may be required to provide the desired depth of the wall and the netting. For deeper bedrock elevations, excavation could be substantial due to the depth required to reach rock and the area required to achieve acceptable slopes for the excavated area. Further excavation behind the face of the wall would be required to install the two dead man anchors and tiebacks.

All three drilled piers would extend into the rock, which improves anchorage but increases complication and construction cost. Drilling and installation for the two piers north of the Schiller Station Dock should be completed from a barge. Due to limited waterway access to the area just south of Screen House #2, it is unlikely the single drilled shaft south of Screen House#2 could be drilled from a barge. Therefore, it is recommended this installation be performed from the shore using a crane-mounted rig. This type of drill rig is commonly used in applications requiring greater torque and depth capability. However, crane-mounted rigs provide an additional ability to position the rotary table and auger distances 75 ft. or more from the base of the crane boom using an extended mount. All three drilled shafts should be cased, with the casing also acting as the concrete form for the pier extending up from the bore hole. The reinforcing cage would be lowered into place by a crane, and the underwater concrete placement should be performed using the tremie method.

A sufficiently heavy metal chain should be attached to the bottom edge of the Dyneema barrier net along the entire length. This chain may be attached by the manufacturer or at the site. The barrier net should be anchored to each of the concrete piers (new and existing), with anchorage at the shore provided through attachment to the shore retaining walls. Anchorage of the barrier net to the shore retaining walls restrains and resists current load on the net while providing accessibility to remove or replace the nets if needed. Divers would be required to install and anchor the barrier nets in the river.

6.6 Cost Estimate

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

7 Summary and Conclusions

There are several likely pathways by which compliance with the new CWA Section 316(b) rule may be achieved. However, there are three compliance scenarios that provide the highest likelihood for a cost-effective solution.

First, of the two conceptual designs evaluated in this report, the barrier net offers much lower installation costs but will require higher operation and maintenance costs due to the likelihood of frequent repairs. Both the wedgewire screens and barrier net technologies can achieve the 0.5 fps maximum design velocity under 40 CFR 125.94(c)(2), ensuring compliance. As stated in the 2008 Response, narrow-slot wedgewire screens would provide increased entrainment performance relative to wide-slot screens due to the smaller opening size; however, wide-slot screens are re-evaluated in this report as a means to achieve the 0.5 fps maximum design velocity and satisfy the rule. Aquatic microfiltration barrier systems were evaluated in the 2008 Response as being technologically infeasible due to space limitations. However, an impingement barrier net has a greater flow capacity per square foot. Therefore, the required net length is smaller and can be designed within the space constraints at Schiller Station. By selecting either compliance option, evaluating the biological efficacy is not required under the final §316(b) regulations.

Second, installation of modified Ristroph screens with an upgraded FHRS can provide compliance under 40 CFR 125.94(c)(5) as one of the pre-approved technologies. Given the uncertainty associated with Class 5 ASTM E2516-11 (Ref. 8.10) cost estimates, the cost associated with installation of this technology is likely along the same order of magnitude as that of the wide-slot wedgewire screens; however, a conceptual design has not been created to confirm this with a higher degree of certainty. Similar to the barrier net and wedgewire screens, installation of this technology represents a pre-approved solution. This technology was not revisited in detail because there were not significant changes since the 2008 Response. However, selecting this BTA compliance option would require Schiller Station to perform a site-specific impingement technology performance optimization study that includes two years of biological sampling. The study must demonstrate that the operation of the modified traveling screens has been optimized to minimize impingement mortality.

Third, another candidate technology for compliance would be for Unit 4 to reduce its actual through-screen velocity to 0.5 fps or less by renovating the retired-in-place Unit 3 intake and installing new traveling water screens. As discussed in the 2008 Response, this would be expected to reduce the through-screen velocity to below 0.5 fps, ensuring compliance under §125.94(c)(3). However, this method of compliance is not available to Units 5 and 6.

8 References

8.1 Environment Agency, "Cooling Water Options for the New Generation of Nuclear Power Stations in the UK." SC070015/SR3, June 2010.

8.2 GEA Power Cooling, Inc. "PAC Systems & Wind Mitigation." November 2009.

8.3 "Dry and Parallel Condensing Systems." http://mydocs.epri.com/docs/publicmeet-ingmaterials/11-26-2012/Rasmussen-Eric-SPX.pdf. Accessed 8/16/2014.

8.4 EPRI, September 30, 2004, "EPRI Clean Water Act 316(b) Fish Protection Technology Workshop Presentations."

8.5 SPX Cooling Technologies (SPX). Cooling Tower Fundamentals. 2nd Edition. Overland Park, KS. 2006.

8.6 Normandeau Associates, Inc., Newington Station 316 Demonstration, Volume II, 316(b) Demonstration, 1979.

8.7 "Wet Cooling Towers." http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s04.pdf. Accessed August 18, 2014.

8.8 United States Nuclear Regulatory Commission, Regulatory Guide 4.7, Rev. 2, "General Site Suitability Criteria for Nuclear Power Stations." April 1998. Accession Number ML003739894.

8.9 Enercon Services, Inc. in consultation with Normandeau Associates, Inc., October 2008, PSNH Schiller Station Report "Response to United States Environmental Protection Agency CWA §308 Letter,"

8.10 ASTM E2516-11, "Standard Classification for Cost Estimate Classification System," ASTM International, 2011.

8.11 Performance, Cost, and Environmental Effects of Saltwater Cooling Towers, California Energy Commission Public Interest Energy Research Program, January 2010.

8.12 ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures"

8.13 "Tidal Currents in the Piscataqua River, NH – Preliminary Findings from the 2007 National Current Observation Program survey," Carl Kammerer, NOAA/NOS/CO-OPS & UNH/Joint Hydrographic Center

8.14 Drawing 175-B-4, Rev. 1, "Screen Well Excavation and Riprap"

8.15 Drawing 9900-21, Rev. 0, "Project 3 & 4 Screen House Proposed Excavation"

8.16 ERDC/GSL TR-00-2, "Assessment of Heavy-Lift Equipment for In-the-Wet Construction of Navigation Structures," November 2000.

8.17 SPX Cooling Tower Library. "Drift Eliminators, A Turn for the Better." http://spxcooling.com/pdf/SB-1C.pdf

8.18 EPRI Status Report TR-114013, "Fish Protection at Cooling Water Intakes." December 1999.

8.19 EPRI Technical Report 1013309, "Design Considerations and Specifications for Fish Barrier Net Deployment at Cooling Water Intake Structures." October 2006.

8.20 Alden – Desalination Intake Solutions Workshop. "Oak Creek Power Plant Expansion Project, Offshore Wedge-wire Screen Intake." October 2008.

8.21 Johnson Surface Water Intake Screens, "Product Application Guide."

8.22 ANSI/AWWA C207-94, "AWWA Standard for Steel Pipe Flanges for Waterworks Service – Sizes 4 in. through 144 in." American Water Works Association. Effective November 1, 1994.

8.23 ENERCON Services. "Response to Environmental Protection Agency's Information Request for NPDES Permit Re-Issuance." August 2013.

8.24 Drawing 544-20, Rev. 6, "Concrete Details – Sheet 1, Screen House."

8.25 Drawing 175-B-6, Rev. 4, "Screen Well Substructure – Sections Sheet 2."

8.26 Pankratz, Tom M. "Screening Equipment Handbook – For Industrial and Municipal Wastewater Treatment."

8.27 Ovivo: Brackett Green Double and Single Entry Drum Screen. http://www.ovivowater.com/DoubleandSingleEntryDrumScreen. Accessed August 29, 2014.

8.28 U.S. Army Costal Engineering Research Center, "Shore Protection Manual," 1973.

Attachment 1

[redacted]

[redacted]

[redacted]

Wedgewire Screen Option Construction Cost Estimate

[redacted]

[redacted]

Item	Description	Quantity	Unit	Unit Price	Cost	Source (RSMeans are regional costs from Portsmouth, NH)
[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]						
			[redacted]	[redacted]	[redacted]	
	[redacted]			[redacted]	[redacted]	[redacted]
	[redacted]			[redacted]	[redacted]	[redacted]
	[redacted]			[redacted]	[redacted]	[redacted]
	[redacted]			[redacted]	[redacted]	[redacted]
	[redacted]			[redacted]	[redacted]	[redacted]
	[redacted]			[redacted]	[redacted]	[redacted]
[redacted]						
[redacted]		[redacted]	[redacted]			

[redacted] more information.

[redacted]		
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

Attachment 2

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

8 7 6 5 4 3 2 1

D

C

B

A

[redacted]

[redacted]

Attachment 3: Update of Impingement Abundance and Mortality Assessment for Schiller Station Response Supplement to United States Environmental Protection Agency CWA 308 Letter

Prepared for
PUBLIC SERVICE OF NEW HAMPSHIRE
Environmental Services
780 North Commercial Street
Manchester, NH 03105

Prepared by
NORMANDEAU ASSOCIATES, INC.
25 Nashua Road
Bedford, NH 03110

R-22240.033

October 2014

Table of Contents

Page

1.0 INTRODUCTION 1

2.0 OVERVIEW OF THE FINAL §316(B) REGULATIONS AND THEIR APPLICABILITY TO SCHILLER STATION 2

3.0 IMPINGEMENT ABUNDANCE AND MORTALITY AT SCHILLER STATION DURING 1 JANUARY 2011 THROUGH 31 DECEMBER 2013 6

4.0 WIDE-SLOT WEDGEWIRE SCREENS AS BTA AT SCHILLER STATION 8

5.0 BARRIER NET AS BTA AT SCHILLER STATION 9

6.0 LITERATURE CITED: 12

List of Tables

Page

Table A3-1. Schiller Station's weekly and annual total operating intake flow sampled from 2 October 2006 through 30 September 2007 compared to the corresponding weekly average actual intake flows for 1 January 2011 through 31 December 2013 (both expressed as millions of gallons per week). 13

Table A3-2. Weekly and annual total impingement abundance of fragile and non-fragile fish (Adj-I) and macro-crustaceans (I) estimated for Schiller Station Units 4, 5 and 6 combined in 2006 through 2007 and 2011 through 2013. 15

Table A3-3. Survival status (number alive, dead, stunned) and percent (%) composition of fragile and non-fragile fish taxa collected and observed in impingement survival samples from Schiller Station (Units 4, 5, and 6 combined) during 2 October 2006 through 30 September 2007. 17

Table A3-4. Survival status (number alive, dead, stunned) and percent (%) composition of macro-crustaceans collected and observed in impingement survival samples from Schiller Station (Units 4, 5, and 6 combined) during the 52 week sampling year from 2 October 2006 through 30 September 2007. 18

Table A3-5. Annual impingement abundance and mortality for the existing screens and return systems installed and operated at Schiller Station Units 4, 5, and 6 for design intake flow, the 2006 through 2007 actual intake flows, and the 2011 through 2013 actual intake flows. 19

Table A3-6. Piscataqua River current velocity frequency distribution observed from the National Oceanographic and Atmospheric Administration (NOAA) river current monitoring station PIR0708 located in the river channel at Schiller Station from 21 June through 1 August 2007[1]. 20

Table A3-7. Piscataqua River current direction frequency distribution observed from the National Oceanographic and Atmospheric Administration (NOAA) river current monitoring station PIR0708 located in the river channel at Schiller Station from 21 June through 1 August 2007[1]. 21

1.0 Introduction

Public Service Company of New Hampshire (PSNH) operates the Schiller Station (Schiller Station) using a once-through cooling water intake structure (CWIS) to obtain condenser cooling water from the Piscataqua River in Portsmouth, New Hampshire under an existing National Pollutant Discharge Elimination System permit (NPDES Permit NH0001473) issued by the United States Environmental Protection Agency (USEPA). On October 31, 2007 the USEPA sent an information request letter to PSNH under Section 308 of the Clean Water Act (CWA) regarding the Station's compliance with CWA §316(b), 33 U.S.C. §1326(b) (§308 Letter). In the §308 Letter, USEPA requested certain technology information from PSNH to support their evaluation of Schiller Station's NPDES renewal application. In October 2008, PSNH submitted a response (2008 Response) prepared by Enercon Services, Inc. (ENERCON) and Normandeau Associates, Inc. (Normandeau). The 2008 Response evaluated the engineering feasibility and estimated the biological effectiveness of certain technologies and operational measures that would be generally expected to reduce impingement mortality and/or entrainment mortality of fish and shellfish withdrawn from the Piscataqua River in the cooling water used by Schiller Station.

USEPA issued several additional or follow-up 308 requests to support their evaluation of Schiller Station's NPDES renewal application after the 2008 Response was provided. USEPA sent a 308 request dated 4 May 2010 for a thermal plume characterization study at Schiller Station to be performed from 15 June through 15 November 2010, and these data along with other thermal discharge information were provided to satisfy this request in late November 2010. PSNH also submitted a separate response to another 308 request in August 2013 that was prepared by ENERCON.

The USEPA published the final regulations to establish requirements for cooling water intake structures at existing facilities in the Federal Register on Friday, 15 August 2014 (40CFR Parts 122 and 125; Volume 79, No. 158, pages 48300-48439). The stated purpose of these final §316(b) regulations is to reduce impingement and entrainment of fish and other aquatic organisms at cooling water intake structures used by certain existing power generation and manufacturing facilities for the withdrawal of cooling water. These regulations are applicable to facilities like Schiller Station that are designed to withdraw more than 2 million gallons per day (MGD) of surface water and use at least 25% of the water withdrawn exclusively for non-contact cooling purposes.

Normandeau reviewed the recent (15 August 2014) publication of the final §316(b) regulations and the three most recent years of actual intake flow (AIF) records for the CWIS to prepare this Attachment 3 update of impingement abundance and mortality response supplement for Schiller Station. This Attachment 3 Report does not seek to re-evaluate and update all technologies and operational measures examined in the 2008 Response, or in subsequent responses, just those options considered most feasible from an engineering perspective for application at Schiller Station from among the compliance options specified in the final §316(b) regulations.

The objectives of this Attachment 3 response supplement were:

1. Review the final 316b regulations and their applicability to Schiller Station,
2. Establish the impingement abundance and mortality for Schiller Station fish and macro-crustaceans based on the three most recent years of AIF records (2011 through 2013).
3. Evaluate the potential efficacy of wide-slot wedgewire screens as a Best Technology Available to Minimize Adverse Environmental Impact (BTA) for reducing impingement mortality at Schiller Station;
4. Evaluate the potential efficacy of a barrier net as BTA for reducing impingement mortality at Schiller Station;

2.0 Overview of the Final §316(b) Regulations and their Applicability to Schiller Station

The procedure for demonstrating compliance with §316(b) of the Clean Water Act is specified by 40 CFR §122.21 of the final §316b regulations. There are fourteen permit application requirements specified in the final §316(b) regulations, and the applicable requirements will likely be addressed in the next NPDES permit for Schiller Station. The table below presents a listing of all of the permit application requirements, and the narrative that follows identifies and briefly explains those requirements that are expected to be applicable to Schiller Station.

§122.21(r)	Description
(1)	Applicable Facilities Definitions
(2)	Source Water Physical Data
(3)	Cooling Water Intake Structure Data
(4)	Biological Characterization Study
(5)	Cooling Water System Data
(6)	Proposed IM Reduction Plan
(7)	Performance studies
(8)	Operational status
(9)	Entrainment Characterization Study
(10)	Comprehensive Technology Feasibility Plan
(11)	Economic Benefits Evaluation
(12)	Non-Water Quality and Other Environmental Impacts
(13)	Peer Review for r10, r11, or r12
(14)	New Units

Applicable Facilities are defined in §122.21 (r) (1) as existing facilities to which the §316(b) regulations apply because they have a cooling water intake structure that supplies cooling water for the purpose of non-contact cooling withdrawn from the surface waters of the United States. Existing facilities are further distinguished into those withdrawing less than 2 million gallons per day (MGD), those withdrawing between 2 and 125 MGD, and those withdrawing more than 125 MGD based on the actual intake flow (AIF) determined from the average intake flows over the three most recent years of operating records. New units at an existing facility and also distinguished from existing units.

Source Water Physical Data required by §122.21 (r) (2) were previously summarized in Section 2 of the Proposal for Information Collection (PIC) for Schiller Station that was submitted to USEPA on 6 October 2006 (Normandeau 2006) and also summarized in Section 2.2 of the §308 Response Letter of October 2008 (Enercon 2008). We are unaware of any new source water physical data obtained since preparation of the Schiller PIC, except for a thermal stratification study performed in the nearfield area of the Piscataqua River during the summer and fall of 2010 and NOAA current velocity and flow direction data obtained from 21 June through 1 August 2007. Federal and state agency (NOAA, USGS, etc.) and academic (UNH) data bases will be reviewed to determine if any additional studies have been performed since these previous documents were prepared that describe the hydrological and geomorphological characteristics of the Piscataqua River near Schiller Station.

Cooling Water Intake Structure Data required by §122.21 (r) (3) were previously summarized for each intake (Unit 4, Unit 5, Unit 6) at Schiller Station in Section 3 of the PIC that was submitted to USEPA on 6 October 2006 (Normandeau 2006) and also summarized in Section 2.3 of the §308 Response Letter of October 2008 (Enercon 2008).

Source Water Baseline Biological Characterization Data §122.21 (r) (4) were previously summarized for Schiller Station in Section 6 of the PIC that was submitted to USEPA on 6 October 2006 (Normandeau 2006), and in Section 6 of the entrainment and impingement characterization study report (Normandeau 2008). We are unaware of any new source water biological characterization data obtained since preparation of the Schiller PIC. Federal and state agency (NOAA, USGS, NHFG, etc.) and academic (UNH) data bases will be reviewed to determine if any new biological characterization studies have been performed since the previous reports were prepared that describe the baseline biological characteristics of the Piscataqua River near Schiller Station.

Cooling Water System Data §122.21 (r) (5) were previously summarized for each Unit at Schiller Station in Section 4 of the PIC that was submitted to USEPA on 6 October 2006 (Normandeau 2006) and also summarized in Sections 2 and 3 of the §308 Response Letter of October 2008 (Enercon 2008). Updated actual intake flows (AIFs) for each unit at Schiller Station will be provided for the three most recent years of data available (2011 through 2013).

A Proposed Impingement Mortality Reduction Plan §122.21 (r) (6) will likely be required for Schiller Station because the AIF for the three most recent years of available cooling water intake flows is above 2 MGD and less than 125 MGD. Compliance options for impingement mortality reductions include selection of one of the following:

1. Closed cycle recirculating system - §125.94(c)(1),
2. Design through-screen intake velocity <0.5 fps - §125.94(c)(2),
3. Actual through-screen intake velocity <0.5 fps - §125.94(c)(3),
4. Have an existing offshore velocity cap >800 feet offshore - §125.94(c)(4),
5. Install modified traveling screens - §125.94(c)(5),
6. Use a combination of technologies and operational measures such as flow reductions or scheduled outages - §125.94(c)(6), or
7. Demonstrate that the existing system meets the impingement mortality performance standard of 24% latent mortality (excluding fragile species) - §125.94(c)(7).

A case can also be made for some facilities that the existing levels of impingement mortality is *de minimis* based on impingement abundance numbers or age 1 equivalent abundance in relation to mean annual intake flows. The acceptance of a *de minimis* demonstration is at the discretion of the USEPA Director.

Entrainment Performance Studies §122.21 (r) (7) previously performed at Schiller Station must be submitted to USEPA to allow the Director to establish technology-based requirements for entrainment. Site-specific studies describing the efficacy of various technologies to reduce entrainment abundance, through-system entrainment survival studies of eggs and larvae, and entrainment abundance analyses should be provided if available with a description of their relevance and representativeness to the current conditions at Schiller Station. Studies older than ten years may be rejected by the EPA Director if the source waterbody has changed significantly over that time period. An entrainment abundance and survival (through CWIS) characterization study was performed at Schiller Station in 2006 through 2007 (Normandeau 2008), which provided the basis for an evaluation of the entrainment reduction performance of various technologies or operational measures in Sections 6 and Attachment 6 of the §308 Response Letter to USEPA of October 2008 (Enercon 2008).

Operational Status §122.21 (r) (8) must be described for each unit at Schiller Station. This information was previously summarized for each Unit at Schiller Station in Section 4 of the PIC that was submitted to USEPA on 6 October 2006 (Normandeau 2006) and also summarized in Sections 2 and 3 of the §308 Response Letter of October 2008 (Enercon 2008). Updated operational status will be reviewed and any fundamental changes described for each unit at Schiller Station by examining station records for the period since the two previous reports were prepared.

An Entrainment Characterization Study §122.21 (r) (9) was performed at Schiller Station in 2006 through 2007 (Normandeau 2008) and is therefore considered current and not needed. Furthermore, based on the observed AIF for Schiller Station of less than 125 MGD for the most recent three-year period (2011 through 2013), an entrainment reduction requirement from the USEPA Director is not anticipated.

A Comprehensive Technical Feasibility Plan and Cost Evaluation Study §122.21 (r) (10) is also not required because this plan and study is applicable to facilities required to evaluate entrainment reductions, and the observed AIF of less than 125 MGD for the most recent three-year period (2011 through 2013) should exempt Schiller Station from the entrainment reduction requirement of the new §316(b) regulations at the discretion of the USEPA Director. The technical feasibility and costs of various impingement and entrainment reduction technologies considered candidates for application to Schiller Station were described in the §308 Response Letter of October 2008 (Enercon 2008).

An Economic Benefits Evaluation Study §122.21 (r) (11) is also not required because this study is applicable to facilities required to evaluate entrainment reductions, and the observed AIF of less than 125 MGD for the most recent three-year period (2011 through 2013) should exempt Schiller Station from the entrainment reduction requirement of the new §316(b) regulations at the discretion of the USEPA Director.

The Non-Water Quality Environmental and Other Impacts Assessment §122.21 (r) (12) should be described for the impingement mortality reduction plan selected for Schiller Station under §122.21 (r) (6) above. The non-water quality environmental and other impacts were described for the technologies considered candidates for application to Schiller Station in the §308 Response Letter of October 2008 (Enercon 2008). This assessment is not required for entrainment reductions, because the observed AIF of less than 125 MGD for the most recent three-year period (2011 through 2013) should exempt Schiller Station from the entrainment reduction requirement of the new §316(b) regulations at the discretion of the USEPA Director.

A Peer Review §122.21 (r) (13) is specified for facilities that must provide permit application studies to address entrainment and the applicable sections of §122.21 (r) (10) (11) and (12). However, we do not expect Schiller to be required to address these sections because the observed AIF of less than 125 MGD for the most recent three-year period (2011 through 2013) should exempt Schiller Station from the entrainment reduction requirement of the new §316(b) regulations at the discretion of the USEPA Director.

New Units §122.21 (r) (14) are not proposed for Schiller Station.

3.0 Impingement Abundance and Mortality at Schiller Station during 1 January 2011 through 31 December 2013

A characterization study was performed in each of 52 consecutive weeks at Units 4, 5 and 6 of Schiller Station from 2 October 2006 through 30 September 2007 (Normandeau 2008) that provides recent and relevant data for estimating impingement abundance and mortality. Schiller Station weekly average intake flows have been reduced by 36% since the 2006 through 2007 Study, mostly by reducing the operation of Units 4 and 6, making the weekly average AIF from Schiller Station from 1 January 2011 through 31 December 2013 the most current and appropriate CWIS operating regime to estimate impingement abundance and mortality for compliance with the new §316(b) regulations (Table A3-1).

Weekly impingement rates (density as number of fish or macro-crustaceans impinged per million gallons of water sampled, fish adjusted for collection efficiency; Appendix

Tables C-3 and C-4, Normandeau 2008) at each Unit (4, 5 or 6) from the 2006 through 2007 Study were multiplied by the associated weekly AIF from Schiller Station for 1 January 2011 through 31 December 2013 to estimate the current weekly and annual impingement abundance of fish and macro-crustaceans for the three units combined (Table A3-2). Fish species impinged at Schiller during the 2006 through 2007 Study were also categorized as fragile or non-fragile species according to the specifications of §125.92(m) of the new §316(b) regulations. Annual impingement abundance of fragile fish species present at Schiller Station (Rainbow Smelt, Atlantic Menhaden, Atlantic Herring, Blueback Herring, and Alewife) was reduced by 42% in 2011 through 2013 compared to 2006 through 2007, while non-fragile fish species annual impingement abundance was reduced by 39%, and macro-crustacean impingement abundance (Green Crab, Rock Crab, American Lobster, Horseshoe Crab and Jonah Crab) was reduced by 49% (Table A3-2) due to the recent flow reductions. No Federally-listed threatened or endangered species were observed in the impingement collections from Schiller Station.

Impingement mortality was estimated from the latent survival observations for the existing traveling screens and fish return systems at Schiller Station (Units 4, 5 and 6 combined) for the fragile and non-fragile fish species (Table A3-3) and macro-crustaceans (Table A3-4) during the 2006 through 2007 Study. The observed latent mortality was 100% for the fragile fish species present in the impingement collections at Schiller Station (Rainbow Smelt, Atlantic Menhaden, Atlantic Herring, Blueback Herring, and Alewife), while non-fragile fish species (predominantly White Hake, Cunner, Northern Pipefish, Cunner and Grubby) exhibited an overall latent mortality of 49.0% (Table A3-3). Macro-crustaceans (Green Crab, Rock Crab, American Lobster, Horseshoe Crab and Jonah Crab) impinged on the existing traveling screens at Schiller Station Units 4, 5, and 6 combined were hardy compared to the fragile and non-fragile fish species, exhibiting a latent impingement mortality of 28.6% (Table A3-4).

Annual impingement abundance and mortality for Schiller Station were estimated for comparison with the new §316(b) regulations to determine if the existing CWIS at each Unit achieved the specified impingement mortality performance standard of 24% (§125.94(c)(7)). The comparison was made by applying the observed latent mortality rates of non-fragile fish and macro-crustaceans from the 2006 through 2007 Study to the annual impingement abundance estimated using the AIF observed for the three most recent years of operation of Schiller Station Units 4, 5 and 6 (1 January 2011 through 31 December 2013). Relatively few latent mortality observations for non-fragile fish (n=49) and macro-crustaceans (n=308) from the 2006 through 2007 Study (Tables A3-3 and A3-4) required mortality estimates to be aggregated into non-fragile fish or macro-crustacean categories and not applied to individual species. Furthermore, there were too few survival observations from each Unit, requiring latent mortality values of 49.0% for non-fragile fish (Table A3-3) and 28.6% for macro-crustaceans (Table A3-4) to be derived from all three Units combined at Schiller Station. If the survival data were weighted by the annual total impingement abundance of non-fragile fish or macro-crustaceans and not by their proportion in the survival samples as presented in Tables A3-3 and A3-4, the latent mortality was 55.2% for non-fragile fish and was 28.7% for macro-crustaceans from all three Units combined at Schiller Station.

The previous 2008 Response estimates of impingement abundance were also used to estimate latent impingement mortality for comparison to the design intake flows, the actual 2006 through 2007 intake flows, and the current 2011 through 2013 AIF for each Unit and for all three Units combined (Table A3-5). The percent mortality achieved by the existing CWIS configuration of traveling screens and return systems was estimated as 36.3% for 2011through 2013 AIF (Table A3-5). Although the annual number of fish and macro-crustaceans impinged at Schiller Station (all three Units combined) was reduced by 47.5% due to flow reductions mostly at Units 4 and 6, relatively high abundance and survival of hardy macro-crustaceans impinged at Schiller Station (Table A3-4) were offset by relatively low survival of non-fragile fish species (Table A3-3) to produce this result.

4.0 Wide-Slot Wedgewire Screens as BTA at Schiller Station

ENERCON (Section 5) has evaluated the engineering feasibility of installing wide-slot (0.375–inch clear space openings; 9.5 mm) wedgewire screens with a design through screen intake velocity of 0.33 fps as a compliance option to satisfy the BTA standards for impingement mortality at Schiller Station. Operating a cooling water intake structure with sufficient open area of the screening system to provide a maximum design through-screen intake velocity of 0.5 fps or less is the §125.94(c)(2) compliance option specified by the new §316(b) regulations. By selecting this option, evaluating the biological efficacy of these proposed wide-slot wedgewire screens is not required under the final §316(b) regulations.

Recent research in a laboratory flume (Normandeau and ASA 2011a, 2011b;) and in the Hudson River estuary (ASA and Normandeau 2012) has demonstrated that performance of cylindrical wedgewire screens is related to three factors: physical exclusion by the slot width, behavioral avoidance of the intake flow by the fish, and the hydraulic bypass due to sweeping flow of river currents along the surface of the wedgewire screen in a direction perpendicular to the slot openings (i.e., parallel to the slot width). Wedgewire screens with slot widths of 2, 3, 6, and 9 mm were tested at flume velocities of 0.25, 0.50, and 1.0 fps, with through-slot velocities of 0.25 and 0.50

fps for a total of 24 combinations of slot width, flume velocity, and through-slot velocity. Physical exclusion exhibited a direct relationship to greatest body depth, and fish (eggs, larvae, or juveniles) with a greatest body depth larger than the slot width were physically excluded. Behavioral avoidance was typically higher for the smaller slot widths, and a lower through-slot velocity. Overall, avoidance and hydraulic bypass were higher at higher ratios of sweeping velocity to through-slot velocity, particularly when this ratio exceeded 1:1. These mechanistic studies demonstrated that hydraulic bypass and avoidance were the prevailing modes of effectiveness of cylindrical wedgewire screens. Exclusion also operated to reduce entrainment of organisms larger than the slot width.

The Piscataqua River location of Schiller Station appears ideal for effective operation of wide-slot wedgewire screens due to the relatively consistent high sweeping velocity along a predominant north-south tidal axis. The frequency distribution of the Piscataqua River velocities near Schiller Station reveals that the sweeping flow exceeds the design through slot intake velocity of 0.33 fps nearly 100% of the time throughout the water column, achieving velocities as high as 6.0 fps for 10% of the time near the river bottom and velocities of 7.0 fps for 10% of the time near the surface (Table A3-6). Relative to the design through slot intake velocity of 0.33 fps, the ratio of sweeping velocity to through slot velocity for a near bottom installation of wide-slot wedgewire screens at Schiller Station is expected to range from 1.5 to 19.5, which is considerably higher than the range of effectiveness observed in the laboratory experiments described in the previous paragraph. Furthermore, the Piscataqua River currents flow along a predominant north (360°, flood) south (180°, ebb) axis (Table A3-7) for 97% of the time. The design and year-round operation of wide-slot wedgewire screens at Schiller Station are capable of achieving the BTA requirements of the new 316(b) regulations for impingement mortality, and their location in the consistent high current velocity environment of the Piscataqua River should also offer significant effectiveness for entrainment reductions if the long axis of each half-diameter wedgewire screen is aligned with the predominant north south directional tidal currents and the slot width dimension is aligned parallel to this axis.

5.0 Barrier Net as BTA at Schiller Station

ENERCON (Section 6) has also evaluated the engineering feasibility of installing a single 3/8-inch (0.375–inch) mesh barrier net to completely surround the two separate CWISs at Schiller Station. The primary consideration in the design and operation of the proposed barrier net is to maintain a through-net velocity of less than 0.5 fps as a compliance option to satisfy the BTA standards for impingement mortality at Schiller Station. Operating a cooling water intake structure with sufficient screening open area to provide a maximum design through-screen intake velocity of 0.5 fps or less based on design intake flow (DIF) is the §125.94(c)(2) compliance option specified by the new §316(b) regulations. By selecting this option, evaluating the biological efficacy of the proposed barrier net is not required under the final §316(b) regulations.

The efficacy of a deployed barrier net is directly related to the amount of time the net operates as designed. Impingement at Schiller Station during 2006 through 2007 varied throughout the year, with the lowest monthly impingement percent abundance of 2.3% observed during May, the highest of 33.0% observed in April, and the remaining months were between 2.6% and 14.5% of the annual total impingement abundance (Normandeau 2008, Table 4-7). By selecting this compliance option, the final §316(b) regulations specify that the facility must demonstrate that the maximum velocity of less than 0.5 fps as water passes through the structural members of the net mesh is achieved during minimum source water elevation and under all conditions, in all months of deployment, including periods of high debris loading and ice buildup for all ambient river currents.

A seasonally-deployed barrier net has been installed and operated for impingement mortality reductions at the Bowline Point Generating Station since 1973 (Normandeau 2014). Bowline Station consists of two 600 MWe coal-fired units, each withdrawing up to 552.9 million gallons per day of once through cooling water from a common CWIS bulkhead. The Bowline CWIS is located on a small low-velocity embayment (Bowline Pond) on the west bank of the Hudson River Estuary about 60 km (37.5 miles) north of New York City. The present barrier net configuration (since 1977-1978) is a V-shaped net about 91.4 m (300 feet) long on each leg by 10 m (33 feet) deep that is made from 0.95-cm (3.8-inch) square mesh multifilament nylon. The Bowline barrier net is deployed to enclose the CWIS bulkhead to reduce fish impingement during the fall, winter, and early spring months, which is the historic period of peak impingement. Suction from the cooling water pumps provides most of the through-mesh velocity of the Bowline barrier net.

The observed difference in the rate of impingement between pre-deployment and post-deployment periods indicates that the seasonal use of the barrier net has been effective in reducing impingement at Bowline Station (Normandeau 2014). Additional evidence of the effectiveness of the barrier net is provided by the rapid decline in the impingement rate immediately following the maintenance activities to correct deployment problems. Occasional problems affecting net efficiency have been encountered during the seasonal deployment periods indicating breaches in the net as a complete barrier system. Two specific problems, a buildup of algae during 1981 and large amounts of detritus and terrestrial leaves in 1982, 1987 and 1988, caused the net to lift off the bottom, creating an opening in the barrier that resulted in higher rates of impingement (Normandeau 2014). Periodic breaches in the barrier net have been detected in some years by weekly impingement monitoring. For example, 1,155 fish were impinged per 24-hour sample during the week of 17 January 2013, compared to a maximum count of 197 fish per 24 hours during the previous 32 weekly impingement samples (Normandeau 2014). When this increase in impingement rate was observed, a crew was sent to inspect the net, find the breach, and restore the net to operate as designed. Restoration of low impingement rates in subsequent weeks confirmed the effectiveness of the repairs.

The engineering design of the barrier net for Schiller Station (ENERCON Section 7) must account for the combination of debris, ice and high ambient current velocities in the Piscataqua River, each of these factors may individually or collectively affect the performance of the barrier net. To estimate debris loading, data from the traveling screens was quantified for each six-hour impingement sample during the 2006 through 2007 Study at Schiller Station (Normandeau 2008, Appendix Table C-2). The highest periods of debris loading in the water filtered through the 3/8-inch traveling screens at Schiller Station were during the autumn months of October and November 2006, when a maximum of 17.4 gallons of terrestrial vegetation were collected per million gallons of water sampled during a six-hour period on 12 October at Unit 4, 19.5 gallons of aquatic vegetation were collected per million gallons of water sampled during a six-hour period on 12 October at Unit 5, and 16.2 gallons of terrestrial vegetation were collected per million gallons of water sampled during a six-hour period on 2 November at Unit 6. High debris loads in the autumn months may cause even the best designed barrier net to breach, as described in the preceding paragraph for the Bowline barrier net. There are no records of the amount of ice floes and ice buildup in the Piscataqua River at Schiller Station, but there is considerable ice formed upstream in Great Bay, sufficient to support an active recreational smelt fishery through the ice in each year. This ice will melt during the spring thaw and can be carried in the Piscataqua River currents downstream past Schiller Station, possibly clogging the proposed barrier net installation if operated in March or April.

Perhaps the most critical environmental factor influencing the effective deployment of a barrier net to reduce impingement mortality at Schiller Station is the consistent high river current velocities. While the entire surface area of the proposed barrier net is sufficient to reduce the design through-screen intake velocity of 0.5 fps, the designed barrier net has a 75 foot mesh panel on the north side and a 70 foot mesh panel on the south side to completely enclose both CWISs of the Schiller Station (ENERCON Attachment 2, page 4/7). The north panel of the designed barrier net would be aligned at an oblique or perpendicular angle to the prevailing Piscataqua River current direction during ebb (south-flowing, 180°) tide currents, and the south panel would align at an oblique or perpendicular angle to the flood (north-flowing, 360°) currents (Table A3-7). As described in Section 4 above (Table A3-6), the Piscataqua River current velocity throughout the water column is almost always above 0.5 fps, and is above 5.0 fps more than 40% of the time. Debris, fish and ice carried by the tidal currents would be exposed to impingement on the north and south sections of the designed barrier net. The barrier net designed for Schiller station must accommodate these considerations for effective performance as BTA.

6.0 Literature Cited:

ASA (ASA Analysis and Communications, Inc.) and Normandeau (Normandeau Associates, Inc.) 2012. Wedgewire Screen Efficacy Study at Indian Point Energy Center. Prepared for Indian Point Energy Center, January 2012.

Enercon Services, Inc. (Enercon). 2008. Response to United States Environmental Protection Agency CWA §308 Letter: PSNH Schiller Station, Portsmouth New Hampshire. October 2008.

Normandeau Associates, Inc, (Normandeau). 2006. Proposal for Information Collection to Address Compliance with the Clean Water Act 316(b) Phase II Regulations at Schiller Station, Portsmouth New Hampshire. October 2006.

Normandeau Associates, Inc, (Normandeau). 2008. Entrainment and Impingement Studies Performed at Schiller Generating Station from September 2006 through September 2007. April 2008.

Normandeau (Normandeau Associates, Inc.) and ASA (ASA Analysis and Communications, Inc.) 2011a. 2010 IPEC Wedgewire Screen Laboratory Study. Prepared for Indian Point Energy Center, January 2011.

Normandeau (Normandeau Associates, Inc.) and ASA (ASA Analysis and Communications, Inc.) 2011b. 2011 IPEC Wedgewire Screen Laboratory Study. Prepared for Indian Point Energy Center, July 2011.

Normandeau (Normandeau Associates Inc.). 2014. Bowline Point Generating Station 2013 impingement studies. Prepared for NRG Bowline, LLC.

Table A3-1. Schiller Station's weekly and annual total operating intake flow sampled from 2 October 2006 through 30 September 2007 compared to the corresponding weekly average actual intake flows for 1 January 2011 through 31 December 2013 (both expressed as millions of gallons per week).

Month	Week	2006-2007	2011-2013
October	40	870.8	323.6
	41	870.8	357.5
	42	626.0	393.8
	43	585.2	407.8
	44	585.2	471.2
November	45	585.2	600.3
	46	665.1	368.2
	47	870.8	572.1
	48	870.8	677.4
December	49	870.8	543.4
	50	870.8	586.6
	51	870.8	418.8
	52	870.8	568.1
January	1	870.8	798.8
	2	870.8	619.7
	3	870.8	768.8
	4	870.8	683.7
	5	870.8	623.1
February	6	870.8	678.1
	7	870.8	713.4
	8	870.8	577.3
	9	870.8	516.5
March	10	703.6	532.9
	11	578.2	432.3
	12	578.2	479.0
	13	494.9	525.9
April	14	578.2	455.7
	15	804.6	496.3
	16	639.2	478.3
	17	870.8	494.7
	18	870.8	550.3
May	19	870.8	387.8
	20	870.8	483.9
	21	870.8	493.7
	22	870.8	603.6
June	23	870.8	483.1
	24	870.8	325.6
	25	870.8	370.0
	26	870.8	473.2

(continued)

Table A3-1. (Continued)

Month	Week	2006-2007	2011-2013
July	27	870.8	692.2
	28	870.8	572.2
	29	870.8	669.5
	30	870.8	661.7
	31	870.8	638.7
August	32	870.8	434.0
	33	870.8	460.7
	34	870.8	477.7
	35	870.8	422.3
September	36	752.4	303.9
	37	870.8	454.6
	38	870.8	292.6
	39	870.8	407.1
Annual Total Flow		**42137.2**	**26,821.9**
Daily Actual Intake Flow		**115.8**	**73.7**

Table A3-2. Weekly and annual total impingement abundance of fragile and non-fragile fish (Adj-I) and macro-crustaceans (I) estimated for Schiller Station Units 4, 5 and 6 combined in 2006 through 2007 and 2011 through 2013.

Month	Week #	2006-2007 Abundance Units 4, 5, and 6 Combined				2011-2013 Abundance Units 4, 5, and 6 Combined			
		Fragile Fish[1,2]	Non-Fragile Fish	Macro-crustaceans[3]	Total	Fragile Fish[1,2]	Non-Fragile Fish	Macro-crustaceans[3]	Total
January	1	65	88	237	390	55	77	200	333
	2	0	155	272	427	0	105	143	248
	3	56	250	172	479	52	208	141	402
	4	48	25	162	235	35	23	121	180
	5	24	64	77	165	15	49	50	114
February	6	0	53	21	74	0	38	14	52
	7	0	121	7	128	0	91	5	96
	8	0	16	71	87	0	11	35	46
	9	0	26	93	119	0	15	38	53
March	10	15	15	14	43	9	15	9	32
	11	0	15	63	78	0	7	38	46
	12	8	80	21	109	5	69	16	91
	13	5	13	42	61	4	11	32	48
April	14	22	44	119	184	9	20	58	87
	15	0	72	386	457	0	30	162	192
	16	317	1,055	226	1,598	177	562	123	862
	17	15	145	644	804	11	92	450	553
	18	8	95	828	931	5	58	541	604
May	19	0	38	717	755	0	18	281	299
	20	0	55	374	429	0	29	172	201
	21	0	16	154	170	0	16	61	77
	22	7	7	319	333	4	4	198	205
June	23	7	37	361	406	2	12	128	143
	24	0	35	391	426	0	35	56	91
	25	7	93	327	427	2	38	92	131
	26	0	106	459	565	0	34	173	208
July	27	0	43	237	280	0	40	182	222
	28	0	0	168	168	0	0	104	104
	29	0	40	175	215	0	32	135	167
	30	0	24	246	270	0	18	169	188
	31	0	34	99	133	0	27	68	95
August	32	0	218	174	392	0	211	74	286
	33	0	0	200	200	0	0	83	83
	34	0	8	162	170	0	5	99	104
	35	0	8	178	187	0	6	44	50
September	36	0	7	102	110	0	0	14	14
	37	15	7	133	155	2	9	48	59
	38	0	30	95	125	0	9	25	34
	39	0	117	197	314	0	61	64	125

(continued)

Table A3-2. (Continued)

Month	Week #	2006-2007 Abundance Units 4, 5, and 6 Combined				2011-2013 Abundance Units 4, 5, and 6 Combined			
		Fragile Fish[1,2]	Non-Fragile Fish	Macro-crustaceans[3]	Total	Fragile Fish[1,2]	Non-Fragile Fish	Macro-crustaceans[3]	Total
October	40	0	47	169	216	0	2	15	17
	41	0	82	142	224	0	10	3	13
	42	0	18	223	241	0	15	190	205
	43	0	26	35	61	0	12	34	46
	44	13	105	14	132	11	81	28	120
November	45	0	0	49	49	0	4	60	64
	46	37	56	158	251	17	10	69	96
	47	206	291	907	1,404	125	161	483	769
	48	42	42	527	611	28	28	367	423
December	49	342	134	570	1,046	163	66	274	502
	50	0	0	419	419	0	0	182	182
	51	0	8	253	261	0	2	81	83
	52	0	40	470	509	0	27	257	284
Annual Total		**1,259**	**4,107**	**12,656**	**18,022**	**732**	**2,504**	**6,490**	**9,726**

[1] Weekly and annual total impingement abundance for fish (Adj-I) was the density sampled (fish/million gallons), corrected for collection efficiency, and multiplied by the weekly actual intake flow (million gallons).

[2] The following fish species observed in the Schiller Station impingement samples from 2006 through 2007 were considered fragile species according to §125.92(m) of the §316(b) regulations: Rainbow Smelt, Atlantic Menhaden, Atlantic Herring, Blueback Herring and Alewife.

[3] Macrocrustacean abundance (I) observed in the Schiller Station impingement samples from 2006 through 2007 include Green Crab, Rock Crab, American Lobster, Horseshoe Crab and Jonah Crab, and was estimated as the density sampled (macrocrustaceans/million gallons) multiplied by the weekly actual intake flow (million gallons).

.

Table A3-3. Survival status (number alive, dead, stunned) and percent (%) composition of fragile and non-fragile fish taxa collected and observed in impingement survival samples from Schiller Station (Units 4, 5, and 6 combined) during 2 October 2006 through 30 September 2007.

Common Name	Fragile Species (§125.92(m) of the §316(b) Regulations)	Annual Impingement Abundance (Adj-I)	% Composition	Total Collected for Survival	Alive at Collection	Dead at Collection	Stunned at Collection	Initial Survival	Total Observed for Latent Survival	Alive After Latent Holding Period[1]	Dead After Latent Holding Period[1]	Stunned after Latent Holding Period[1]	Latent Survival[1]	Latent Impingement Mortality[2]
Rainbow Smelt	Yes	580	10.8%	8	0	8	0	0.0%	0	0	0	0		
Atlantic Menhaden	Yes	306	5.7%	4	0	4	0	0.0%	0	0	0	0		
Atlantic Herring	Yes	277	5.2%	21	0	21	0	0.0%	0	0	0	0		
Blueback Herring	Yes	63	1.2%	4	1	3	0	25.0%	1	0	0	1	0.0%	100.0%
Alewife	Yes	23	0.4%	1	0	1	0	0.0%	0	0	0	0		
Fragile Species Subtotal	**Yes**	**1,249**	**23.3%**	**38**	**1**	**37**	**0**	**2.6%**	**1**	**0**	**0**	**1**	**0.0%**	**100.0%**
White Hake	No	686	12.8%	19	6	13	0	31.6%	6	0	0	6	0.0%	100.0%
Cunner	No	623	11.6%	17	4	12	1	29.4%	5	4	0	1	80.0%	20.0%
Northern Pipefish	No	579	10.8%	7	5	2	0	71.4%	5	2	0	3	40.0%	60.0%
Winter Flounder	No	534	10.0%	11	7	3	1	72.7%	8	6	1	1	75.0%	25.0%
Grubby	No	458	8.5%	12	11	1	0	91.7%	11	8	3	0	72.7%	27.3%
Lumpfish	No	333	6.2%	14	10	4	0	71.4%	10	3	1	6	30.0%	70.0%
White Perch	No	186	3.5%	6	0	5	1	16.7%	1	0	0	1	0.0%	100.0%
Atlantic Silverside	No	114	2.1%	1	0	1	0	0.0%	0	0	0	0		
Windowpane	No	70	1.3%	1	1	0	0	100.0%	1	1	0	0	100.0%	0.0%
Three spine Stickleback	No	49	0.9%	3	1	2	0	33.3%	1	1	0	0	100.0%	0.0%
Atlantic Tomcod	No	47	0.9%	3	0	3	0	0.0%	0	0	0	0		
Emerald Shiner	No	31	0.6%	1	0	1	0	0.0%	0	0	0	0		
Rock Gunnel	No	24	0.4%	1	1	0	0	100.0%	1	0	1	0	0.0%	100.0%
Pollock	No	23	0.4%	1	0	1	0	0.0%	0	0	0	0		
Non-Fragile Species Subtotal	**No**	**3,757**	**70.0%**	**97**	**46**	**48**	**3**	**50.5%**	**49**	**25**	**6**	**18**	**51.0%**	**49.0%**
All Others (no survival observations)	**N/A[3]**	**359**	**6.7%**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**	**N/A[3]**
Total		**5,365**	**100.0%**	**135**	**47**	**85**	**3**	**37.0%**	**50**	**25**	**6**	**19**	**50.0%**	**50.0%**

[1] Fish were collected during the first 12 hours of impingement sampling and observed for latent survival after 24 hours of collection. Therefore the shortest latent observation period was 12 hours and the longest was 24 hours.

[2] Latent mortality was calculated as the number of fish stunned or dead at the end of the latent observation period divided by the number of fish alive or stunned at the time of collection. [3] N/A = not applicable because none were observed for survival

Table A3-4. Survival status (number alive, dead, stunned) and percent (%) composition of macro-crustaceans collected and observed in impingement survival samples from Schiller Station (Units 4, 5, and 6 combined) during the 52 week sampling year from 2 October 2006 through 30 September 2007.

Common Name	Fragile Species (§125.92(m) of the §316(b) Regulations)	Annual Impingement Abundance (I)	% Composition	Total Collected for Survival	Alive at Collection	Dead at Collection	Stunned at Collection	Initial Survival	Total Observed for Latent Survival	Alive After Latent Holding Period[1]	Dead After Latent Holding Period[1]	Stunned after Latent Holding Period[1]	Latent Survival[1]	Latent Impingement Mortality[2]
Green Crab	No	8,924	70.6%	229	181	10	38	**95.6%**	219	164	32	23	**74.9%**	**25.1%**
Atlantic Rock Crab	No	3,324	26.3%	87	70	4	13	**95.4%**	83	53	22	8	**63.9%**	**36.1%**
American Lobster	No	302	2.4%	11	4	6	1	**45.5%**	5	2	3	0	**40.0%**	**60.0%**
Horseshoe Crab	No	70	0.6%	1	1	0	0	**100.0%**	1	1	0	0	**100.0%**	**0.0%**
Jonah Crab	No	29	0.2%	0	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]	N/A[3]
Total	**No**	**12,649**	**100.0%**	**328**	**256**	**20**	**52**	**93.9%**	**308**	**220**	**57**	**31**	**71.4%**	**28.6%**

[1] Macrocrustaceans were collected during the first 12 hours of impingement sampling and observed for latent survival after 24 hours of collection. Therefore the shortest latent observation period was 12 hours and the longest was 24 hours.

[2]Latent mortality was calculated as the number of macrocrustaceans stunned or dead at the end of the latent observation period divided by the number of macrocrustaceans alive or stunned at the time of collection.

[3] N/A = not applicable because none were observed for survival

Table A3-5. Annual impingement abundance and mortality for the existing screens and return systems installed and operated at Schiller Station Units 4, 5, and 6 for design intake flow, the 2006 through 2007 actual intake flows, and the 2011 through 2013 actual intake flows.

		Annual Number Impinged					Existing Screens Impingement Mortality				
Flow	Unit	Non-fragile Fish	Fragile Fish	Total Fish	Macro-crustaceans	Total	Non-fragile Fish	Fragile Fish	Macro-crustaceans	Non-fragile Fish & Macro-crustaceans Total	Latent Percent Mortality[2]
Design Flow	4	2,479	1,000	3,479	10,166	13,646	1,387	N/A[1]	2,919	4,306	34.1
	5	956	135	1,090	1,659	2,750	534	N/A	476	1,011	38.7
	6	808	119	927	1,218	2,144	452	N/A	350	802	39.6
	All	**4,243**	**1,254**	**5,497**	**13,043**	**18,540**	2,373	**N/A**	3,745	6,118	35.4
2006-2007 Actual Intake Flow	4	2,351	1,006	3,356	9,754	13,110	1,315	N/A	2,801	4,116	34.0
	5	983	135	1,118	1,669	2,787	550	N/A	479	1,029	38.8
	6	773	119	891	1,233	2,124	432	N/A	354	786	39.2
	All	**4,107**	**1,259**	**5,366**	**12,656**	**18,022**	2,297	**N/A**	3,634	5,931	35.4
2011-2013 Actual Intake Flow	4	1,197	534	1,731	4,513	6,243	669	N/A	1,296	1,965	34.4
	5	829	120	949	1,485	2,433	464	N/A	426	890	38.5
	6	478	79	556	493	1,049	267	N/A	142	409	42.1
	All	**2,504**	**732**	**3,236**	**6,490**	**9,726**	1,400	**N/A**	1,864	3,264	36.3

[1] NA = fragile fish mortality is not applicable to §125.94(c)(7) impingement mortality standard of the §316(b) regulations.

[2]Latent mortality was calculated as the number of fish or macrocrustaceans stunned or dead at the end of the latent observation period divided by the number of fish or macrocrustaceans alive or stunned at the time of collection.

Table A3-6. Piscataqua River current velocity frequency distribution observed from the National Oceanographic and Atmospheric Administration (NOAA) river current monitoring station PIR0708 located in the river channel at Schiller Station from 21 June through 1 August 2007[1].

Bin (feet per second; fps)	Frequency of Occurrence at 2.6 feet of depth[2]	Frequency of Occurrence 51.8 feet of depth[2]	Cumulative Frequency of Occurrence at 2.6 feet of depth[2]	Cumulative Frequency of Occurrence 51.8 feet of depth[2]
0.0	0%	0%	0%	0%
0.5	3%	3%	3%	3%
1.0	11%	5%	14%	8%
1.5	8%	4%	22%	12%
2.0	9%	3%	31%	15%
2.5	6%	7%	37%	22%
3.0	3%	5%	40%	27%
3.5	4%	6%	44%	33%
4.0	3%	7%	47%	40%
4.5	6%	20%	53%	60%
5.0	7%	13%	60%	73%
5.5	7%	16%	67%	89%
6.0	16%	10%	83%	99%
6.5	8%	1%	91%	100%
7.0	10%	0%	100%	100%
7.5	0%	0%	100%	100%

[1]The raw data were taken from this NOAA web site: http://tidesandcurrents.noaa.gov/cdata/StationInfo?id=PIR0708

[2]Rounding to the nearest whole percentage may present the appearance that the cumulative frequency does not sum to 100%

Table A3-7. Piscataqua River current direction frequency distribution observed from the National Oceanographic and Atmospheric Administration (NOAA) river current monitoring station PIR0708 located in the river channel at Schiller Station from 21 June through 1 August 2007[1].

Bin (degrees from true north)	Frequency of Occurrence (2.6 feet of depth)[2]	Frequency of Occurrence (51.8 feet of depth)[2]
1°-45°	1%	1%
46°-90°	0%	1%
91°-135°	1%	0%
136°-180°	51%	50%
181°-225°	1%	1%
226°-270°	0%	0%
271°-315°	1%	0%
316°-360°	46%	47%

[1]The raw data were taken from this NOAA web site:
http://tidesandcurrents.noaa.gov/cdata/StationInfo?id=PIR0708

[2]Rounding to the nearest whole percentage may present the appearance that the cumulative frequency does not sum to 100%