SUPER LAW GROUP, LLC

January 27, 2016

VIA EMAIL

Michael Cobb (cobb.michael@epa.gov)
U.S. Environmental Protection Agency
5 Post Office Square, Suite 100 (OEP06-1)
Boston, MA 02109-3912

Re: **Comments of Sierra Club Regarding Renewal of Schiller Station NPDES Permit No. NH0001473**

Dear Mr. Webster:

We are writing on behalf of Sierra Club with regard to the National Pollutant Discharge Elimination System ("NPDES") permit for Public Service of New Hampshire's ("PSNH") (d/b/a Eversource Energy) Schiller Station ("Schiller"), located on the Piscataqua River in Portsmouth, New Hampshire. Schiller currently operates under NPDES permit NH0001473, which was issued in 1990 in the second year of George H.W. Bush's presidency. The permit term expired in 1995 and has been administratively continued ever since. On October 30, 2015, EPA Region 1 issued a draft NPDES permit (the "Draft Permit") for Schiller.[1] The Draft Permit's modest environmental improvements to a permit last modified decades ago fall short of where Schiller needs to be in 2016, and for the years to come.

As your office recently explained to the U.S. Court of Appeals for the First Circuit, Schiller's two cooling water intake structures "provide no protection against entrainment and little protection against impingement mortality."[2] Thus, even though the Clean Water Act dictates that NPDES permits "are for fixed terms not exceeding five years"[3] and that cooling water intakes must "reflect the best technology available for minimizing adverse environmental impact,"[4] Schiller has operated for over 20 years on an expired permit with little or no technology to minimize fish kills or thermal discharges. Dramatic improvement is necessary.

These comments are intended to assist the Region by providing technical and legal information germane to the Schiller Station, its adverse environmental impacts and the applicable statutory and regulatory requirements. These comments are accompanied by three reports examining the

[1] EPA Region 1, Schiller Station Draft Authorization to Discharge Under the National Pollutant Discharge Elimination System NPDES Permit NH0001473 (Oct. 30, 2015) (hereinafter "Schiller Draft Permit).
[2] Declaration of David M. Webster in Support of Opposition to Petition for a Writ of Mandamus ("Webster Decl."), 1st Cir. Case No. 12-1860, March 6, 2013, at ¶ 80(b)(ii).
[3] *See* 33 U.S.C. §§ 1342(b)(1)(B), 1342(a)(3).
[4] *See* 33 U.S.C. § 1326(b).

411 STATE STREET, SUITE 2R · BROOKLYN, NEW YORK 11217
TEL: 212-242-2355 FAX: 855-242-7956 www.superlawgroup.com

engineering, economics, and biology related to the BTA determination, prepared (respectively) by Powers Engineering,[5] Synapse Energy Economics,[6] and Petrudev.[7]

I.

EXECUTIVE SUMMARY

Our chief concern is that the antiquated once-through cooling system for Schiller's electricity-generating turbines has the capacity to draw more than 150 million gallons of water per day ("MGD") out of the Piscataqua River.[8] According to your office, the once-through cooling system also collects and kills nearly 1.7 billion aquatic organisms annually.[9] The cooling system crushes larger fish and other animals against the intake structure (impingement) and sucks smaller organisms through the cooling water intake system (entrainment). It then discharges heated, chemically treated water that further harms fish, eelgrass, and other organisms in the Piscataqua River.

According to PSNH's own studies, more than 42 taxa of fish and macrocrustaceans are killed at Schiller, including at least three species listed as "species of concern" by the National Marine Fisheries Service: rainbow smelt, alewife and blueback herring. In addition, three species federally-listed as endangered - shortnose sturgeon, Atlantic sturgeon and Atlantic salmon - may be adversely affected by Schiller's intake structures. To date, EPA has not discussed endangered Atlantic salmon in the permit record.

These harms are unacceptable and are not adequately addressed by the EPA's decision to select cylindrical wedgewire screens as the Best Technology Available. To minimize Schiller's adverse environmental impacts, as required by CWA § 316(b), EPA should require PSNH to convert Schiller to a closed-cycle cooling system that will virtually eliminate these problems. As these comments and accompanying expert reports demonstrate, the aquatic impacts of the plant's

[5] The Powers Engineering report ("Powers Report") was prepared by William Powers. Mr. Powers is a mechanical engineer and consultant on environmental and energy matters and the owner and operator of Powers Engineering. At Powers Engineering he has carried out cooling system retrofit evaluations for coal plants, nuclear plants, and natural gas combined cycle plants and prepared sections on combined cycle power plant air emission controls and air cooling systems for Electric Power Research Institute guidance documents. A copy of the Powers Engineering report is attached as Exhibit 1.

[6] The Synapse Energy Economics Report ("Synapse Report") was prepared by Frank Ackerman, PhD. Dr. Ackerman is expert in the economics of climate change and energy, cost-benefit analysis and regulations, among other things. At Synapse, he has analyzed water-energy dependencies and related problems facing the U.S. electricity industry, critiqued a number of flawed economic studies related to clean energy and the environment, and filed expert testimony on the economics of coal-plant investments and alternative options. Dr. Ackerman received his PhD in economics from Harvard University and has taught economics at Tufts University and the University of Massachusetts. In addition, Dr. Ackerman prepared a memorandum updating the Synapse Report, which memorandum is hereinafter referred to as the "Synapse Memorandum." A copy of the Synapse Report and Memorandum are attached as Exhibit 2.

[7] The Petrudev Report was prepared by Petrudev Inc., a consulting company that specializes in technical reviews of fisheries studies including impingement and entrainment of fish and shellfish from different industrial water users. Staff are also very familiar with thermal effects on fish and other invertebrates and their assessments.. A copy of the Petrudev Report is attached as Exhibit 3.

[8] EPA Region 1, Schiller Station Draft Authorization Discharge Under the National Pollutant Discharge Elimination System NPDES Permit NH0001473 – Fact Sheet at 18 (Oct. 30, 2015) (hereinafter "Schiller Fact Sheet").

[9] *Id.*

existing once-through cooling system are significant and detrimental, the Clean Water Act ("CWA") requires that these impacts be minimized through the permit renewal process, and, consistent with previous determinations by EPA and other permitting authorities, the installation of closed-cycle cooling is both necessary to minimizing these impacts and is technically feasible and affordable at the plant.

If EPA instead selects cylindrical wedgewire screens as BTA in Schiller's final NPDES permit, then Sierra Club proposes that EPA include a water withdrawal limit in the permit that replicates the current low-capacity factor conditions at Schiller. Because EPA proposed wedgewire screens in light of these conditions, an enforceable water withdrawal limit will ensure that the anticipated environmental benefits are fully realized going forward.

Notwithstanding Sierra Club's disagreement with the proposed BTA determination, Sierra Club agrees with EPA's decision to set a through-slot velocity limit on any screen to be used (including the screens for a closed-cycle cooling system using the river for makeup water). As discussed below and in the attached report from Petrudev, Sierra Club believes that the correct velocity limit to protect the species adversely affected by Schiller is 0.2 fps, and not 0.5 fps. Further, to make the velocity requirement more than a mere aspiration, Sierra Club proposes that the final NPDES permit include required continuous through-slot velocity monitoring. Given the fouling risks associated with cylindrical wedgewire screens, a monitoring requirement will make sure that the screens are operating as designed.

Finally, EPA should not issue a final permit without terminating or incorporating currently unpermitted discharges associated with Schiller's onsite landfill. For decades, the now-inactive landfill received harmful industrial waste streams, most of which remain in place today. The permittee's own monitoring data show that leachate from the landfill has migrated through groundwater beyond the landfill perimeter. Given the short distance and prevailing direction of groundwater flow (i.e. toward the river), there is an extremely high likelihood that contaminated leachate from the landfill is reaching the Piscataqua River, via hydrologically connected groundwater, meaning that landfill is an unpermitted point source of discharge to the Piscataqua.

II.

BACKGROUND

A. The Piscataqua River

Schiller Station is located on the southwestern bank of the Piscataqua River, a 12 mile long (19 km) tidal estuary that marks the boundary between coastal New Hampshire and Maine. The river is formed at the confluence of the Cocheco River and the Salmon Falls River and runs southeastward until it empties into the Atlantic Ocean.[10] The Piscataqua is the gateway for all organisms migrating to and from the Great Bay and Little Bay estuaries.

The Piscataqua River is important for diadromous fish species. The river also provides a variety of social, recreational and economic benefits including fishing, business, boating, and whale

[10] Petrudev Report at 1-1.

watching. As an estuarine environment mixing freshwater and saltwater and receiving flow from the Great Bay and Little Bay estuaries, the Piscataqua River is highly productive, ecologically important and sensitive. Historically, the Piscataqua River has provided dense eelgrass habitat and provided breeding grounds and nurseries, nutrients, and food for a diverse range of aquatic species including at least 50 fish species and at least nine "macro crustaceans:" American lobster, horseshoe crabs, and seven species of true crabs.[11]

Of the species of fish and crustaceans known to inhabit the area around Schiller, the eggs of at least 21 different species of fish and the larvae of 27 species have been recorded killed at Schiller, along with the larvae of eight of the nine macro-crustacean species found in the area and juveniles and adults from five of the nine macro-crustacean species.[12] In other words, Schiller kills various life stages of the majority of species for which biologists have conducted sampling.

B. Schiller Generating Station and its Current Cooling Water Intake System

Schiller Station is a 163 megawatt (MW) facility that consists of: two 48 MW coal-fired units, Units 4 and 6, which use oil as a back-up fuel; one 48 MW wood-fired unit, Unit 5; and one 19 MW combustion turbine.[13] Units 4, 5, and 6 began commercial operation in the 1950s.

Over the last several years, Schiller's coal burning units (units 4 and 6) have operated at a reduced capacity factor. While Schiller's wood-burning unit continues to operate at a capacity factor of around 80%, the capacity factors for Units 4 and 6 have been significantly lower (16.1% and 16% respectively, since 2011).[14]

Units 4, 5, and 6 employ once-through cooling systems drawing through two cooling water intakes with a total maximum design intake flow of 125 million gallons per day (MGD). The estimated design heat rejection rate of Schiller's once-through cooling system is 759 MMBtu/hr.[15] All of this heat is discharged back into the Piscataqua River.

C. Current Regulation of Cooling Water Intakes at Schiller

On September 11, 1990, EPA Region 1 issued NPDES Permit No. NH0001473 to PSNH for Schiller Station, superseding the permit issued on December 31, 1984, and authorizing the continued operation of Schiller's once-through cooling system.[16] The Region modified the permit on May 31, 1991, and the permit expired on September 30, 1995.[17]

The 1990 permit authorized the use of the once-through cooling system, which is equipped with trash racks, intake screens, and a fish return system that uses 40 PSI of water pressure to blast

[11] Petrudev Report at 2-2 - 2-3.
[12] *Id.*
[13] Schiller Fact Sheet at 5.
[14] Schiller Fact Sheet at 139.
[15] Powers Report at 2.
[16] *See* EPA Region 1, Schiller Authorization to Discharge Under the National Pollutant Discharge Elimination System NH0001473 (Sept. 11, 1990) (the "1990 Permit").
[17] Schiller Fact Sheet at 6.

organisms off the screens.[18] The 1990 permit recorded EPA's determination, based on then-current engineering judgment, that Schiller employed the best technology available for minimizing adverse environmental impact.[19] Since 1990, however, EPA has learned a great deal more about the severe impacts of impingement and entrainment on aquatic communities and endangered species, and has extensively studied a wide range of fish protection technologies. Sierra Club agrees with EPA that the 1990 BTA determination is severely outdated, and needs dramatic improvement.

For the past eighteen-and-a-half years, the expired 1990 permit has been administratively continued. Since December 2004, Region 1 and PSNH have exchanged correspondence and other documentation concerning PSNH's renewal application. In light of significant changes to Schiller's operation over the preceeding 15 years, EPA asked PSNH to submit a new NPDES renewal application and related materials.

In 2008, PSNH submitted a study on the feasibility of various options to reduce impingement and entrainment at Schiller. PSNH and its consultants found that:

> the use of mechanical draft cooling towers in a closed-cycle cooling configuration was determined to be technologically feasible at Schiller Station and potentially provide the most biological benefits of the various technologies and operational measures evaluated . . . .[20]

Still, PSNH argued against the use of cooling towers at Schiller, on the grounds that "the initial and ongoing costs are both wholly disproportionate to these benefits."[21] PSNH claimed that the best technology available at Schiller is a system of cylindrical wedgewire screens, with a through slot velocity of not more than 0.5 feet per second (fps), although PSNH did not determine in its study what size of slot and what materials would prove feasible at Schiller.[22]

In 2010, EPA asked PSNH to explain how it had reached the conclusion that cooling towers were not the best technology available because the costs of cooling towers were wholly disproportionate to the environmental benefits. PSNH explained that its view was based "solely on a comparison of the capital costs of the various technologies and their respective I&E performance."[23] As discussed further below, however, neither PSNH's estimates of the costs or of the environmental benefits are believable.

Schiller's arguments notwithstanding, EPA preliminarily determined, "based on Schiller's October 2008 response, that closed-cycle cooling is the Best Technology Available (BTA) for

---

[18] *See* 1990 Permit at 2; *see also* PSNH (prepared by Enercon Services, Inc. and Normandeau Associates, Inc.), *Response to United States Environmental Protection Agency CWA §308 Letter, PSNH Schiller Station Portsmouth, New Hampshire* at 4-12 (Oct. 2008) ("316(b) Report").
[19] *See* 1990 Permit at 3.
[20] 316(b) Report at v.
[21] *Id*.
[22] *Id.*
[23] Letter from Linda T. Landis, Senior Counsel, PSNH to Stephen Perkins, Director, Office of Ecosystem Protection, US EPA Region 1 at 3 (June 17, 2010).

Schiller Station."[24] Sierra Club strongly supports EPA's preliminary determination that closed-cycle cooling is the BTA at Schiller and urges EPA to carry it forward into a final NPDES permit.

D. Impingement and Entrainment

Power plants, through their cooling water intakes, cause massive adverse environmental impacts to populations of fish and other aquatic organisms. At Schiller, adverse impacts result from both impingement (organisms striking and being caught against the intake screens) and entrainment (organisms being sucked into the plant's cooling water intakes). The existing cooling system, with its 3/8 inch traveling screens and through-screen velocities up to 1.38 fps,[25] does not minimize significant adverse environmental impacts on the aquatic communities in the Piscataqua River. A large variety of fish and macrocrustaceans of all life stages are present in the Piscataqua River in the vicinity of Schiller Station. All of these organisms are or may be negatively impacted by Schiller's cooling water system.

1. Fish

At least 46 fish species have been recorded in the vicinity of Schiller Station based on entrainment and impingement monitoring conducted in 2006-2007 by PSNH's consultant Normandeau Associates.[26] Fish species comprise resident and seasonal fish, as well as migratory (e.g., anadromous, catadromous) fish. Normandeau estimated that over 145 million fish are entrained and 5,365 fish are impinged at Schiller annually.[27] Moreover, due to several shortcomings in Normandeau's monitoring, the extent of impacts from operations at Schiller is systematically underestimated. Indeed, EPA estimates annual impingement and entrainment mortality at 5,557 and 156 million.[28] Petrudev's attached report suggests that it might be even greater.

In addition to the fish species recorded near Schiller through Normandeau's monitoring, the following fish species are also present in the Piscataqua River according to the New Hampshire Fish and Game Department, the National Marine Fisheries Service (NMFS), and the non-profit conservation organization NatureServe[29]:

- American shad (*Alosa sapidissima*);
- Sea lamprey (*Petromyzon marinus*);
- Brown trout (*Salmo trutta*);

---

[24] *See* Letter from Stephen S. Perkins, EPA Region 1 to William H. Smagula, PSNH Generation, regarding Information Request for NPDES Permit Re-Issuance, NPDES Permit No: NH0001473 at 5 (May 4, 2010) ("Perkins Letter"). EPA noted that its preliminary determination to require Schiller to install closed-cycle cooling was made "in the absence of any site specific information regarding the 'availability' of wedgewire screens for use at Schiller Station."
[25] *See* 316(b) report at 6 & 12.
[26] Petrudev Report at 2-1.
[27] Detailed results related to entrainment and impingement studies are presented in Sections 2.2 to 2.4 of the attached Petrudev Report.
[28] Schiller Fact Sheet at 94 & 96.
[29] NatureServe Explorer, http://www.natureserve.org/explorer/servlet/NatureServe?init=Species (last visited Jan. 25, 2016).

- Brook trout (*Salvelinus fontinalis*);
- Rainbow trout (*Oncorhynchus mykiss*);
- Atlantic salmon (*Salmo salar*) – Gulf of Maine Distinct Population Segment is endangered under the federal *Endangered Species Act (ESA)*;
- Atlantic sturgeon (*Acipenser oxyrinchus oxyrichnus*) – Gulf of Maine Distinct Population Segment is listed as threatened under the federal *ESA*; and,
- Shortnose sturgeon (*Acipenser brevirostrum*) – listed as endangered under the federal *ESA.*

The endangered Atlantic salmon has been extirpated as a breeding population in much of its historic range, including the Piscataqua River and Great Bay estuary.[30] Historically, the Cocheco and Lamprey rivers were home to major runs of the Atlantic salmon.[31] Both of these rivers can only be accessed by fish that first pass Schiller on the Piscataqua River, and migrating fry journeying to the ocean must also pass Schiller. Efforts to restore spawning populations of Atlantic salmon in New Hampshire and Connecticut have been underway for nearly 40 years.[32] NMFS has designated the Piscataqua River, the Great Bay estuary, and its tributary rivers such as the Cocheco and the Lamprey Rivers essential fish habitat for Atlantic salmon.[33]

The Atlantic sturgeon Gulf of Maine Distinct Population Segment (DPS) is listed as threatened under the federal Endangered Species Act.[34] In 2007, in the fact sheet supporting a draft NPDES permit for the Newington Energy Facility (a power plant less than a mile upstream of Schiller), EPA acknowledged that Atlantic sturgeon had been captured in the Piscataqua River in the past.[35] That same year, NMFS published a status review of Atlantic Sturgeon which noted that the recorded catch included "a large gravid female Atlantic sturgeon (228 cm TL) weighing 98 kg (of which 15.9 kg were eggs)" at the head-of-tide in the Salmon Falls River in 1990.[36] But the review went on to note that since 1990 there had been no further reported catches and concluded that, as a breeding population, the Atlantic sturgeon is extirpated in the Great Bay.

Recovery of a breeding population of Atlantic sturgeon in its historic habitat – including the Piscataqua River and its tributaries – is a priority under the Endangered Species Act. In 2013, in its final listing rule for Atlantic sturgeon, NMFS stated that Atlantic sturgeon are present in the

[30] *See* NMFS and FWS, *Final Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar)* at 1-5 (Nov. 2005).
[31] *See id.* at 1-6.
[32] *See id.* at 1-5.
[33] *See* Atlantic Salmon Biological Review Team, Status Review for Anadromous Atlantic Salmon (*Salmo salar*) in the United States at 149 (2006), *available at* http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsalmon.pdf (last visited on Jan. 25, 2016) ("Essential fish habitat for Atlantic salmon is described as all waters currently or historically accessible to Atlantic salmon within the streams, rivers, lakes, ponds, wetlands, and other water bodies of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut and that meet conditions for eggs, larvae, juveniles, adults and/or spawning adults.")
[34] *See* Petrudev Report at 2-21.
[35] *Id.*
[36] Atlantic Sturgeon Status Review Team, *Status Review of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus)* at 10 (2007), *available at* http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsturgeon2007.pdf (last visited on Jan. 25, 2016).

Piscataqua River.[37] The capture of a large gravid female less than 25 years ago leaves hope that these long-lived fishes are still capable of repopulating this historic habitat.

NMFS has listed the shortnose sturgeon as an endangered species and has determined that the species is found in the Piscataqua River.[38] The NMFS' Recovery Plan for shortnose sturgeon specifically identifies impingement and entrainment at cooling water intakes as a source of shortnose sturgeon mortality.[39] EPA also has concluded that juvenile and adult stages of shortnose sturgeon are found near Schiller.[40] The attached report from Petrudev notes that, although shortnose sturgeon were not recorded during entrainment and impingement monitoring at Schiller, the sampling methods and approach used in Schiller's monitoring likely are not robust enough to adequately sample this species given their expected low abundance. Additionally, Petrudev notes that Schiller's last impingement and entrainment study involved a low sampling frequency during the period when shortnose sturgeon larvae would be most susceptible to entrainment.[41]

2. Macrocrustacea

Schiller has entrained or impinged several crab species and a lobster species. Normandeau estimated that over 1.3 billion macrocrustaceans are entrained and 12,649 macrocrustaceans are impinged annually.[42] EPA's estimates are even higher: 1.4 billion for entrainment and 13,536 macrocrustaceans for impingement.[43] The most commonly impinged species at Schiller are green crab, Atlantic rock crab and American lobster.[44]

By PSNH's estimates, Schiller impinges and entrains more than 145 million individual fish, eggs, and larvae annually from more than 35 taxa, as well as 1.3 billion individual macro-crustaceans from at least seven taxa.[45] Petrudev has reviewed the impingement and entrainment studies submitted by PSNH and concluded that, using PSNH's figures, a closed cycle cooling retrofit would save approximately 1.3 billion animals every year.[46] EPA's higher estimates for aquatic life mortality lend additional support to Petrudev's conclusion and would require an upward adjustment in Petrudev's estimates.

E. Cooling Water Intake Regulation in the Draft NPDES

Despite EPA's preliminary determination that closed-cycle cooling is the BTA at Schiller, in the Draft Permit, EPA rejected closed-cycle cooling as BTA for minimizing adverse environmental impacts, after recognizing both that closed cycle cooling is the most effective technology for

---

37 *See* Petrudev Report at 2-21.
38 *See id.* at 2-20.
39 *See id.*
40 *See* EPA Region 1, Draft National Pollutant Discharge Elimination System (NPDES) Permit to Discharge to Waters of The United States Pursuant to the Clean Water Act (CWA) NH0023661- Fact Sheet at 31-32 (2007) ("PSNH Newington Fact Sheet").
41 *See* Petrudev Report at 2-20.
42 Petrudev Report at 2-4.
43 Schiller Fact Sheet at 95-96
44 *Id.* at 96.
45 *See* Petrudev Report at 2-4.
46 *See id.* at Table 6.2

minimizing impingement and entrainment mortality, and after finding that converting Schiller from open-cycle to closed-cycle cooling is both technically and financially feasible.[47]

Instead, EPA has proposed use of cylindrical wedgewire screens, finding that, with an intake velocity kept below 0.5 fps and a screen-slot size below 0.8 mm, this technology could achieve between 80-95% impingement reduction.[48] For entrainment, the level of reduction achievable with wedgewire screens will depend on the screen-slot size installed at Schiller. The draft permit requires Schiller to conduct pilot testing to determine, from the different screen slot-sizes, the optimal slot-size (0.6 mm; 0.69 mm; and 0.80 mm). EPA estimated that a 0.8 mm slot size would reduce fish entrainment mortality by 37 %, the 0.69 mm slot-size by 44%, and the 0.6 slot-size by 49%.[49]

EPA estimates that all slot sizes would reduce macro-crustacean entrainment mortality by 100%. As discussed below, this is perhaps the single most critical assumption in EPA's entire BTA analysis, and EPA has absolutely no support for the proposition.

Even with the 100% macro-crustacean entrainment survival assumption, EPA's total estimate is that cylindrical wedgewire screens would reduce total impingement and entrainment mortality by 92%. By contrast, EPA estimated that mechanical draft wet cooling towers would reduce entrainment and impingement by 96.9 to 100%.[50] As discussed below, the correct figure for cooling towers is 100% because EPA has already determined that use of grey water for makeup is an "available" technology, and thus a cooling tower need not draw any water from the Piscataqua at all.

F. Thermal Discharges

Schiller is located on a stretch of the Piscataqua River that is dredged for navigation and heavily used by other industrial facilities that consume river water. Next door on Gosling Road sits the PSNH Newington generating station. PSNH Newington is a 420 MW gas and oil fueled power plant.[51] The PSNH Newington NPDES permit[52] authorizes Newington to operate a once-through cooling water intake system that withdraws up to 324.6 MGD of cooling water to the Piscataqua River and discharges a similar volume of heated water back into the river.

The Newington discharge canal is approximately 1400 feet upriver from the nearest of Schiller's three thermal discharge outfalls (and less than 2000 feet from the farthest of Schiller's outfalls). The Newington NPDES permit establishes a thermal discharge mixing zone that allows for a thermal plume occupying up to 25 acres of the river at an increased temperature (ΔT) of 4 ºF (2.2 ºC); and a 60 acre area with a ΔT of 1.5 ºF (0.83 ºC). Depending on tide conditions, these large mixing zones can easily overlap all of Schiller's discharge points and plumes. If Schiller and

[47] Schiller Fact Sheet at 202.
[48] Draft Permit at 15; Schiller Fact Sheet at 113.
[49] Schiller Fact Sheet at 110.
[50] *Id.* at 145.
[51] PSNH Newington's generating capacity is variously reported by different sources as 400 MW, 406 MW, and 420 MW. Sierra Club uses the figure provided in the NPDES permit of 420 MW.
[52] EPA Region 1, PSNH-Newington Station Authorization to Discharge Under the National Pollutant Discharge Elimination System Permit No. NH0001601 (Sept. 30, 1993), *Available at* http://www.epa.gov/region1/npdes/permits/finalnh0001601permit.pdf (last visited on Jan. 25, 2016).

PSNH Newington are running simultaneously during peak demand periods, they can withdraw (and discharge) about 450 MGD from the Piscataqua.

A few miles upstream of Schiller is another power plant, the Newington Energy Facility, operated by Newington Energy, LLC (and owned by Essential Power, LLC).[53] Newington Energy Facility is a combined-cycle natural gas plant that uses mechanical draft cooling towers rather than a once-through cooling system. In the Newington Energy Facility's NPDES Permit, EPA reviewed then-listed federal endangered and threatened species and indicated that juvenile and adult stages of shortnose sturgeon have the potential to be found near the Newington Facility.[54] The existence of Newington Energy Facility is interesting not only because it is located near to Schiller, but because it is a 525MW power plant yet, thanks to the use of cooling towers, it draws only 10.8 MGD of water from the Piscataqua, compared to 324.6 MGD at PSNH Newington and another 150 MGD at Schiller.

In order to generate power, Schiller must dispose of millions of BTUs of waste heat every year. Under its current permit, Schiller is authorized, by way of a CWA § 316(a) variance, to discharge 150 million gallons of cooling water daily at a differential above ambient water temperatures (ΔT) of up to 25ºF, and at a maximum temperature of 95ºF.[55] Further, the discharge cannot cause water temperatures in excess of 84ºF outside of a zone 200 feet in any direction from the discharge. In 2010, along with a new application to renew the NPDES permit, EPA asked PSNH to submit data about Schiller's thermal discharge.[56]

EPA has concluded that Schiller's existing thermal discharge has not caused appreciable harm to the balanced, indigenous population (BIP) of shellfish, fish and wildlife in the Pascataqua River. Thus, EPA has proposed to retain the 316(a) variance in the current permit. However, in reaching this conclusion, EPA failed to engage in a complete "cumulative impacts" analysis, examining how the impacts of Schiller's thermal discharge will interact with other significant impacts, like climate change, on affected species.

H. Coal Ash Landfill

An inactive coal ash landfill occupies two acres on the southeastern portion of the Schiller site, several hundred yards from the banks of the Piscataqua River.[57] From 1949 until 1979, the landfill received various wastes. According to an environmental review conducted for PSNH, this unlined landfill is known to contain fly ash, waste oil, and 55-gallon steel drums.[58] Given its age and the needs of a power plant, the landfill may also contain used solvents and PCB-laden transformer fluids. During the closure and capping of the landfill, which occurred between 1980 and 1982, certain asbestos containing materials were removed, but any remaining harmful or

[53] Petrudev Report at 2-21.
[54] EPA Region 1, EP Newington Energy Facility Authorization to Discharge Under the National Pollutant Discharge Elimination System at 26 (Permit No. NH0023361) (Oct. 25, 2012) available at http://www3.epa.gov/region1/npdes/permits/2012/finalnh0023361permit.pdf (last visited on Jan. 25, 2016).
[55] *See*1990 Permit at 7-11 (setting flow and temperature effluent limitations for outfalls 001 to 004).
[56] *See* Perkins Letter at 2-4.
[57] ESS Group, *PSNH Generating Asset Environmental Review* at 11 (Mar. 31, 2014) (hereinafter "ESS Environmental Review).
[58] *Id.* at 15.

toxic materials remain on site.[59] The landfill remains an inadequately characterized and monitored liability.

There is evidence that leachate from the landfill has reached groundwater and migrated beyond the perimeter of the landfill. PSNH installed four groundwater monitoring wells, which it only monitors annually. Groundwater monitoring in July 2013 detected levels of manganese above ambient levels and groundwater quality standards.[60] Given the very close proximity between the landfill and the Piscataqua River, and the prevailing direction of groundwater flow to the river, there is a reasonable likelihood that pollutants from the landfill are reaching surface water via hydrologically connected groundwater.

III.

APPLICABLE LEGAL REQUIREMENTS

In enacting the Clean Water Act, Congress established as a national goal the elimination of all discharges of pollution into navigable waters.[61] In furtherance of the goal of eliminating all discharges into waters of the United States, the CWA provides that no pollutant may be discharged from any point source without a NPDES permit. Any failure to comply with a permit "constitutes a violation of the Clean Water Act."[62] The NPDES permit program is thus an integral part of the CWA's plan to eliminate pollution discharges, and to restore and maintain the health and integrity of the nation's waters.[63]

In New Hampshire, EPA's Regional Office is the NPDES permitting authority. As the New Hampshire Code of Administrative Rules, Part Env-Wq 301 acknowledges, New Hampshire's state water permitting regulations do not apply to "[facilities] that require both a state discharge permit and a federal National Pollutant Discharge Elimination System (NPDES) permit under Section 402 of the Clean Water Act, which are subject to regulations adopted by EPA under 40 CFR, including but not limited to 40 CFR 122 and 125."[64]

A. Technology Requirements

The CWA requires that NPDES permits include effluent limits based on the performance achievable through the use of statutorily-prescribed levels of technology that "will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants."[65] Technology-based effluent limitations ("TBELs") constitute a minimum level of controls that must be included in a NPDES permit "regardless of a discharge's effect on water quality."[66]

[59] *Id.*
[60] *Id.*
[61] *See* 33 U.S.C. § 1251(a)(1).
[62] 40 C.F.R. § 122.41(a).
[63] *See* 33 U.S.C. § 1342 (establishing permit program requirements).
[64] *See* N.H. Code of Admin. Rules Part Env-Wq 301.02(b).
[65] 33 U.S.C. § 1311(b)(2)(A)(i), *see also id*. § 1311(b)(1)(A).
[66] *Am. Petroleum Inst. v. EPA*, 661 F.2d 340, 344 (5th Cir. 1981).

For sources constructed prior to the passage of the Federal Water Pollution Control Act of 1972 such as Schiller, discharges of pollutants must be eliminated or controlled through application of Best Available Technology ("BAT").[67] In accordance with the CWA's goal to eliminate all discharges of pollutants, BAT limits "shall require the elimination of discharges of all pollutants if the Administrator finds, on the basis of information available to him . . . that such elimination is technologically and economically achievable . . . ."[68]

The requirement to meet the BAT standard is ongoing; it compels polluting industries to meet ever more stringent limitations on the path towards complete elimination of water pollution.[69] With each renewal of a NPDES permit, the permitting agency must reconsider whether further pollution reductions are attainable. The goal of the law is continuous, rapid improvement:

> The BAT standard reflects the intention of Congress to use the latest scientific research and technology in setting effluent limits, pushing industries toward the goal of zero discharge as quickly as possible. In setting BAT, EPA uses not the average plant, but the optimally operating plant, the pilot plant which acts as a beacon to show what is possible.[70]

EPA often codifies effluent limitation guidelines that reflect the BAT standards for particular discharges, pollutants, and activities found in a category of point sources. These guidelines become the floor – the minimum level of control that must be imposed in a NPDES permit. But where EPA has not set effluent limitation guidelines for a pollutant or source or particular activity, or where such guidelines are inadequate, a state-permitting agency must promulgate permit effluent limitations, in accordance with BAT, on a case-by-case basis.[71] In seeking out the best available technology that is economically achievable, the agency must consider the best state of the art practices in the industry and beyond. "Congress intended these [BAT] limitations to be based on the performance of the single best-performing plant in an industrial field."[72]

A technology is considered "available" where there is, has been, or could feasibly be use within an industry. Courts have explained that even where "no plant in a given industry has adopted a pollution control device which could be installed does not mean that the device is not 'available,'" thus ensuring that industry cannot game the system by all agreeing to not adopt the latest, best pollution control technology.[73]

Likewise, a technology is "economically achievable" under the BAT standard if it is affordable for the best-run facility within an industry.[74] "BAT should represent a

---

[67] *See* 33 U.S.C. § 1311(b)(2)(A).
[68] 33 U.S.C. § 1311(b)(2)(A).
[69] *See NRDC v. EPA,* 822 F.2d 104, 123 (D.C. Cir. 1987).
[70] *Kennecott v. EPA*, 780 F.2d 445, 448 (4th Cir. 1985), citing 1 *Legislative History of the Federal Water Pollution Control Act of 1972*, 798 (Committee Print compiled for the Senate Committee on Public Works by the Library of Congress), Ser. No. 93-1 (1973).
[71] *See* 40 C.F.R. § 125.3(c)(2) & (3); *see also Texas Oil & Gas Ass'n v. EPA*, 161 F.3d 923, 928-29 (5th Cir. 1998).
[72] *Chem. Mfrs. Ass'n v. EPA*, 870 F.2d 177, 226 (5th Cir. 1989).
[73] *Hooker Chems. & Plastics Corp. v. Train*, 537 F.2d 620, 636 (2d Cir. 1976).
[74] *See, e.g., Reynolds Metals Co. v. EPA,* 760 F.2d 549, 562 (4th Cir. 1985); *Tanner's Council of Am. v. Train,* 540 F.2d 1188, 1191-92 (4th Cir. 1976).

commitment of the maximum resources economically possible to the ultimate goal of eliminating all polluting discharges."[75]

B. Water Quality Requirements

One of the most important functions that a state performs under the Clean Water Act is to promulgate water quality standards.[76] Water quality standards consist of both "designated 'uses' for a body of water (e.g., public water supply, recreation, agriculture) and a set of 'criteria' specifying the maximum concentration of pollutants that may be present in the water without impairing its suitability for designated uses."[77] Although EPA is the NPDES permitting authority in New Hampshire, the state plays a vital role in establishing water quality standards for the Piscataqua River and the Great Bay Estuary.[78]

The designated uses of the Piscataqua River in the vicinity of Schiller include: aquatic life, public water supplies after adequate treatment, fish consumption, primary contact recreation, secondary contact recreation, shellfishing, and wildlife.[79] Unfortunately, this segment of the river is impaired for aquatic life, fish consumption, primary contact recreation, secondary contact recreation and shellfishing.[80]

After application of the most stringent treatment technologies available under the BAT standard, if a discharge causes or contributes, or has the reasonable potential to cause or contribute to a violation of water quality standards, the permitting agency must also include any limits in the NPDES permits necessary to ensure that water quality standards are maintained and not violated.[81] This obligation includes compliance with both narrative and numeric water quality standards.[82]

C. Cooling Water Systems

[75] *Natural Res. Def. Council v. EPA*, 863 F.2d 1420, 1426 (9th Cir. 1988) (quotations omitted); *see also EPA v. Nat'l Crushed Stone Ass'n*, 449 U.S. 64, 74-75 (1980) (if a discharger of pollutants can afford the best available technology, then it must meet, and should not be allowed a variance from, stringent BAT limits).

[76] *See* 33 U.S.C. §§ 1313(a)-(c) (requiring states to adopt water quality standards and requiring EPA to set water quality standards when states fail to do so).

[77] *American Paper Inst. v. EPA*, 996 F.2d 346, 349 (D.C. Cir. 1993); *see* 33 U.S.C. § 1313(c)(2)(A).

[78] *See* New Hampshire R.S.A. §§ 485-A:8 and 485-A:9 (establishing water quality standards for various classes of waters and procedures for classifying water bodies). See also N.H. Code of Admin. Rules Part Env-Wq. 1700 et seq. ("Surface Water Quality Regulations").

[79] *See* New Hampshire R.S.A. §§ 485-A:8(II) (Class B waters "shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies."); *see also* N.H. Code of Admin. Rules Part Env-Wq. 1703.01(c) ("All surface waters shall provide, wherever attainable, for the protection and propagation of fish, shellfish and wildlife, and for recreation in and on the surface waters.").

[80] *See* 2008 Waterbody Report for Lower Piscataqua River-South, available at http://iaspub.epa.gov/tmdl_waters10/attains_waterbody.control?p_au_id=NHEST600031001-02-02&p_cycle=2008&p_state=NH&p_report_type=#attainments (last visited on Jan. 25, 2016).

[81] 40 C.F.R. § 122.44(d). These limits are generally referred to as Water Quality Based Effluent Limits ("WQBELs"). "[T]he permit must contain effluent limits" for any pollutant for which the state determines there is a reasonable potential for the pollutant to cause or contribute to a violation. *Id.* § 122.44(d)(1)(iii); *see also Am. Paper Inst. v. EPA*, 996 F.2d 346, 350 (D.C. Cir. 1993); *Waterkeeper Alliance, Inc. v. EPA*, 399 F.3d 486, 502 (2d. Cir. 2005). New Jersey has incorporated this federal requirement into state law. *See* N.J.S.A. § 58:10A-6(f) ("A permit issued by the department . . . shall require the permittee . . . such further discharge restrictions and safeguards against unauthorized discharge as may be necessary to meet water quality standards. . . .").

[82] 40 C.F.R. § 122.44(d)(1).

Section 316(b) of the CWA requires that the "location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."[83] As with all technology-based standards, dischargers must comply with Section 316(b)'s technology-based effluent limitations immediately, meaning that Schiller should have been brought into compliance long ago. The plant now must be brought into compliance with Section 316(b) "as soon as possible," and, in the interim, must be subject to "interim requirements and dates for their achievement."[84]

In 2004, EPA published regulations designed to implement Section 316(b) at existing power plants like Schiller. Following legal challenges, however, the Second Circuit remanded numerous aspects of the rule to the EPA.[85] The U.S. Supreme Court reviewed the Second Circuit's decision on the limited issue of whether Section 316(b) authorizes EPA to consider costs in relation to benefits.[86] Other aspects of the *Riverkeeper II* decision were not addressed by the Supreme court's review. In response to the Second Circuit's remand of extensive portions of the rule, EPA withdrew the entire regulation for existing facilities so that it could revise the rule to be consistent with the Clean Water Act.[87]

EPA's new CWA § 316(b) regulations became effective on October 14, 2014, setting national requirements under Section 316(b) for cooling water intake structures at existing facilities. For entrainment control, the new regulations are not a significant departure from the site-specific Best Professional Judgement process that controlled BTA determinations in prior decades. The new regulations still require the permit writers to engage in a case-by-case BTA selections, but the new rule specifies five factors that the permit writer must consider in establishing the site-specific entrainment standard:

> (i) Numbers and types of organisms entrained… (ii) Impact of changes in [air] emissions … associated with entrainment technologies; (iii) Land availability inasmuch as it relates to the feasibility of entrainment technology; (iv) Remaining [facility] useful plant life; and (v) Quantified and qualitative social benefits and costs of available entrainment technologies when such information on both benefits and costs is of sufficient rigor to make a decision.[88]

In addition, the Rule provides that the BTA decision "may" also be based on six additional factors "to the extent the applicant submitted information . . . on these factors,"[89] and may also be based on *any* "additional information" requested by the permit writer.[90] The six additional factors are:

> (i) Entrainment impacts on the waterbody; (ii) Thermal discharge impacts; (iii) Credit for reductions in flow associated with the retirement of units occurring

[83] 33 U.S.C. § 1326(b).
[84] 40 C.F.R. § 122.47(a); *see also* 33 U.S.C. § 1311(b).
[85] *See Riverkeeper Inc. v. U.S. Envtl. Prot. Agency* ("*Riverkeeper* II"), 475 F.3d 83 (2d Cir. 2007).
[86] *Entergy Corp. v. Riverkeeper, Inc.*, 556 U.S. 208 (2009).
[87] *See* EPA, National Pollutant Discharge Elimination System—Suspension of Regulations Establishing Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Suspension of Final Rule, 72 Fed. Reg. 37,107 (July 9, 2007).
[88] 40 CFR § 125.98(f)(2).
[89] 40 CFR § 125.98(f)(3).
[90] 40 CFR § 125.98(i).

> within the ten years preceding October 14, 2014; (iv) Impacts on the reliability of energy delivery within the immediate area; (v) Impacts on water consumption; and (vi) Availability of process water, gray water, waste water, reclaimed water, or other waters of appropriate quantity and quality for reuse as cooling water.[91]

The rule provides also that "[t]he weight given to each factor *is within the Director's discretion* based upon the circumstances of each facility."[92]

To control impingement, the new regulations designate a set of "pre-approved" technologies that a facility can implement to satisfy the BTA standard. The regulations also allow a facility to use other technologies to meet the BTA standard if it can show that they will perform sufficiently.[93] Approval of such an alternative technology would require the permit writer to make a site-specific decision. Because the current permit proceeding began prior to October 14, 2014, EPA *may* base its site-specific BTA determination for entrainment on some or all of the factors specified in 40 C.F.R. §§ 125.98(f)(2) and (3), and discussed above. Likewise, EPA has discretion to base the BTA determination for reducing impingement mortality on the BTA standards for impingement mortality at § 125.94(c), in the new regulations.

D. Thermal Discharges

EPA acknowledges that "thermal pollution has long been recognized to cause harm to the structure and function of aquatic ecosystems."[94] Accordingly, the Clean Water Act defines heat as a pollutant subject to technology-based BAT limits.[95] As discussed above, BAT is a stringent standard that relentlessly pursues the elimination of pollution, including thermal pollution.

In addition, states are required to identify waterbodies for which technology-based thermal controls are insufficient "to assure protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife" and impose more stringent "total maximum daily thermal loads" and water quality-based effluent limitations for heat in order to ensure that the receiving water meets water quality criteria.[96]

In New Hampshire, for Class B waters like the Piscataqua River, "[a]ny stream temperature increase associated with the discharge of treated sewage, waste or cooling water, water diversions, or releases shall not be such as to appreciably interfere with the uses assigned to this

[91] *Id.*
[92] 40 CFR § 125.98(f)(3) (emphasis added).
[93] *See* 40 C.F.R. §§ 125.94(c)(6) and (7).
[94] National Pollutant Discharge Elimination System – Cooling Water Intake Structures at Existing Facilities and Phase I Facilities, 76 Fed. Reg. 22174, 22,246 (proposed Apr. 20, 2011).
[95] *See* 33 U.S.C. §§ 1311(b)(2)(F) (requiring that BAT effluent limitations be established for all non-toxic pollutants by 1989), 1362(6) (defining "pollutant" to include heat); *see also* N.J.S.A. § 58:10A-3(n) (defining "pollutant" to include "thermal waste").
[96] 33 U.S.C. § 1313(d) (requiring states to identify bodies of water for which technology-based thermal controls are insufficiently stringent and to impose "total maximum daily thermal loads" to protect these waters); *see also id*. § 1312 (requiring imposition of water quality-based effluent limitations on the discharge of pollutants when necessary to meet water quality standards).

class."[97] The uses assigned to the Piscataqua include "the protection and propagation of fish, shellfish and wildlife . . . ."[98]

Conversely, Section 316(a) of the Clean Water Act also authorizes permitting agencies to issue a variance that lowers the level of thermal pollution control required in a NPDES permit. The variance is only available if the discharger of thermal pollution source is able to demonstrate that the proposed technology-based BAT limitation would be more stringent than necessary to protect a balanced, indigenous population of fish, shellfish and wildlife.[99] In seeking to obtain or to renew such a "thermal discharge variance" under Section 316(a), the *polluter* bears the burden of proving that the alternative limit it seeks will assure protection of a balanced indigenous population of shellfish, fish and wildlife considering the "cumulative impact of its thermal discharge together with all other significant impacts on the species affected."[100] If the polluter does not carry its burden of proof, no variance to BAT limits can be included in the NPDES permit.[101]

A "balanced, indigenous population" is defined by EPA regulations to mean "a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by a lack of domination by pollution tolerant species."[102] To determine what a balanced indigenous population looks like, the permitting authority must consider what species would inhabit the receiving water body if it were not degraded by thermal discharges.[103]

In assessing the impact of a cooling water system on a waterbody, it is important to always compare the current condition of the waterbody with its condition before the cooling water intakes caused appreciable harm, because disruptions to the indigenous ecosystem that occurred decades ago may persist until now – and may still be redressable if the cooling water system is adequately controlled. Thus, for example, in drafting a NPDES permit for the Merrimack power plant in New Hampshire, EPA referred back to a 1979 report on entrainment and impingement because "any adverse effects of [entrainment] upon the indigenous fish community probably would have occurred within the first few years of operation [when] . . . the station may have induced additional mortality upon the parent stock populations, and therefore reduced reproductive potential and subsequent standing crops."[104] Similarly, at Schiller, the relevant comparison point is not the Piscataqua today, but the Piscataqua as it was many decades ago.

---

[97] N.H. R.S.A. § 485-A:8(II).
[98] N.H. Code of Admin. Rules Part Env.-Wq. 1703.01(c).
[99] *See* 33 U.S.C. § 1326(a).
[100] 40 C.F.R. § 125.73(a); *see also* Memorandum from James A. Hanlon, US EPA, to Directors of EPA Regional Water Divisions, regarding Implementation of Clean Water Act Section 316(a) Thermal Variances in NPDES Permits (Review of Existing Requirements) (Oct. 28, 2008), *available at* http://www.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-338.pdf (last visited on Jan. 25, 2016) (emphasizing that polluters have the burden of proof and must support a variance request with cumulative impact analysis) (hereinafter "Hanlon Thermal Memo").
[101] *See* Hanlon Thermal Memo at 2.
[102] 33 U.S.C. § 1326(a)*; see also* 40 C.F.R. §§ 125.58(f), 125.71(c) (both defining a balanced indigenous population in similar terms).
[103] *In re Dominion Energy Brayton Point, L.L.C.*, 12 E.A.D. at 555-58.
[104] *See, e.g.*, EPA Region 1, Clean Water Act NPDES Permitting Determinations for the Thermal Discharge and Cooling Water Intake Structures at Merrimack Station in Bow, New Hampshire (NPDES Permit No. NH 0001465) at 337 (hereinafter "Merrimack Determination").

This focus on restoring the Piscataqua to its historic health implements the Clean Water Act's goal of restoring "the chemical, physical and biological integrity of the Nation's waters."[105]

E. Endangered Species Act Consultation

The new Section 316(b) regulations provide a procedure for ensuring that the cooling water intake requirements of a NPDES permit are protective of threatened and endangered species. The new regulations demand that the permitting agencies "transmit all permit applications for facilities . . . to the appropriate Field Office of the U.S. Fish and Wildlife Service and/or Regional Office of the National Marine Fisheries Service upon receipt for a 60 day review prior to public notice of the draft or proposed permit."[106] In addition, the permitting agency must:

> provide the public notice and an opportunity to comment as required . . and must submit a copy of the fact sheet or statement of basis (for EPA- issued permits), the permit application (if any) and the draft permit (if any) to the appropriate Field Office of the. Fish and Wildlife Service and/or Regional Office of the National Marine Fisheries Service. This includes notice of specific cooling water intake structure requirements at § 124.10(d)(1)(ix) of this chapter, notice of the draft permit, and any specific information the Director has about threatened or endangered species and critical habitat that are or may be present in the action area, including any proposed control measures and monitoring and reporting requirements for such species and habitat.[107]

This procedural element of the new Section 316(b) regulations allow NMFS and FWS the opportunity to identify measures to protect federally-listed threatened and endangered species, which measures the director has the authority to include as enforceable permit terms.[108]

IV

DETAILED COMMENTS

A. EPA Region 1 Should Require Closed-Cycle Cooling or Its Equivalent as Best Technology Available to Reduce Impingement and Entrainment Mortality Caused by Cooling Water Intake Structures.

Sierra Club supports EPA's preliminary determination, reached in 2010, that closed-cycle cooling is the BTA for Schiller.[109] Sierra Club strongly disagrees with EPA's proposed BTA determination in the Draft Permit.

1. Closed-cycle Cooling is the Best Technology Available for Minimizing Entrainment and Impingement of Aquatic Life.

---

[105] 33 U.S.C. § 1251.
[106] 40 C.F.R. § 125.98(h).
[107] *Id.*
[108] 40 C.F.R. 124.94(g).
[109] *See* 2010 Perkins Letter at 5.

The best technology available to minimize the adverse environmental impact of Schiller's cooling water intake structure is to convert Schiller from the existing 125 MGD once-through cooling system to a closed-cycle cooling system that uses just 2.2 MGD of make-up water, which can be sourced as grey water from the Pierce Island WWTP or salt water from the Piscataqua River.[110] By EPA's own reckoning, as well as PSNH's, such a closed-loop system is technically available at Schiller, and it would reduce impingement and entrainment by 97%-100% (depending on saltwater or greywater makeup).[111]

The attached analysis from Petrudev states conservatively, with use of saltwater makeup, that "[e]ntrainment reductions of 95% are expected," meaning 7.3 million ichthyoplankton and 65.5 million macrocrustaceans entrained compared to existing technology which results in 145 million ichthyoplankton and 1.3 billion macrocrustaceans entrained, or a net savings of more than 1.3 billion organisms – at least 137.7 million fish eggs and larvae and 1.235 billion macrocrustaceans, plus reduced impingement.[112] Such a conversion also would eliminate Schiller's thermal pollution of the Piscataqua River.[113]

As noted earlier, these estimates are based on PSNH's baseline entrainment figures and must be adjusted upwards to conform to EPA's baseline entrainment estimate – Sierra Club agrees with EPA's upward adjustment to align with Schiller's design intake flow, and believes that Petrudev's estimates, so adjusted, are consistent with the impingement and entrainment estimates that EPA presents for closed-cycle cooling in the Fact Sheet.

EPA has long been aware that closed-cycle cooling is technically feasible at Schiller and would protect the Piscataqua River's aquatic ecosystem to a far greater degree than any other technology. In 2010, EPA reached a preliminary determination "based on Schiller's October 2008 response, that closed-cycle cooling is the Best Technology Available (BTA) for Schiller Station."[114] Sierra Club strongly supports EPA's preliminary determination and urges EPA to carry this determination forward into a final NPDES permit.

EPA and other permitting authorities rendering their best professional judgment with respect to thermal electrical generating units have determined that the best technology available to minimize adverse environmental impacts requires a reduction in water withdrawals and impingement and entrainment commensurate with that achievable by closed-cycle cooling.[115]

---

[110] Both Powers Engineering and PSNH concur that a sufficient volume of grey water is available at Schiller to serve as make-up water for a closed-cycle cooling system. Use of gray water for cooling has been successfully implemented at a number of facilities nationwide, including the Palo Verde nuclear plant in Arizona and Bergen Station, a natural gas-fired power plant in New Jersey.

[111] *See* Schiller Fact Sheet at 157; 316(b) report at 107.

[112] *See* Petrudev at 6-6. The report also notes that the efficacy of a closed-cycle cooling system "is expected to be slightly lower (<95% reduction) for impingement compared to entrainment since impingement is not likely proportional to flow." *Id.* (citation omitted).

[113] *See id*.

[114] 2010 Perkins Letter at 5.

[115] *See, e.g.*, Notice of Denial: Joint Application for CWA § 401 Water Quality Certification; NRC License Renewal – Entergy Nuclear Indian Point Units 2 and 3, NYS DEC Nos.: 3-5522-00011/00030 (IP2) & 3-5522-00105/00031 (IP3) (N.Y.S. D.E.C. Apr. 2, 2010) (denying water quality certification on grounds that implementation of closed-cycle cooling was necessary to comply with Section 316(b)) [hereinafter "Indian Point Notice of Denial"]; SPDES Fact Sheet Narrative, National Grid – E.F. Barrett Power Station (Oct. 2009) (setting forth New York Department of

Schiller is substantially similar to the facilities for which permitting agencies have required installation of closed-cycle cooling to reduce impingement and entrainment mortality.

For example, at Brayton Point, EPA Region 1 issued (and the EPA's Environmental Appeals Board upheld) a permit provision that "would essentially require closed-cycle cooling for the entire station" as BTA.[116] Like Brayton Point in Fall River, Massachusetts, for which EPA Region 1 required installation of cooling towers pursuant to 316(b), Schiller Station is located in estuarine waters.[117] And absent closed-cycle cooling, both Brayton Point and Schiller entrain more than a billion aquatic organisms every year.[118] EPA determined closed-cycle cooling to be BTA at Brayton Point, and it is likewise BTA here.[119]

More recently, EPA Region 1 has also proposed cooling towers as BTA under Section 316(b) for the Merrimack Station, which like Schiller is located in New Hampshire and owned and operated by PSNH.[120] Merrimack station has two cooling water intake structures allowing for a total intake flow of 287 MGD,[121] which is a little more than double the 124 MGD design flow of Schiller. But despite drawing half as much water, impingement and entrainment levels at Schiller are 420 times higher than at Merrimack (using EPA's baseline figures: 1.59 billion organisms at Schiller, compared to 3.8 million at Merrimack).[122] If cooling towers are warranted to protect aquatic life at Merrimack, they are certainly justified at Schiller.

Likewise, the New York State Department of Environmental Conservation ("DEC") has deemed closed-cycle cooling to be BTA for facilities in New York. E.F. Barrett is a two-unit facility.[123] The receiving water, Barnum's Channel in the Town of Hempstead on the southern shore of Long Island, is also an estuarine waterbody with a diverse finfish community, similar to the Piscataqua.[124] Levels of entrainment are likewise comparable, and indeed are slightly *lower* at E.F. Barrett: 1.2 billion eggs and larvae, as compared to 1.4 billion organisms at Schiller.[125]

Environmental Conservation's determination that closed-cycle cooling is BTA for E.F. Barrett Power Station); New Jersey Department of Environmental Protection, Draft NPDES Permit for Oyster Creek Generating Station (Jan. 7, 2010) (concluding as BPJ that closed-cycle cooling was BTA under § 316(b) for Oyster Creek) [Note that this requirement was modified in the December 21, 2011 final NPDES permit following a December 9, 2010 administrative consent order requiring shutdown of the plant by December 31, 2019]; *see also* EPA, Merrimack Station draft NPDES permit and fact sheet (proposing requirement of closed-cycle cooling as BTA under § 316(b)), *available at* http://www.epa.gov/region1/npdes/merrimackstation/; Mirant Canal Station, Authorization to Discharge Under the National Pollutant Discharge Elimination System at 16 (issued by EPA Region 1 on Aug. 1, 2008) (requiring reductions in entrainment to levels commensurate with closed-cycle cooling).

[116] *See In re Dominion Energy Brayton Point*, 12 E.A.D. at 504, 597-618.

[117] *See id.* at 502.

[118] According to EPA's 2002 case study, Brayton Point's annual average entrainment is 16,703,221,011 organisms and average annual impingement is 44,752. U.S. EPA, Phase II-- Large existing electric generating plants, Proposed Rule - Case Study Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule, Part F, at F3-21, Table F3-10.

[119] As with Schiller Station, thermal discharges were also a significant concern at Brayton Point.

[120] EPA Region 1, Merrimack Station Authorization to Discharge Under the National Pollutant Discharge Elimination System (Permit No. NH 0001465)-Fact Sheet at 4.

[121] Merrimack Determination at ii-iii.

[122] *See id.* at xiv.

[123] SPDES Fact Sheet Narrative, National Grid – E.F. Barrett Power Station (Permit No. 000-5908).

[124] *Id.*

[125] *Id.* at 1-2.

Moreover, in arriving at the conclusion that closed-cycle cooling was BTA, a wide array of alternative control technologies were evaluated, including a number of screening alternatives, an impingement net barrier and variable speed pumps.[126] These are similar and indeed appear to be a more inclusive set of technologies than were evaluated for Schiller. DEC based its determination that BTA was cooling towers on several factors, noting among other things that the technology will reduce entrainment of eggs and larvae "more than any other technology or operational measure available to reduce aquatic impacts."[127] New York DEC also noted the ancillary benefits of abating thermal discharges from the facility, which as described below, are likewise worthy of consideration at Schiller.[128]

New York DEC also required cooling towers as BTA under Section 316(b) for the Indian Point nuclear plant. Indian Point, while a larger facility than Schiller with a higher intake flow rate, nevertheless generates impingement and entrainment impacts comparable to those at Schiller. The aquatic communities around the two plants are similar, with the estuary around the Indian Point facilities serving as a "spawning and nursery ground for important fish and shellfish species, such as striped bass, American shad, Atlantic and shortnose sturgeon, and river herring."[129] Existing controls for Indian Point Units 2 and 3 prior to the 316(b) BTA determination were "modified Ristroph-type traveling screens, fish handling and return systems, and low pressure screenwash systems intended to reduce the number of aquatic organisms injured and killed by being impinged by the facilities' CWISs each year."[130] And, significantly, entrainment levels at Indian Point prior to installation of cooling towers appear to have been directly comparable to those at Schiller, with the Final Environmental Impact Statement indicating that approximately 1.4 to 2.0 billion organisms from the six key species studied were entrained annually.[131]

Elsewhere, the New Jersey Department of Environmental Protection ("NJ DEP") exercised its best professional judgment in requiring cooling towers as BTA in its 2010 draft permit for the Oyster Creek nuclear plant in Forked River, New Jersey.[132] Based on sampling conducted from 2005 to 2007, entrainment at Oyster Creek appears to be comparable to or lower than at Schiller, from approximately 600 million aquatic organisms to 1.35 billion.[133] In reaching its 316(b) determination, NJ DEP evaluated a wide array of alternative control technologies including a number of screening alternatives (including various types of fine mesh screens) as well as optimization of dilution pump operations, and determined that BTA for the facility is closed-cycle cooling.[134] NJ DEP focused on the fact that closed-cycle cooling would reduce water

[126] *Id.* at 2 of 8.
[127] *Id.* at 4 of 8.
[128] *See id.*
[129] Indian Point Notice of Denial at 7-8.
[130] *Id.* at 3.
[131] Final Environmental Impact Statement Concerning the Applications to Renew New York State Pollutant Discharge Elimination System (SPDES) Permits for the Roseton 1 & 2, Bowline 1 & 2, and Indian Point 2 & 3 Steam Electric Generating Stations, Accepted by the New York Department of Environmental Conservation on June 25, 2003, at 2-3 Tables 1 & 2.
[132] Oyster Creek December 2010 Draft Permit, Fact Sheet at 5 (Station withdraws 662.4 MGD for use as non-contact cooling water; station also withdraws water from a separate intake which is mixed with the cooling water to mitigate thermal discharge issues).
[133] *See id.* at 17 (summing entrainment estimates in table).
[134] *See id.* at 10.

intake usage significantly thereby decreasing impingement and entrainment effects and that it is one of the few technologies available to target entrainment effects,[135] which are likewise a significant concern at Schiller.

In sum, these and other similar decision establish that cooling towers are BTA for plants that kill as many organisms as Schiller.

2. Closed-Cycle Cooling Is Economically Justified at Schiller

EPA believes that cooling towers will reduce impingement and entrainment mortality by as much as 97%, while cylindrical wedgewire screens will reduce impingement mortality by 87%, fish entrainment mortality between 37-49% (depending on screen screen-slot size), and macro-crustacean entrainment mortality by 100%. EPA proposed cylindrical wedgewire screens as BTA because EPA believes that wedgewire screens are 40 times less expensive than cooling towers, and that the increased cost of cooling towers is not justified by the increase in benefits.

a. EPA's Approach to Cost-Benefit Analysis is Misguided

EPA has engaged in a comparative cost-benefit analysis of closed-cycle cooling and wedgewire screens that is deeply flawed because EPA engaged in an unsound comparison of the two technologies' cost-effectiveness, rather than actually comparing the costs and benefits offered by each technology

Instead of comparing the net benefits of the two options, EPA compared the benefit-cost ratios of the two competing technologies and found that wedge-wire screens are more cost effective because screens achieve substantial reductions in impingement and entrainment mortality at a cost 40 times less than closed-cycle cooling. EPA concluded "its far greater costs, as compared to the fine-mesh wedgewire screen option, are not warranted by the additional margin of reduction in adverse environmental effects that it could achieve."[136]

This analysis is misguided because it values a technology's cost-effectiveness (i.e., cost per unit of impingement and entrainment reductions), over the maximization of benefits. The Synapse Report explains:

> This is not a logical deduction from the cost ratios and benefit ratios that EPA has presented. Rather, it makes a strong but implicit judgment about the low value of the environmental benefits at stake. Consider two monetary options, with the same cost and benefit profiles identified in this discussion. Plan A requires spending $1 on some protective measure to avoid $100 of damages; Plan B requires spending $40 to avoid $200 of damages. It is true that Plan B costs 40 times as much but saves only twice as much. It is also true that Plan A has a net value of $99 while Plan B has a net value of $160, making the more expensive plan a much better deal.[137]

[135] *Id.* at 25.
[136] Id. at 157.
[137] Synapse Memorandum at 2 (1/14/16).

To be sure, a side-by-side comparison of two technologies' cost-effectiveness is appropriate where the technologies are roughly equivalent in their impingement and entrainment reduction capacity. But where, as here, you have one technology, closed-cycle cooling, that far surpasses the other, wedgewire screens, in its effectiveness, such a comparison does not maximize benefits.

Indeed, EPA itself recognized this concept in the fact sheet associated with the repermitting of the Merimmack power plant. There, EPA explained, an approach that involves "a comparative assessment of the cost per unit of performance by different options" is not helpful "where there are wide disparities in the performance of alternative technologies and those with lower costs-per-unit-of-performance fail to reach some threshold of adequate performance."[138]

Professor Ackerman, the author of the Synapse Report, echos EPA: "In the absence of [cost and benefits] estimates, nothing can be concluded from EPA's examination of relative costs. A "cost-cost" analysis of this type is normally inconclusive, in the absence of hard information about the relevant costs and benefits."[139] Thus, he explains that the way to a logically sound cost-benefit analysis of "the Schiller CWIS options is to estimate actual dollar values for costs and benefits."[140]

In short, EPA's analysis says nothing of whether the higher cost of closed-cycle cooling is justified by its benefits and whether the benefits exceed the net-benefits of wedgewire screens. Therefore, EPA should redo its cost-benefit analysis to focus on which of the BTA options will produce the greatest net benefit to society.

In the Synapse report, Professor Ackerman follows through on the cost-benefit analysis and provides a rough monetized analysis. Synapse uses the cost figures provided by PSNH. And to imperfectly and conservatively monetize the benefits provide by saving an additional 80 million organisms every year through the use of cooling towers rather than wedgewire screens, Synapse relied on monetary valuations of those fish based on econometric research that EPA commissioned in 2012 in support of its national cooling water intake structure regulations. The Synapse report concludes that, even with a very conservative benefits valuation, the fish are worth at least as much as the cost of cooling towers:

> the annual entrainment mortality reduction of 80 million individuals achieved by cooling towers rather than the best wedgewire screen option at Schiller would represent about 370,000 adult equivalents. Using my completion of the EPA willingness to pay survey, this mortality reduction would have a value in 2013 dollars of $1.9 million using EPA's assumptions, or $3.8 - $4.8 million using my preferred versions. The present value of 30 years of entrainment mortality reduction at these rates, using EPA's 5.3 percent real discount rate, is $30 million using the EPA assumptions, or $60 - $75 million using my alternatives. (The discount rate and the 30 year horizon are from the fact sheet, 150.)

[138] *Id.*
[139] *Id.*
[140] *Id.*

> In other words, the monetized value of reduced entrainment mortality is roughly equal to the cost of cooling towers, at the conservative valuation of fish (and additional non-monetized benefits of reduced fish mortality should tip the balance toward cooling towers). At my recommended valuation of fish, the net monetized benefit of cooling towers far exceeds the net benefit of wedgewire screens. There is no basis for EPA's undocumented certainty that the costs of cooling towers are clearly excessive in comparison to the benefits they achieve. Based on a hard look at the missing numbers, EPA should reconsider its decision and declare cooling towers to be BTA at Schiller.[141]

b. EPA Has Relied on PSNH's Vastly Overestimated Capital and O&M Costs

PSNH claims that cooling towers are not available at Schiller because the costs of cooling towers are disproportionate to their benefits. This claim is based on PSNH's own cost estimates, which peg the initial capital cost of cooling towers at between $65.7 and $60.9 million, with ongoing annual costs of $21.3 million.[142] As the attached report from Powers Engineering and Synapse Energy Economics show, these cost estimates are not remotely credible and are out of step with both government and industry cost-estimation models.

Cost estimation methods developed by EPA, cooling tower manufacturers, and the Electric Power Research Institute – the power industry's largest research think tank and lobbying arm – all suggest that capital costs are about half of PSNH's claims.[143] And as the attached report from Synapse Energy Economics concludes, net ongoing annual costs of a retrofit, including any energy penalty would be approximately $1 million, not $21.3 million, as PSNH claims.[144]

c. EPA Has Undervalued The Benefits of Closed-Cycle Cooling by Basing its Calculations on Salt Water Makeup rather than Grey Water, and by Relying on PSNH's Low Estimate of Schiller's Impingement and Entrainment

EPA has undervalued the benefits of closed-cycle cooling in two important ways: 1) EPA improperly compared wedgewire screens to closed-cycle cooling using sea water, rather than grey water, as make-up; and 2) EPA relies on PSNH's unrealistically low impingement estimates and on entrainment sampling that was not properly designed to be representative of natural variation.

[141] *Id.* at 4.

[142] Sierra Club is unsure why EPA considers PSNH's cost estimates to be confidential business information. Despite PSNH's apparent claim that this data is CBI, PSNH's technical studies are in the public domain – they were released to Sierra Club under the Freedom of Information Act years ago. Thus, Sierra Club's comments discuss the actual economic analysis prepared by PSNH and we expect EPA to do the same in responding to comments.

[143] *See* Powers Report at 4 - 6 (establishing estimates under various methodologies ranging from a low of $21 million for a non-plume abated tower using manufacturer figures to, at most, $33.5 million for a plume-abated tower using EPRI methodologies); Synapse Memorandum – Comments on Draft NPDES Permit for Schiller Station at 2 (1/14/16).

[144] *See* Synapse Report at 3 - 5 (estimating annual operating costs of $300 - $530K per year escalating over time, plus energy penalty costs of approximately $500K).

First, EPA's should have compared cylindrical wedgewire screens to cooling towers that rely on gray water as make-up, which would reduce impingement and entrainment by 100%. Instead, EPA compared wedgewire screens to cooling towers that rely on saltwater as makeup, which achieve would reduce impingement and entrainment by 97%. The Fact Sheet makes clear that the Pierce Island Wastewater Treatment Plant would be able to provide sufficient grey water as make-up water if Schiller was retrofitted to closed-cycle cooling and that.[145] EPA concluded that "using grey water for make-up water [is] a potential BTA for minimizing impingement and entrainment if cooling towers are installed."[146] By comparing wedgewire screens to cooling towers with sea water make-up, EPA tipped the analysis in favor of its propose BTA.

Second, PSNH's impingement and entrainment estimates require further adjustment. Sierra Club agrees with EPA's decision to estimate entrainment losses based on the plant's design flow of 124.4 mgd, rather than the plant's 5-year average operating flow Schiller used in its estimates.[147] Further, Sierra Club agrees with EPA decision to estimate entrainment mortality by assuming 100% mortality for entrained larvae, rather than Schiller's unscientific survival rates. However, in determining the best technology available to minimize the significant adverse environmental impacts of Schiller's once-through cooling system, EPA should take into consideration the fact that those environmental impacts are still understated by PSNH, and that PSNH's numeric estimates should be scrutinized. Nevertheless it bears repeating that, by any reasonable standard, even with PSNH's undercounts, EPA's estimates show that Schiller impinges and entrains a significant number of fish and crustaceans – more than 1.7 billion every year.

PSNH attempts to downplay the extremely high impingement and entrainment rates by claiming that only a small fraction of the 1.7 billion impinged and entrained organisms actually die. While EPA properly rejected PSNH's entrainment mortality rates, EPA has wrongly accepted the impingement mortality estimates put forward by PSNH's consultant, Normandeau Associates.

Normandeau's impingement mortality rates are unrealistic and inconsistent with experience elsewhere. Normandeau's estimated impingement mortality rates are calculated based on a 12 hour hold to observe latent mortality, rather than the industry norm of either 24 or 48 hold. Petrudev concluded that Normandeau's decision to report on such a short hold time leads to "survival estimates for both fish and macrocrustacea [that] are not long enough in duration, and therefore may be subject to error."[148]

Further, PSNH's impingement and entrainment numbers do not respond directly to all of the requirements set by EPA, and may not be representative, therefore EPA should act conservatively by treating PSNH's figures as lower-bound estimates. There are at least two problems with the representativeness of PSNH's figures.

---

[145] Schiller Fact Sheet at 145-46.
[146] *Id.*
[147] Schiller Fact Sheet at 93
[148] Petrudev at 3-10.

First, PSNH did not accurately compare entrainment densities with egg and larval densities in the Piscataqua River, as requested by EPA.[149] Second, EPA requested that PSNH establish an entrainment and impingement sampling method that would generate results representative of year to year variations. Normandeau concentrated its sampling in a single 13 month period, creating a narrow five week overlap period in which samples can be compared year-on-year. But as the attached report from Petrudev shows, Normandeau selected a period of low variability and very low entrainment and impingement as the overlap period in which to conduct the year-on-year comparison. This period is not representative of higher periods of impingement, and PSNH's year-on-year comparison does not have a seasonal component. Thus, the five week window cannot be extrapolated out to other times of year and EPA cannot be sure that the sampling results are representative of long run impingement and entrainment rates.[150] In light of the uncertainties that PSNH's sampling methodology creates, EPA should consider PSNH's impingement and entrainment results to be lower-bound estimates.

3. EPA is Not Required to Conduct a Monetized Cost-Benefit Analysis

As the Synapse Report indicates, even a monetized cost-benefit analysis using conservative benefits valuations (i.e. underestimates of benefits) suggests that cooling towers not only provide net benefits, but that they deliver greater net benefits than wedgewire screens. Nonetheless, it is vital to note that monetization of benefits and costs is not required by state or federal law.

At similar power plants, EPA has considered costs and benefits rigorously and quantitatively, but without using questionable monetization techniques. Applied at Schiller, the approaches used by EPA show that the existing once-through cooling system has significant adverse environmental impacts and that the benefits of replacing it with a closed cycle cooling system at Schiller amply justify the costs.

In particular, EPA Region 1 should look to the economic evaluation it conducted at the Merrimack power station as a relevant point of comparison for Schiller. EPA's analytical process, applied to Schiller, shows that closed cycle cooling is both technically feasible and economically sensible.

As noted above, Schiller bears strong similarities to Merrimack, which EPA Region 1 recently determined must install a closed cycle cooling system. Both are PSNH owned and operated. But while Schiller withdraws only half as much water as Merrimack, and therefore is less costly to convert to a closed-cycle system, the plant entrains 300 times more organisms than Merrimack (145 million fish eggs and larvae and 1.3 billion macrocrustaceans at Schiller, compared to 3.8 million fish and eggs at Merrimack). Since EPA concluded that cooling towers are economical at Merrimack, *a fortiori* they are economically justified at Schiller.

At Merrimack, EPA concluded that the cost of retrofitting hybrid wet-dry mechanical draft cooling towers and operating in a closed-cycle mode year-round "would be significant but economically achievable for PSNH" at an "after-tax cash flow cost . . . of $111.8 million, with an annual equivalent cost of $9.0 million (at 5.3 percent over 21 years) on an after-tax, nominal

[149] *See id.* at 3-6.
[150] See *id*. at 3-7; 3-10.

dollar basis (i.e., including the effects of inflation)."[151] EPA found this cost not only affordable, but reasonable in relation to the major reduction in environmental harm that would be achieved by reducing intake and thermal discharge by 95%.[152] Even using PSNH's grossly exaggerated cost estimates, the capital cost of a closed-cycle cooling retrofit at Schiller would be only half that at Merrimack. And as the above referenced reports show, in reality the considerably smaller cooling system needed for Schiller should cost less than a third as much as the Merrimack cooling system, but will deliver significantly greater environmental benefits.

Next, while EPA decided to monetize social costs at Merrimack, the agency chose to compare these costs to benefits "assessed in terms of the number of organisms saved and a qualitative assessment of the public value of the organisms saved and the aquatic habitat improved."[153] EPA considered trying to monetize benefits and conduct an analysis similar to the one that PSNH had submitted at Schiller years ago, but decided it was not possible:

> [T]ranslating the fish eggs, fish larvae, juvenile fish, and adult fish saved by each BTA option, along with the ecological improvements that may accompany these savings, into a dollar value that fully represents the benefit of each BTA option – i.e., developing a monetized benefits estimate – presents a nearly insurmountable task. . . Estimating the monetary value of all these benefits, however, requires specialized data and expertise and is difficult, time-consuming, controversial and expensive. This is especially so with regard to estimating recreational use values and, even more so, for estimating non-use values arising from ecological improvements. All the benefits or values of ecological improvements, such as protecting fish, cannot necessarily be reduced to a money value, or at least reduced to a money value that can be generated with a reasonable effort and that will be generally accepted. Thus, EPA and state permitting authorities have rarely even attempted to develop estimates of the full monetized benefit of saving aquatic organisms by using the BTA under § 316(b). Benefits have, instead, been assessed qualitatively, which is a reasonable, legally acceptable approach.[154]

Instead, in comparison to the $110 million net present value of costs (or less than $10 million annualized cost) for seasonal closed-cycle cooling at Merrimack, EPA found that:

- Entrainment would be reduced by 95%, saving some 3.6 million eggs and larvae annually.[155]
- Impingement mortality would be reduced by 47%, saving some 4,000 fish annually[156]
- These benefits were considerably greater than the benefits offered by any other technology that would entail the continued use of once-through cooling.
- Continued entrainment at existing levels likely would impede recovery of the aquatic communities.[157]

[151] Merrimack Determination at ix.
[152] *See id.* at x.
[153] *Id*. at xv.
[154] *Id*. at 325-326.
[155] *Id*. at 333, Table 12-3.
[156] *Id*.
[157] *Id*. at 335.

- Closed-cycle cooling "would provide an opportunity to restore biological integrity . . . by reducing both thermal discharges and the loss of fish and forage to entrainment and impingement."[158]
- Because some of the species harmed at Merrimack were popular for recreational fishing, "entrainment and impingement losses . . . undermine the value of the water body as a resource for recreational fishing" and interfered with government attempts to restore fish populations in the river.[159]
- Segments of the waterbody affected by Merrimack, both up and downstream of the plant, though not adjacent to it, had been designated for special protection by the state of New Hampshire and reducing fish kills and thermal pollution would contribute to the state's goals.[160]
- There are no significant adverse secondary environmental effects of converting to closed-cycle cooling.[161]

On the basis of this assessment, EPA required a closed-cycle cooling retrofit at Merrimack. Because of the strong similarities between the two plants and the fact that, the Schiller retrofit is cheaper than the Merrimack retrofit and saves hundreds of millions more animals, the BTA determination made by EPA Region 1 for the Merrimack plant provides an excellent point of comparison to Schiller.

B. EPA's Proposed Determination that Cylindrical Wedgewire Screens are the BTA for Schiller is Arbitrary, Capricious, and an Abuse of EPA's Discretion.

Contrary to EPA's finding, cylindrical wedgewire screens are not the best technology available at Schiller. Sierra Club strongly supports EPA's preliminary determination that closed-cycle cooling is the BTA at Schiller and urges EPA to carry it forward into a final NPDES permit.

1. EPA's BTA determination is arbitrary and capricious because it disregards the considerable uncertainty surrounding the effectiveness of wedgewire screens.

Macro-crustacean larvae and eggs make up about 1.3 billion of the roughly 1.59 billion entrained organisms at Schiller (using EPA's adjusted baseline figures). EPA asserts that 100% of formerly entrained macro-crustacean eggs and larvae will avoid the new screens entirely or survive making contact with them. This 100% survival claim drives EPAs conclusions about the relative benefits of wedgewire screens compared to closed-cycle cooling. By assuming that all 1.3 billion formerly-entrained macro-crustacean larvae and eggs survive contact with the new wedgewire system, EPA is able to conclude that 1.47 billion organisms would be saved by wedgewire screens, which is a 92% total reducing in I&E mortality.[162]

Because so much turns on marco-crustacean entrainment survival, EPA's entire BTA analysis is highly sensitive to uncertainty in this survival rate. If EPA has missed the true value of

---

[158] *Id*.
[159] *Id*.
[160] *Id*. at 335-36.
[161] *Id*. at 341.
[162] Schiller Fact Sheet at 153, Table 10-B.

entrainment survival by even 10% (i.e. the true value is a 90% macro-crustacean survival rate), this would equate to a loss of 130 million organisms a year, an 84% total I&E mortality reduction, and a more than doubling of the gap in entrainment survival between cooling towers and wedgewire screens. Thus, even a small degree of uncertainty about macro-crustacean survival dramatically alters EPA's conclusions about the costs and benefits of wedgewire screens relative to cooling towers.

It is therefore disturbing that EPA admits that its estimate of entrainment survival is highly uncertain, but then ignores that uncertainty in its BTA analysis.

EPA's views on the fate of organisms that were formerly entrained but would now come into contact with wedgewire screens differs radically depending on whether the organisms in question are fish or macro-crustaceans. For fish, "[b]ased on EPA's review of various EPRI reports (2003, 2005, 2007), EPA's TDD for the 316(b) rule and our site specific knowledge of the Piscataqua River, EPA estimated egg survival to be 80% and larval survival to be 12%."[163] From this, EPA projects overall fish entrainment mortality reductions of between 37% and 49%, depending on wedgewire screen size.

Sierra Club notes that EPA's TDD, based on the EPRI studies that EPA Region 1 cites as well as other data, note that these are mean survival rates, and that some of the species affected by Schiller may have lower survival rates. And while Sierra Club has not critically reviewed the EPRI studies in question and cannot comment on their quality, in order to derive the 80% egg and 12% larval survival rates, EPA's TDD reviewed multiple lab and field studies. The larger point is that in citing to the TDD and to the studies it is based on, EPA Region 1 is basing its views on survival of formerly-entrained fish larvae and eggs on *something.*

In contrast, EPA's views on macro-crustracean survival rates are based on absolutely *nothing*. EPA states its belief in 100% entrainment survival of formerly-entrained macro-crustaceans that contact wedgewire screens with a 0.5 fps velocity thus: "EPA estimates a 100% reduction in macrocrustacean entrainment mortality on the grounds that these organisms are hearty enough to survive contact with the wedgewire screens."[164] EPA cites no authority or evidence in support of its belief. As far as Sierra Club can tell, none of the studies that EPA cited for fish egg and larvae survival rates say anything about macro-crustacean fish and larvae. The EPA TDD itself, on which EPA Region 1 also relies, makes no specific statements about macro-crustacean eggs and larvae being hardy enough to survive contact with screens. As Region 1 notes, the TDD concludes generally that among all species studied (overwhelmingly if not exclusively fish species) survival of eggs and larvae is poor. The EPRI 2003 and 2005 studies cited by Region 1 are lab and field studies, respectively, that looked only at fish species.[165]

[163] Schiller Fact Sheet at 154.
[164] Schiller Fact Sheet at 154. Sierra Club assumes that EPA means to describe crustacean larvae as hardy (strong, tough), and not hearty (warm, providing abundant nourishment). Sierra Club is concerned, however, that macro-crustacean larvae drawn to or slowed by contact with a screen may end up providing a hearty meal to predators. Thus, Sierra Club disagrees with EPA's assessment of 100% entrainment survival.
[165] Sierra Club was unable to identify the source cited by EPA as EPRI 2007 – there is no EPRI document dated 2007 in either the Fact Sheet Bibliography or the bibliography to Chapter 6 of the TDD.

Sierra Club agrees with EPA that crustaceans are tough critters. But that's not a basis for rulemaking. If anything, the logical implication of the literature is that macro-crustacean survival rates are somewhere between a 100% survival rate and the survival rates for fish egg and larvae.

EPA repeatedly admits that there is "considerable uncertainty" in its estimate of entrainment mortality reduction.[166] EPA starts by noting that it lacks any site-specific evidence of survival rates:

> If egg and larval mortality by entrainment is simply replaced with mortality by impingement, the CWIS's adverse environmental impact will not have been reduced. PSNH's consultants did not, however, evaluate such survival. They only assessed the ability of different screen slot sizes to exclude organisms from being entrained.[167]

EPA then notes that the scientific literature provides little to no help either:

> At present, EPA has insufficient information that directly assesses egg and larval survival after contacting a fine-mesh wedgewire screen. 79 Fed. Reg. 48335-48336, 48435. See id. at 48331. . . .That said, EPA has collected and reviewed some information from the scientific literature . . . This data suggests that under some circumstances (e.g., low intake velocity) the eggs of some fish species, as well as crustacean larvae, may be capable of surviving contact with a fine-mesh wedgewire screen.[168]

There is an enormous and untenable leap between the idea that "under some circumstances . . . crustacean larvae, *may be capable* of surviving contact with a fine mesh wedgewire screen" (*Id.*, emphasis added), and EPA Region 1's conclusion that *all* of the macro-crustacean eggs and larvae will absolutely survive contact with Schiller's wedgewire screen. The gap is too wide. To treat EPA's assumption as correct would be arbitrary, capricious, and a clear abuse of discretion.

EPA admits as much. EPA acknowledges that "[t] here is no way, however, for EPA to estimate with any precision whether, or how many, more eggs and larvae would avoid contact with the proposed wedgewire screens than currently avoid contact with the existing CWISs."[169] And EPA provides no estimate of how many of the formerly excluded eggs and larvae would be impinged, and thus certainly would not survive contact with the screens and associated predation. Overall, EPA acknowledges that "[t]here is unavoidably significant uncertainty regarding these estimated survival rates because there is a dearth of such information for fine-mesh wedgewire screens generally, and no information specifically for the proposed installation of such screens at Schiller Station."[170]

---

[166] Schiller Fact Sheet at 116-117 & 154.
[167] *Id*. at 116.
[168] *Id.* at 116-117-17.
[169] Id. at 154.
[170] *Id.*

In the face of "unavoidably significant uncertainty,"[171] the only thing that is certain is that EPA's estimate of 100% entrainment survival is wrong – there is some error rate separating EPA's estimate and the true value of entrainment survival. And since the true rate cannot be more than 100%, the error in EPA's assumption is a bias that overestimates the effectiveness of wedgewire screens.

But in its BTA analysis, EPA treats its assumption of 100% survival as if it is certain. On the basis of that assumption, EPA concludes that cylindrical wedgewire screens will save just 80 million organisms less than cooling towers (using river water) and thus deliver what EPA considers an acceptable performance at the price, compared to cooling towers.[172] In sum, EPA acknowledges "unavoidable, significant uncertainty," but proceeds to make its calculations and BTA determination as if there were no uncertainty. That is arbitrary, capricious, unreasonable, and an abuse of discretion.

Sierra Club agrees with EPA that macro-crustacean eggs and larvae are sufficiently robust that their survival rate will be at least equivalent to that of fish. Thus, the true survival rate of macro-crustacean eggs and larvae is less than EPA's 100% estimate, and equal to or greater than the 37% to 49% rate of fish egg and larvae survival. But for purposes of the BTA analysis at Schiller, that is an enormous range. Every 1% error in the survival rate equates to a loss of 13 million organisms annually. If EPA were accounting for uncertainty properly, it would provide an estimated value and associated uncertainty (margin of error). And in this case, even a small error destroys the reasoning behind EPA's conclusion that "[the] costs are not in this case warranted for the additional margin of entrainment mortality reduction that closed-cycle cooling could achieve."[173]

2. EPA's Proposed Determination is Facially Arbitrary and Capricious Because it Departs Drastically from the Merrimack BTA.

Set aside, for a moment, every issue that Sierra Club has raised in these comments about inflated cost estimates, underestimated impingement and entrainment, and EPA's disregard for uncertainty. Even assuming that the data presented in the Fact Sheet is entirely correct and completely certain, EPA Region 1's analysis would still be facially arbitrary when compared to EPA's past BTA determinations: EPA is not treating like power plants alike.

As noted previously, this is not EPA Region 1's first BTA determination. EPA Region 1 has determined that closed cycle cooling is the BTA at two other plants: Brayton Point, and Merrimack. A comparison of the situation of the Merrimack plant with the Schiller plant illustrates just how irrational it is for EPA to propose selection of wedgewire screens as BTA.

The Merrimack power plant draws more than twice as much water as Schiller (285 MGD) and thus cooling towers at Merrimack are proportionately more expensive than at Schiller. But as noted above, Schiller kills about 1.596 *billion* organisms annually while Merrimack kills 3.8

[171] *Id.*
[172] *Id.* at 154 & 165.
[173] *Id.* at 157.

million. Schiller kills 420 times more fish than Merrimack.[174] And cooling towers for Schiller would cost less than half as much as they would for Merrimack. Since EPA determined that cooling towers were the BTA to protect aquatic life at Merrimack, they are certainly the BTA at Schiller, where they will save 420 times more fish at half the price.

Powers Engineering's analysis and the EPRI model both suggest that cooling towers at Schiller should cost about 25% - 30% of what they cost at Merrimack (about $25-$30 million at Schiller, vs. $100 to $110 million at Merrimack). Even on PSNH's inflated cost estimate of $60 million, cooling towers at Schiller cost about half what they did at Merrimack. And EPA found spending $100 million on cooling towers to be cost-justified and thus "available" at Merrimack to save about 4 million organisms annually.

Taking all of EPA's figures at face value (i.e. ignoring uncertainty), opting for cooling towers over wedgewire screens at Schiller would save at least 80 million organisms annually. That is, EPA estimates that 1.55 billion organisms would be saved by cooling towers (assuming 96% macro-crustacean egg and larvae survival), while 1.47 billion organisms would be saved by wedgewire screens (assuming – unrealistically - 100% macro-crustacean egg and larvae survival).[175] The difference is 80 million more organisms saved by cooling towers.

So at minimum, making all possible assumptions in favor of wedgewire screens, the question facing EPA is this: since it is worth spending $100 million at Merrimack to save 4 million organisms per year, why isn't it worth spending $25-$60 million to save 80 million organisms per year at Schiller? The only rational answer is yes. EPA's determination that cooling towers are not cost-justified at Schiller is an abuse of discretion.

Note further that if EPA were to use the correct BTA comparison technology - wet cooling towers with grey water makeup - the differential between towers and screens rises further: 1.596 billion organisms would be saved by cooling towers vs. 1.47 billion organisms saved by wedgewire screens,[176] and thus opting for cooling towers over wedgewire screens would save an additional 126 million organisms annually.

For legal purposes, however, the question of whether cooling towers would save 126 million more organisms or "just" 80 million more organisms annually is academic. EPA Region 1 determined – *correctly* –that for the Merrimack power plant, wet cooling towers costing $100 million were the best technology available to save 4 million fish a year. Taking everything EPA writes in the Fact Sheet as correct, taking PSNH's inflated costs estimates at face value, and deciding every uncertainty in favor of wedgewire screens, it is still patently absurd for EPA to turn around after the Merrimack BTA determination and decide – *on the basis of relative costs* – that wet cooling towers costing $60 million or less (on PSNH's inflated estimates) are *too expensive* to be the best technology available to save 80 million organisms per year at Schiller (much less the hundreds of millions that Sierra Club believes will actually be saved).

[174] Merrimack NPDES Permit-Attachment D, at xiv.
[175] *See* Schiller Fact Sheet at 153, Table 10-B.
[176] Again, this uses EPA's considerably uncertain and totally unsupported assumption that wedgewire screens will lead to 100% survival by previously entrained macro-crustacean eggs and larvae.

3. If Cylindrical Wedgewire Screens are Selected as BTA, the Permit Must Contain a Water Withdrawal Limit.

Despite all of the above, Sierra Club understands EPA's interest in exploring the use of cylindrical wedgewire screens in light of the fact that two of Schiller's units have had low capacity factors for several years. EPA notes in [177]the Fact Sheet that these low capacity factors influence its judgment. See Fact Sheet at 158. That influence is understandable.

Sierra Club agrees that if the permit contained both seasonal outages as EPA proposes, <u>and</u> certainty about the current low water-withdrawal rates – which could be achieved through an enforceable permit term controlling the volume of water withdrawals – that the selection of cylindrical wedgewire screens at Schiller would not be an abuse of EPA's discretion. With 0.5mm wedgewire screens, a 0.2 fps through-screen velocity, seasonal outage for maintenance as proposed by EPA, *and* a water withdrawal limit that achieves current or lower capacity factors, Sierra Club believes that impingement and entrainment mortality are likely to decrease to a level *nearly* comparable to a closed-cycle cooling system drawing from the Piscataqua for makeup water.

EPA reached its proposed BTA determination in light of the fact that Schiller's coal burning units "have been operating at relatively low capacity factors," a trend that is expected to continue.[178] But EPA acknowledges that trends such as these may change over time. In order to ensure the level of environmental protection achievable today, the selection of wedgewire screens as BTA should be backstopped by an enforceable water withdrawal limit that would preserve the current low-capacity factor conditions (around 10 percent for Schiller's coal burning units). Without such a limit, the environmental improvements achieved by wedgewire screens would be impermanent, and subject to unpredictable events in the energy markets, the weather, and elsewhere.

4. If EPA Selects Cylindrical Wedge-Wire Screens it should require a screen-slot size of 0.5 mm and a through-slot velocity of 0.2 fps.

The attached Petrudev Report finds that the most effective use of wedge wire screens at Schiller would operate with 0.5 mm slot-size screens, at a velocity of 0.2 fps.[179] If EPA selects wedgewire screens as BTA in the final permit, Sierra Club urges this configuration be required. Petrudev's proposed slot-size of .5 mm is .1 mm narrow than the smallest slot-size under consideration in EPA's proposed BTA determination and will produce commensurate reductions in entrainment.

The lower through-slot velocity will provide greater reductions in larval impingement and entrainment. Studies detailed in the Petrudev report support the conclusion that a 0.2 fps velocity will eliminate juvenile and adult impingement, and substantially reduce entrainment by up to 85-90% - although this does not equate to a similar reduction in entrainment mortality.

---

[177] Schiller Permit Fact Sheet at 158.
[178] *Id.*
[179] Petrudev Report at 6-6 – 6-7.

Petrudev notes that there is significant uncertainty about the survival of formerly entrained organisms that contact or are impinged on the screens.[180]

The uncertainty about survival rates is a further argument in favor of lower velocity. All else being equal, decreasing the through-slot velocity to 0.2 fps will help limit the significant uncertainty inherent in EPA's unsupported assertion that wedgewire screens will lead to a 100% decrease in entrainment mortality of macro-crustacean eggs and larvae. As a general matter, the slower through-screen velocity increases the likelihood that cross-flow and avoidance behaviors will reduce egg and larval screen contact. In Section 6 of their attached report, Petrudev suggests that if wedgewire screens are used, a through-screen velocity reduction from 0.5 fps to 0.2 fps could reduce entrainment (not entrainment mortality) by around 10%, which equates to about 160 million fish and crustacean eggs and larvae annually.[181] Since a significant fraction of that reduction in entrainment due to reduced velocity is due to increased success of avoidance behavior, it is reasonable to assume that a 0.2 fps velocity would actually reduce contact with screens and thus would reduce the uncertainty in EPA's estimate of entrainment mortality.

5. The Permit Should Require Through-screen Velocity Monitoring.

Sierra Club agrees with EPA's proposed BTA requirement that "[t]he permittee shall verify"[182] the through-screen velocity at the wedgewire screen surface. But verification must be done by measurement, not by calculation as EPA proposes to allow.

In light of the significant operational risks associated with the clogging and fouling of wedgewire screens, verification that the screens are operating as designed, with the required through-screen velocity, is a necessity. So that this requirement is more than just an aspiration, Sierra Club proposes that the Permit require continuous through-screen velocity monitoring on each screen as an enforceable term of the permit. Sierra Club recommends that EPA set a reasonable but brief averaging period to allow Schiller to respond to catastrophic blockages of any screen – such as a daily average velocity limit enforceable at each screen.

6. EPA Is Not Even Certain That Cylindrical Wedge-Wire Screens that achieve a consistent through-screen velocity of 0.5 fps are "available" at Schiller, so they cannot be the Best Technology Available.

Both EPA and PSNH have noted that there are serious implementation risks for wedgewire screens, regarding what PSNH describes as "aggressive marine life fouling" environments.[183] These risks are especially significant for the most effective, narrow width slot screen designs that PSNH knows are "highly susceptible to catastrophic blockage from marine life."[184] According to PSNH's report, the smaller slot sizes that are necessary to achieve greater entrainment reductions are acutely vulnerable to clogging: "the surface may foul with finer debris (i.e., algae) at a faster

[180] *Id.* at 6.8.
[181] *Id.* at 6-6 to 6-7 (suggesting that CWWS entrainment reductions of up to 75% may be possible at 0.5 fps, while 85%-90% is attainable at 0.2 fps).
[182] Draft Permit at 16.
[183] 316b report at 83.
[184] *Id.*

than normal rate, even under low velocity (*i.e.*, less than 0.5fps). . . ."[185] Because the Piscataqua River is an impaired waterbody that is experiencing significant eutrophication, Sierra Club is concerned that PSNH will not be able to "avoid heavy algal blooms and similar types of debris," as recommended by the cylindrical wedgewire screen manufacturers that PSNH quoted in its report.[186]

For this reason, a component of EPA's BTA determination is the requirement that PSNH conduct a pilot test and demonstration report on the use of wedgewire screens. PSNH must evaluate multiple screen size options and consider "each option's ability to reduce entrainment mortality, avoid screen clogging, fouling or other maintenance issues."[187]

The study requirements prove that EPA is putting the cart before the horse: EPA is proposing a system of cylindrical wedgewire screens that achieve a through-screen velocity of 0.5 fps as the best technology available **before** first determining whether cylindrical wedgewire screens can actually maintain a consistent through-screen velocity of 0.5 fps. EPA has determined that its chosen technology is the "best available" before ensuring that it is available at all. This is clearly arbitrary, unreasonable, and unlawful. In Sierra Club's view, the solution is to select closed-cycle cooling as BTA.

But if EPA were to rationalize this BTA determination by coupling cylindrical wedgewire screens with a monitored, 0.2 fps velocity limit, enforceable water withdrawal limits, and seasonal outages, as discussed above, Sierra Club believes that the "availability" issue could be overcome: EPA can alter the permit conditions to define the BTA to include closed-cycle cooling as the default practice *unless* the pilot testing shows that 0.5mm wedgewire screens will maintain consistently the desired velocity (which in Sierra Club's view should be 0.2 fps). Sierra Club requests that if EPA persists with the use of wedgewire screens based on studies, that EPA also include closed-cycle cooling as the default alternative and set a procedure for EPA to review the pilot study results and approve or deny the use of screens in place of cooling towers during the permit term.

6. Conclusion on Wedgewire Screens

No screening technology can deliver the entrainment reductions or thermal benefits of a closed-cycle cooling system. Closed-cycle cooling is the only option that meets the BTA standard of *minimizing* (not just reducing) adverse environmental impact. Closed-cycle cooling is the only technology that can provide entrainment reductions of 97% to 100%, nearly comparable impingement reductions, and the complete elimination of thermal discharge into the Piscataqua.

EPA noted that its preliminary determination to require Schiller to install closed-cycle cooling was made "in the absence of any site specific information regarding the 'availability' of

[185] *Id.*
[186] *Id.* at 84. Sierra Club also notes that for a cylindrical wedgewire screen design to function, six 15-foot long cylinders, with appropriate spacing between them, must be installed in an area where New Hampshire hopes to re-establish eelgrass habitat. Is installation of the screens compatible with returning this area to eelgrass habitat?
[187] Schiller Fact Sheet at 167.

wedgewire screens for use at Schiller Station."[188] But information about the availability of wedgewire screens is not relevant – even if they are an available technology, wedgewire screens are not the best technology available. Indeed, EPA has estimated that "closed-cycle cooling can reduce entrainment mortality for fish eggs and larvae by as much as 97%, whereas the wedgewire screen options with the three smallest slot sizes are estimated to reduce such entrainment mortality by 37%, 44% or 49%, respectively."[189] And juvenile endangered sturgeon and salmon may be among the hundreds of millions of eggs and larvae entrained at Schiller. Further, wedgewire screens provide no ancillary thermal benefit to the Piscataqua River. Even under ideal circumstances, wedgewire screens are nowhere near the performance of a closed-cycle cooling system.

C. Schiller Must Convert to a Closed-Cycle Cooling System to Control Thermal Discharges Pursuant to Section 316(a) of the Clean Water Act

1. EPA Region 1 Cannot Renew Schiller's Thermal Discharge Variance because PSNH Has Not Carried its Burden.

PSNH has not carried its burden of proof because it has not submitted a cumulative impacts analysis that evaluates the impact of the proposed alternative heat limits in light of other significant impacts on the protection of a balanced, indigenous population of fish, shellfish and wildlife in the Piscataqua River.

In seeking a 316(a) variance, whether for the first time or upon renewal, the burden rests with a permit applicant to demonstrate that the alternative limits it seeks will assure protection of a balanced indigenous population of shellfish, fish and wildlife considering the "cumulative impact of its thermal discharge together with all other significant impacts on the species affected."[190] At the very least, PSNH must provide enough information about Schiller's past discharges to demonstrate that "no appreciable harm has resulted . . . to a balanced, indigenous community of shellfish, fish and wildlife in and on the body of water," or alternatively, "[t]hat despite the occurrence of such previous harm, the desired alternative effluent limitations . . . will nevertheless assure the protection and propagation of a balanced, indigenous community . . . ."[191]

The cumulative issues PSNH failed to consider are wide-ranging and include existing turbidity and eutrophication in the Piscataqua River, the effect of Schiller's own discharge of suspended solids on eelgrass, the nearby Newington Plant, and the worsening effects of climate change. By failing to consider the cumulative impact of these environmental issues, PSNH has not met its burden of showing that a variance is warranted.

Sierra Club is principally concerned with the failure of PSNH and EPA to consider climate change which stands to exacerbate the thermal loading already occurring in the Piscataqua River. This calls for heightened attention to Schiller's impacts on temperature-sensitive aquatic organisms, particularly eelgrass, and the Piscataqua's ability to sustain a balanced indigenous population of fish and wildlife.

---

[188] *Id.*
[189] Schiller Permit Factsheet at 155.
[190] 40 C.F.R. § 125.73(a); *see also* Hanlon Thermal Memo.
[191] 40 C.F.R. § 125.73(c)(1).

In considering whether to grant alternative thermal discharge effluent limits under Section 316(a) of the Clean Water Act, NPDES permit writers must take account of the "cumulative impact of [] thermal discharge together with all other significant impacts on the species affected."[192] Climate change has and will continue to have a significant impact on many aquatic species. In Section 5.2.2.7 of the 2010 NPDES Permit Writer's Manual, EPA provides the following guidance for permit writers on how to address climate change:

> Climate Change Considerations - Evaluation of requests for variances under CWA section 316(a) requires consideration of the change to the ambient water temperature because of an effluent discharge. The studies provided by applicants to support their requests frequently include historical thermal data for the receiving water. Permitting authorities should be aware that the effects of global climate change could alter the thermal profile of some receiving waters making the historical record of thermal conditions less representative of future conditions. Where appropriate, water quality models should take these potential changes into account.[193]

When evaluating BAT for thermal discharges and considering renewal of the existing Section 316(a) variance at Schiller, EPA must incorporate the anticipated impacts of climate change into its analysis. Petrudev's analysis of Schiller's thermal discharges includes consideration of the effects of climate change. Petrudev points out that "waters in the Piscataqua/Great Bay region are warming and the thermal discharges from Schiller in combination with the higher ambient temperatures is likely to adversely affect fish and macrocrustaceans such as rainbow smelt, Atlantic herring, tautog, Atlantic tomcod, river herring, and American lobster in ways or to an extent not addressed" by PSNH.[194]

Before continuing the variance, EPA must require PSNH to submit a supplemental cumulative impacts analysis addressing, among other impacts, climate change. Since PSNH has not carried its burden to justify a thermal discharge variance, EPA should deny the variance application.[195]

2. Sierra Club Agrees with EPA that, in the Absence of a Thermal Discharge Variance, Schiller Must Convert to a Closed-Cycle Cooling System.

Schiller must comply with BAT standards on thermal pollution.[196] Schiller's once-through cooling system does not represent BAT for reducing or eliminating thermal discharges. Schiller must also meet the applicable water quality standards for the Piscataqua River. Sierra Club agrees with EPA that wet, mechanical draft cooling towers are the best available technology for controlling heat, will assure compliance with water quality standards, and will assure protection of a balanced, indigenous population of fish, shellfish and wildlife in and on the Piscataqua

[192] 40 CFR § 125.73(a).
[193] EPA, EPA-833-K-10-001, NPDES PERMIT WRITER'S MANUAL § 5.2.27 (2010)
[194] Petrudev Report at 5-3.
[195] Or, at the very least, EPA should order PSNH to complete a supplemental cumulative impacts analysis and only extend the variance until that analysis is complete.
[196] *See* 33 U.S.C. §§ 1311(b)(2)(F) (requiring that BAT effluent limitations be established for all non-toxic pollutants by 1989), 1362(6) (defining "pollutant" to include heat).

River. Because, as noted above, a 316(a) variance at Schiller is not warranted, Schiller should install cooling towers to comply with Section 301 (BAT) standards on thermal pollution.

D. Protection for Endangered Species

1. EPA Should Require Closed-Cycle Cooling System to Protect Endangered Species and Their Habitat.

As noted above, Schiller is located along a reach of the Piscataqua River in which three endangered species of fish are found: Atlantic sturgeon, shortnose sturgeon, and Atlantic salmon. PSNH's failure to detect these species in its limited sampling is not surprising. Endangered species are, by definition, rare. And after reviewing Normandeau's sampling protocol, Petrudev concludes that "[t]he entrainment sampling design for Schiller was not robust enough for periods of high entrainment . . . [and] was not designed to detect species of low abundance such as ESA listed species found in the Piscataqua River."[197] As discussed above, both EPA and NMFS have recognized that all three endangered species are present in the Piscataqua and may use the river, the upstream Salmon and Cocheco rivers, and the larger Great and Little Bay Estuaries for spawning and rearing – or in the case of the Atlantic sturgeon, they may do so again if the species recovers.

Under Section 9 of the Endangered Species Act, PSNH is strictly prohibited from killing, harming, or destroying these animals, from adversely modifying designated critical habitat, or from adversely affecting any habitat in a way that jeopardizes the recovery of these species.[198] Further, the Piscataqua could soon be designated a critical habitat under the Endangered Species Act. The National Marine Fisheries service has not yet designated critical habitat for the Atlantic sturgeon, but is legally obligated to do so and the designation is overdue. Historically, the Great and Little Bay Estuaries and the Piscataqua were an important breeding habitat for the sturgeon. Thus, Schiller may soon be located in – and may soon adversely modify – designated critical Atlantic sturgeon habitat.

Finally, Sierra Club notes that the sturgeon and salmon species discussed above are only a subset of the species evaluated by EPA (headquarters) in its Biological Evaluation of the new Section 316(b) regulations. In the Biological Evaluation prepared by EPA for those rules, EPA reported to the Fish and Wildlife Services and the National Marine Fisheries Service that the following additional species also have habitat range that overlaps with Schiller's cooling water intake: loggerhead turtles; green sea turtles; leatherback turtles; kemp's ridley turtle; hawksbill turtles; piping plover; atlantic least tern; and roseate terns. To Sierra Club's knowledge, EPA has not considered the impact of Schiller's intake system (including loss of prey species) on these endangered species.

EPA cannot authorize PSNH to continue to operate a once-through cooling system that takes endangered individuals, jeopardizes the recovery of the species, and adversely modifies vital

[197] Petrudev report at 3-1.
[198] *See* 16 U.S.C. §§ 1538-39.

habitat for juvenile sturgeon and salmon.[199] The most viable measure to protect both shortnose and Atlantic sturgeon is to convert Schiller to a closed-cycle cooling system. Closed cycle cooling is technically and economically feasible. And short of a complete plant shutdown, there is no other option that will offer as much protection to these species. Closed-cycle cooling system is the only viable alternative that reduces the risk of sturgeon and salmon mortality "to the maximum extent practicable" as required by the Endangered Species Act, 16 U.S.C. § 1539.

2. Schiller Must Consult with FWS and NMFS Regarding Impacts to Endangered Species.

There is no indication in the administrative record that EPA has complied with the new 316(b) regulations by providing to NMFS or FWS a copy of PSNH's NPDES application, the draft permit, the permit fact sheet, and "any specific information the Director has about threatened or endangered species and critical habitat that are or may be present in the action area."[200] Likewise it is unclear whether EPA has afforded NMFS a 60-day period to review those materials. If NMFS and FWS have not had an early opportunity to comment on the draft permit, EPA has violated the requirements of its own regulations and deprived itself of the chance to receive expert feedback that could substantively alter the permit's endangered species protections.

Sierra Club requests that all correspondence between EPA and the Services be included in the administrative record and made public immediately.

E. EPA Has Failed to Consider Unpermitted Discharges Associated with Schiller's Leaking Coal Ash Landfill.

For thirty years, the Schiller landfill was a receptacle for harmful industrial waste streams, including fly ash, a byproduct of burning coal known to contain heavy metals and other toxic pollutants. EPA has failed to consider evidence that Schiller's coal ash landfill is leaking, that a contaminated groundwater plume has migrated beyond the perimeter of the landfill, and has likely already traveled the short distance to the Piscataqua River and caused surface water pollution. Despite infrequent monitoring (and Sierra Club proposes that the permit be revised to require at least quarterly groundwater monitoring), high levels of manganese above standards have been detected in the groundwater. There is no place for the contaminated groundwater plume to go but towards the Piscataqua River, and the plume has had decades to travel there. These discharges are not authorized under the current SPDES permit and, as such, constitute violations of Sections 301 and 402 of the Clean Water Act.[201] EPA must thoroughly study the unpermitted discharge, and address it accordingly in the final Schiller permit.

---

[199] *See Strahan v. Coxe*, 127 F.3d 155, 163 (1st Cir. 1997) (government agency violates ESA if private actions that are regulated and specifically authorized by government result in take of listed species).

[200] 40 C.F.R. § 125.98(h).

[201] 33 U.S.C. §§ 1311(a) ("Except as in compliance with this section and sections 1312, 1316, 1317, 1328, 1342, and 1344 of this title, the discharge of any pollutant by any person shall be unlawful."), 1342. *See also Dague v. City of Burlington*, 935 F.2d 1343, 1354-55 (2d Cir. 1991) (discharge of pollution into groundwater is subject to regulation under the Clean Water Act if the groundwater is "directly hydrologically connected" to waters of the United States), *rev'd in part on other grounds* (award of attorney's fees), 505 U.S. 557); *New York*

EPA should not renew the permit without considering the possibility of ongoing unpermitted discharges.

V.

CONCLUSION

In light of these considerations, Sierra Club respectfully asks that EPA:

- follow through on its initial BTA determination by requiring Schiller to reduce adverse environmental impacts to a degree consistent with the performance of a closed-cycle cooling system. By requiring the use of closed-cycle cooling, EPA will also reduce thermal pollution in the Piscataqua, protect impaired eelgrass habitat, and offer much-needed protections for endangered populations of sturgeon and salmon.

- deny the application for a thermal discharge variance;

- complete the endangered species consultation process contemplated by federal regulations, and then ensure protection of endangered species by requiring use of a closed-cycle cooling system; and

- further investigate the extent of unpermitted discharges from the Schiller coal ash landfill and require that these discharges stop (since the best available technology for a landfill is not to leak).

On behalf of Sierra Club, thank you for your consideration and we look forward to EPA's response.

Very truly yours,

Edan Rotenberg
Super Law Group, LLC
411 State Street, Suite 2R
Brooklyn, New York 11217
edan@superlawgroup.com
(212) 242-2355

---

v. United States, 620 F. Supp. 374, 381 (E.D.N.Y.1985) (a citizen suit may be brought where a discharge to groundwater threatens to contaminate navigable waters).

Exhibit 1

Powers Engineering Report

Declaration on Feasibility and Cost-Effectiveness of Cooling Tower Retrofit at Schiller Station

Bill Powers, P.E.
June 24, 2013

I was requested by the Sierra Club to evaluate the technical feasibility and cost of a closed-cycle cooling system retrofit to the Schiller Station in Portsmouth, New Hampshire. I am a mechanical engineer and consultant on environmental and energy matters. I have owned and operated Powers Engineering for about 19 years. While at Powers Engineering I have carried-out cooling system retrofit evaluations for coal plants, nuclear plants, and natural gas combined cycle plants. I have also prepared sections on combined cycle power plant air emission controls and air cooling systems for Electric Power Research Institute (EPRI) guidance documents.

I graduated from Duke University with a B.S. in mechanical engineering in 1978 and obtained a master's degree in public health (environmental science) from the University of North Carolina at Chapel Hill in 1981. My clients include industry, government, and public interest groups. My resume is provided as **Attachment A** to this declaration.

I. Summary

Closed-cycle cooling is the most effective alternative for minimizing the adverse environmental impact of the cooling water intake structures at the Schiller Station in Portsmouth, New Hampshire. It would be technically feasible and cost-effective to retrofit Schiller Station to closed-cycle cooling to reduce cooling water demand by approximately 95 percent using salt water and 97.5 percent using treated fresh water.[1] Use of treated grey water from the City of Portsmouth's Peirce Island Wastewater Treatment Plant as the closed-cycle cooling makeup water supply would eliminate cooling water withdrawals at Schiller Station. There is adequate space at Schiller station for a cooling tower at a location close to the powerhouse, between the railroad tracks and the coal pile drainage pond. This site was identified by Schiller Station as the preferred location for a cooling tower.

Schiller Station consultant Enercon prepared an estimate of the capital cost and energy penalty of a retrofit plume-abated cooling tower for Schiller Units 4, 5 and 6. Enercon estimates the cost of retrofit plume-abated cooling tower for these units at $372/kW. This is approximately double the cost of independent estimates that range from $174/kW (Powers Engineering) to $201/kW (EPRI).

Enercon overestimates the impact of a cooling tower retrofit on Schiller Station electrical output by at least a factor of 30 relative to independent estimates. One reason for this overestimate appears to be Enercon's failure to account for the effect that warmer Piscataqua River temperatures have in summer months on reducing Schiller Station output.

---

[1] EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, March 28, 2011, p. 2-19. "To better reflect the advances in cooling tower design, EPA now estimates that freshwater cooling towers and saltwater cooling towers reduce impingement mortality and entrainment by 97.5 percent and 94.9 percent, respectively."

II. Size and Cost of Cooling Tower for Schiller Station

Schiller Station is located along the Piscataqua River in Portsmouth, New Hampshire. Schiller Station consists of two 48 MW coal-fired (primary) or fuel oil-fired (backup) units, Units 4 and 6, 48 MW wood-fired (primary) or coal-fired (backup) Unit 5, and one 19 MW combustion turbine. Units 4, 5, and 6 began commercial operation in the 1950s. The capacity factor of Schiller Station was 58 percent in 2009, and 52 percent in 2010.[2]

Units 4, 5, and 6 employ once-through cooling systems with a total withdrawal when operating at full capacity of: Unit 4 - 28,200 gallons per minute (gpm); Unit 5 – 29,000 gpm; and Unit 6 – 29,000 gpm. This is a total of 86,200 gpm of once-through cooling water for Units 4, 5, and 6.[3] Brackish water is withdrawn from the Lower Piscataqua River. The estimated design heat rejection rate of the once-through Schiller Station cooling system is 759 MMBtu/hr.[4,5]

Schiller Station is located in an urban environment, as shown in Figure 1. For this reason a plume-abated cooling tower is likely to be necessary.

Figure 1. Land use in the vicinity of the Schiller Station

---

[2] Synapse Energy Economics, *Economic Analysis of Schiller Station Coal Units*, July 27, 2011, p.5.

[3] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 44.

[4] EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002, p. 5-7. See: http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase2/devdoc_index.cfm.

[5] The design once-through cooling flow at Schiller Station is 86,200 gpm. EPA estimates that 44 percent of heat input to a coal- or wood-fired unit must be rejected by the cooling system. Units 4 and 6 have a design heat input = 574 MMBtu/hr, Unit 5 = 575 MMBtu/hr (see "New Hampshire Department of Environmental Services, *(Air) Permit Application Summary – PSNH Schiller Station , AFS #3301500012*, November 25, 2009, p. 1"). The estimated quantity of heat that must rejected by the Unit 4 and 6 cooling systems (each) is: 0.44 × 574 MMBtu = 253 MMBtu/hr. Assuming the design heat rejection rate for 48 MW Unit 5 is the same as the design heat reject rate for 48 MW Unit 4 and 48 MW Unit 6, the combined cooling system heat rejection rate would be: 3 × 253 MMBtu/hr = 759 MMBtu/hr.

A retrofit to closed-cycle cooling reduces consumptive water use compared to once-through cooling by approximately 95 percent using salt water and 97.5 percent using treated grey water.[6] A closed-cycle cooling retrofit achieves similar reductions in fish larvae entrainment impacts, and large reductions in fish impingement impacts as well.[7]

A cooling tower retrofit at Schiller Station would reduce the design cooling water flow rate from 86,200 gpm to 75,900 gpm.[8] A small amount of the cooling tower circulating water flow, about 1.5 to 2 percent, will evaporate in the tower and must be replenished by a make-up water source. A small amount of water must also be continuously discharged from the cooling tower to prevent excessive build-up of solids in the circulating water.

Six (6) 48 feet by 54.5 feet plume-abated cooling tower cells would be utilized in an inline configuration on the Schiller Station site. The proposed location of the cooling tower, between the railroad tracks and the coal pile drainage pond, was identified by Schiller Station as the preferred location for the cooling tower.[9] The cooling tower location is shown in Figure 2.

Figure 2. Six-cell plume-abated inline cooling tower at Schiller Station

[6] Ibid.
[7] TetraTech, *California's Coastal Power Plants: Alternative Cooling System Analysis*, Chapter 4 – Closed-Cycle Cooling Systems, February 2008, p. 4-8.
[8] The amount of heat that must be removed from the cooling water of Schiller Station, operating at rated capacity, is approximately 759×10^6 Btu/hr. One Btu is the amount of heat input that increased the temperature of one pound of water by 1 ^oF. The circulating cooling water in the cooling tower design assumed in this document will increase 20 ^oF in temperature as flows through the surface condenser tubes while the boiler steam is condensed to water on the exterior surface of the tubes and is circulated back into the boiler. The amount of circulating water needed to remove this heat from Units 4-6 is: $(759 \times 10^6$ Btu/hr$) \div (20$ Btu/lb $H_2O) = 38 \times 10^6$ lb/hr H_2O. There are 8.34 lb of fresh water per gallon. $(38 \times 10^6$ lb/hr $H_2O) \div 8.34$ lb H_2O/gallon = 4,556,000 gallons/hr. In gallons per minute (gpm), the required cooling tower circulating water flowrate is: 4,556,000 gallons/hr ÷ 60 minutes/hr = 75,900 gpm. Assuming the same design cooling tower circulating cooling water flow for 48 MW Unit 5, the cooling tower flow rate per unit would be: 75,900 gpm ÷ 3 = 25,300 gpm.
[9] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 45.

The design specifications, footprint, and cost estimate for a large plume-abated cooling tower, from which the size and cost estimates for the Schiller cooling tower are derived is provided in **Attachment B**.

SPX Thermal Systems, the largest cooling tower manufacturer in the U.S., provided the generic cooling tower specifications and cost estimates. SPX identified the total estimated installed cost of a generic 66-cell, 830,000 gpm plume-abated back-to-back salt water cooling tower, with design approach temperature of 12 °F and range of 20 °F, as \$115.6 million + 3 × \$38.6 million = \$231.4 million. The total number of plume-abated salt water cooling tower cells, based on the SPX specification, would be 66 cells x (75,900 gpm/830,000 gpm) = 6.0 cells. A relatively narrow cooling tower site between the railroad tracks and the coal pile drainage pond, sufficiently wide for an inline cooling tower, has been identified as the preferred cooling tower site by Schiller Station. The dimensions of a 1 × 6 cell plume-abated inline salt water cooling tower would be 54.5 feet by 288 feet.

The capital cost of a greenfield (new construction) 6-cell plume-abated salt water cooling tower would be 9.1 percent of the 66-cell tower cost, assuming linear cost relationship.[10] The cost of a plume-abated 6-cell tower, with 12 °F approach temperature and 20 °F range, would be: \$231.4 million × (6 cells/66 cells) = \$21 million.[11]

Design cooling tower approach temperature ranges from 8 to 15 °F.[12] Approach temperature is a measure of how close in °F the temperature of the circulating water that has passed through the cooling tower cell approaches the ambient wet bulb temperature at design conditions. In general, warmer, more humid conditions lead to lower approach temperatures in the southeastern U.S. and cooler, drier climates lead to higher approach temperatures in the northern and western regions.[13] Holding other performance requirements constant, a lower approach temperature translates into a larger cooling tower.[14]

PSNH consultant Enercon identifies an 8 °F approach temperature as the optimum balance between performance, and size, initial cost, and operating costs for a retrofit cooling tower at

---

[10] 6 cells ÷ 66 cells = 0.091 (9.1%)

[11] See **Attachment B**. Total estimated installed cost of 66-cell, 830,000 gpm plumed-abated SPX Clear Skies™ salt water cooling tower, with design approach temperature of 12 °F and range of 20 °F, is \$115.6 million + 3 × \$38.6 million = \$231.4 million. This is a unit cost of: \$231.4 million ÷ 830,00 gpm = \$279/gpm. The cost of a plume-abated back-to-back salt water 6-cell tower, with 12 °F approach temperature and 20 °F range, would be \$231.4 million x (6 cells/66 cells) = ~\$21 million.

[12] J. Maulbetsch, *Comparison of Alternate Cooling Technologies for California Power Plants - Economic, Environmental and Other Tradeoffs,* CEC Consultant Report, February 2002, pp. 2-8 and 2-9. "Tower approach, $T_{\text{cold water}} - T_{\text{ambient wet bulb}}$: 8 to 15 °F. In general, warmer, more humid conditions lead to lower approach temperatures in the southeastern U.S. and cooler, drier climates lead to higher ones in the northern and western regions."

[13] Ibid.

[14] Enercon Service, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, Figure 5.2, p. 41. A cooling tower with an 8 °F approach temperature would have a size factor of 1.7. A cooling tower with an 12 °F approach temperature would have a size factor of 1.3. The cooling tower with the 8 °F approach temperature would be about 30 percent larger (1.7/1.3 = 1.308) than the cooling tower with a 12 °F approach temperature.

Schiller Station.[15] However, Enercon identified a 12 ^{o}F approach temperature as the optimum balance between performance, and size, initial cost, and operating costs in the retrofit cooling tower analysis that Enercon prepared for the Indian Point Energy Center north of New York City.[16] The retrofit cooling tower evaluated by Powers Engineering for Schiller Station also uses a 12 ^{o}F design approach temperature.

There are additional costs associated with retrofitting an existing plant. Retrofit-related expenses are estimated by the EPA to typically add about 20 percent to the cost of a cooling tower installation.[17] In this instance, 20 percent in additional retrofit expenses would be in the range of $3 million for the conventional back-to-back salt water cooling tower and $4 million for the plume-abated back-to-back salt water cooling tower. Therefore, the total cost of retrofitting Schiller with a plume-abated salt water cooling tower would be approximately: $21 million + $4 million = $25 million.

The Electric Power Research Institute (EPRI) has developed a cost estimation model for retrofit cooling towers that was referenced by the EPA in its draft March 2011 316(b) Phase II Technical Development Document (TDD) for existing once-through cooled power plants. EPRI members include electric utilities and power generation companies.[18]. For the specific-example of Schiller station, assuming use of a 6-cell plume-abated cooling tower serving Units 4, 5, and 6 with a circulating cooling tower flow rate of 75,900 gpm, the EPRI model estimates a cooling tower capital cost of approximately $29 million.[19]

The EPRI cooling tower cost estimation methodology is generic in nature and does not distinguish between fresh water and salt water cooling towers. Enercon evaluated a 4-cell plume-abated cooling tower for Schiller Station. Enercon assumed no reduction in circulating cooling water flow rate between the current once-through cooled flowrate of 87,600 gpm and a closed cycle cooling configuration. Using the EPRI cost calculation procedure, the Enercon cooling tower capital cost would be approximately $33.5 million.[20]

---

[15] Ibid, p. 40. "The 8 ^{o}F approach design point is considered the optimum trade-off between total capacity and performance, size, initial cost and operating costs."

[16] Enercon Services, Inc., *Conversion of Indian Point Units 2 & 3 to a Closed-Loop Cooling Water Configuration*, prepared for Entergy Indian Point Nuclear 2 & 3, February 2010. *Attachment 1: Economic and Environmental Impacts Associated with Conversion of Indian Point Units 2 and 3 to a Closed-Loop Condenser Cooling Water Configuration*, June 2003 Report, p. 23. "Since the 88°F condenser inlet water will only occur at maximum ambient conditions, and the wet section fan parasitic losses occur continuously, the 12°F approach tower design point was considered the optimum trade-off between total capacity and performance, and size, initial cost, and operating costs."

[17] EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002, p. 2-33. "Additional Cooling Tower Retrofit Scaling Factor: 20 percent."

[18] EPRI "Our Members" webpage: http://www.epri.com/About-Us/Pages/Our-Members.aspx.

[19] U.S. EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, March 28, 2011, Exhibit 8-6, p. 8-18. Capital cost of retrofit plume-abated cooling tower = $263/gpm (conventional tower base case) + $120/gpm (plume-abatement adder). Circulating cooling tower flow rate is 75,900 gpm. Therefore capital cost of plume-abated cooling tower = ($383/gpm) × 75,900 gpm = $29,069,700. Capital cost of conventional cooling tower = ($263/gpm) × 75,900 gpm = $19,961,700.

[20] Ibid. ($383/gpm) × 87,600 gpm = $33,550,300.

Units 4, 5, and 6 at Schiller Station have a total capacity of 144 MW (144,000 kW). A standard measure of unit capital cost in the electric power industry is “\$/kW”. In the case of the Schiller Station, the unit capital cost of a \$25 million plume-abated salt water cooling tower retrofit would be: ($\$25 \times 10^6$) ÷ 144,000 kW = \$174/kW. If plume-abated was not required and a conventional cooling tower could be used at Schiller Station, the estimated capital cost for the conventional cooling tower would be \$118/kW.[21]

The estimated plume-abated cooling tower retrofit cost of \$174/kW, and \$118/kW for a conventional cooling tower alternative, is consistent with available government and industry retrofit cooling tower cost estimates.

The unit cost of a plume-abated back-to-back cooling tower at Schiller Station using the EPRI model estimate would be \$201/kW.[22] The unit cost of a conventional back-to-back cooling tower at Schiller Station using the EPRI model estimate would be \$139/kW.[23]

The accuracy of preliminary engineering cost estimates is typically in the range of ± 30 percent.[24] The retrofit cooling tower cost based on the generic SPX manufacturer’s cost estimate, adjusted to reflect the additional cost of a retrofit installation, is within 30 percent of the EPRI retrofit cooling tower cost estimation model.

A comprehensive analysis of cooling tower retrofit costs at eleven coastal boiler plants in California determined a retrofit cost range of \$88/kW to \$151/kW for conventional cooling towers.[25] The one plume-abated cooling tower retrofit included in the study had a projected capital cost of \$200/kW.[26] SPX estimates that a plume-abated cooling tower is about 50 percent higher cost than a conventional cooling tower.[27] By way of comparison, the owner of 4,000 MW

---

[21] See **Attachment B**, SPX Thermal Equipment & Services, *Nuclear Plant Retrofit Comparison for Powers Engineering*, June 9, 2009. Unit cost of a 66-cell, 830,000 gpm plumed-abated SPX Clear Skies™ salt water cooling tower: \$231.4 million ÷ 830,000 gpm = \$279/gpm. The capital cost estimate for the equivalent conventional salt water cooling tower, consisting of 60 cells and an 830,000 gpm flow rate, is: \$38.6 million + 3 × \$38.6 million = \$154.4 million. This is a unit cost of: \$154.4 million ÷ 830,000 gpm = \$186/gpm. The cooling tower flow rate at Schiller is 75,900 gpm. The capital cost of a conventional cooling tower at Schiller, assuming a 20% retrofit adder, would be: \$186/gpm ×75,900 gpm × 1.20 = \$16.94 million. The unit capital cost would be: \$16.94 million ÷ 144,000 kW = \$118/kW.

[22] \$29 million ÷ 144,000 kW = \$201.4 /kW.

[23] \$20.0 million ÷ 144,000 kW = \$138.9 /kW.

[24] U.S. EPA, *EPA Air Pollution Control Cost Manual 6th Edition, Chapter 2 - Cost Estimation: Concepts and Methodology*, January 2002, p. 2-3. “The costs and estimating methodology in this Manual are directed toward the “study” estimate with a nominal accuracy of ± 30% percent. According to Perry’s Chemical Engineer’s Handbook, a study estimate is “… used to estimate the economic feasibility of a project before expending significant funds for piloting, marketing, land surveys, and acquisition … [However] it can be prepared at relatively low cost with minimum data.”

[25] TetraTech, *California’s Coastal Power Plants: Alternative Cooling System Analysis*, February 2008. The cost of a conventional cooling tower retrofit at one plant, Pittsburg Power Plant in the Bay Area, was an outlier at \$193/kW. The reason for the higher cost at this plant is the relatively high expense of the circulating water piping due to the distance, approximately 4,000 feet, from the boilers to the cooling towers.

[26] Ibid. Scattergood Power Plant adjacent to LAX would utilize a conservatively-designed plume-abated cooling tower, with an approach temperature of 12 °F and a range of approximately 18 °F, at a projected cost of \$200/kW.

[27] Attachment B. Plume-abated cooling is 50 percent higher cost than conventional cooling tower for same application: \$231.4 million/\$154.4 million = 1.50 (50 percent higher cost).

of coastal California boiler plant capacity, AES Corporation, independently estimated an average cooling tower retrofit cost range of $115/kW to $125/kW.[28]

This compares to the Schiller Station retrofit cooling tower capital cost estimate of $53.6 million for a plume-abated salt water cooling tower and $48.5 million for a plume-abated grey water cooling tower.[29] This translates into a unit capital of $372/kW for the plume-abated salt water cooling tower and $337/kW for the plume-abated grey water cooling tower.[30] These high costs are estimated despite Schiller Station consultant Enercon's statement that it has located a suitable, easy to develop cooling tower site near the powerhouse that will minimize the length of new pipe runs to and from the cooling tower.[31]

A comparison of Powers Engineering, EPRI, and Enercon capital cost estimates for plume-abated salt water cooling tower at Schiller Station is provided in Table 1.

Table 1. Comparison of Capital Cost Estimates for Plume-Abated Salt Water Cooling Tower at Schiller Station

Source of estimate	Plume-abated cooling tower unit capital cost ($/kW)
Powers Engineering, based on SPX generic plume-abated cooling tower cost estimate and EPA retrofit cost adder	174
EPRI	201
Schiller Station estimate	372

III. Cooling Tower Energy Penalty

A mechanical draft cooling tower retrofit introduces an energy penalty consisting of: 1) slightly reduced power output due to the higher backpressure on the steam turbine caused by the incrementally higher cooling water temperature (relative to once-through cooling), 2) extra

[28] California Energy Commission, Workshop transcript for *2009 Integrated Energy Policy Report - Options for Maintaining Electric System Reliability*, May 11, 2009, p. 108: http://www.energy.ca.gov/2009_energypolicy/documents/2009-05-11_workshop/2009-05-11_Transcript.pdf. "MR. PENDERGRAFT: Hello. Eric Pendergraft with AES. . . a rough ballpark for wet cooling at our sites it's approximately $125 or $115 a kilowatt. So for our 4,000 megawatts you're looking at, you know, 500 million dollars, half a billion dollars to retrofit with wet cooling." (Powers Engineering note – The AES fleet-wide retrofit cooling tower cost estimate is presumptively for conventional cooling towers.)

[29] Enercon Service, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 50.

[30] Plume-abated salt water cooling tower = $53.6 million ÷ 144,000 kW = $372.2 /kW. Plume-abated grey water cooling tower = $48.5 million ÷ 144,000 kW = $336.8 /kW.

[31] Ibid, p. 45. "The evaluated cooling tower location is south of the plant between the railroad track and the coal pile runoff basin. This location would provide adequate space, be relatively close to the Station powerhouse (minimizing the required length of circulating water piping and associated pumping losses), and require minimal earthwork to be suitable for the tower erection."

pumping power needed to pump cooling water through the cooling tower, and 3) electricity demand of the large diameter fans in each cooling tower cell.

A. Steam Turbine Efficiency Penalty Imposed by Conversion to Closed-Cycle Cooling

The estimated annual average turbine efficiency penalty for a retrofit cooling tower at Schiller Station is approximately 0.2 percent. This estimate is based on detailed efficiency penalty analyses for two coal-fired plants. The first is the Powers Engineering analysis of the turbine efficiency penalty that would be incurred by retrofitting 235 MW coal-fired Danskammer Unit 4 to a plume-abated wet cooling tower.[32] This analysis is included as **Attachment C** to this report. Danskammer Unit 4 is cooled with water from the Hudson River. The second analysis was conducted on the retrofit cooling tower at the 346 MW coal-fired Jeffries Generating Station in South Carolina.[33]

The coal-fired Danskammer Unit 4 cooling tower retrofit analysis assumed use of a plume-abated cooling tower with a 13 ºF approach temperature and 20 ºF range. The annual average turbine efficiency penalty of the cooling tower relative to the existing once through cooling configuration was calculated by Powers Engineering to be approximately 0.2 percent. The peak turbine efficiency penalty was calculated to be approximately 1.5 percent.[34]

The reason for the small annual average turbine efficiency penalty at Danskammer is that the Hudson River increases to over 80 ºF in summer, which increases backpressure on the turbine. This same phenomenon also occurs at Schiller Station. Surface condenser cooling water inlet temperatures as high as 82 ^{o}F have been recorded at Schiller Station.[35] Normandeau Associates has measured mid-August water temperatures in the Piscataqua River in front of Schiller Station over 78 ^{o}F.[36]

A detailed efficiency penalty study was conducted by the U.S. Army Corps of Engineers on the 346 MW Jeffries Generating Station. The Corps of Engineers identified the annual average turbine efficiency penalty of the Jefferies Generating Station cooling tower retrofit, using a cooling tower with a design 10 ºF approach temperature, as 0.16 percent. The peak efficiency penalty was calculated to be 0.90 percent. The EPA has summarized the Corps of Engineers study, stating:

---

[32] William Powers, P.E., *Rebuttal Testimony on Behalf of Petitioners Riverkeeper, Inc., Scenic Hudson Inc. and Natural Resources Defense Council, Inc., NYDEC - In The Matter of a Renewal and Modification of a State Pollutant Discharge Elimination System ("SPDES") Permit SPDES No. NY-0006262 by Dynegy Northeast Generation, Inc., on Behalf of Dynegy Danskammer, LLC* (Danskammer Generating Station), November 7, 2005, Exhibit 11.

[33] EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002, p. 5-34 ("2002 Phase II TDD"). See: http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/phase2/upload/2009_03_26_316b_phase2_devdoc_ph2toc.pdf

[34] Ibid.

[35] Enercon Service, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 51.

[36] Normandeau Associates, *letter to Allen Parker, PSNH – Thermal Data Requested by EPA Region 1 Regarding Schiller Station NPDES Permit Reissuance*, October 22, 2010, Table 4, p. 5. Maximum water temperature, 60 feet offshore, period August 15 – September 14, 2010 = 25.6 ^{o}C.(78.1 ^{o}F).

> “The Jefferies Generating Station – a 346 MW, coal-fired plant in South Carolina – owned by Santee Cooper, conducted a turbine efficiency loss study in the late 1980s. The study lasted several years (1985 to 1990). The efficiency penalties determined by Santee Cooper were a maximum of 0.97 percent of plant capacity (for both units, combined) and an annual average of 0.16 percent for the year 1988. The Agency notes that its fossil-fuel estimate for the national-average, peak-summer, turbine energy penalty is 0.90 percent and the mean-annual, national-average energy penalty is 0.35 percent (at 100 percent of maximum load).”
>
> “The Agency contacted Santee Cooper to learn about the cooling system conversions at Jefferies (Henderson, 2002). The Charleston District of the U.S. Army Corps of Engineers paid for the construction of the tower system (a common, mechanical-draft, concrete cooling tower unit for both units with a design approach of 10 ºF and a range of 19 ºF) because of the re-diversion of the Santee Cooper River.”[37]

Enercon errs in its analysis of the steam turbine penalty imposed by closed cycle cooling by assuming a basecase where the once-through cooled units are always operating at an ideal design backpressure of 1.5 inches mercury (Hg).[38] For Schiller Units 4, 5, and 6, a backpressure of 1.5 inches Hg is achieved at a river water temperature of about 60 ^{o}F.[39] However, as Enercon states, the water temperature at the inlet(s) to the surface condenser(s) at Schiller Station can be as high as 82 ^{o}F.[40] Enercon does not account for the substantial performance penalty of high inlet water temperature that affects the existing once-through cooled system in calculating the steam turbine efficiency penalty for a cooling tower retrofit. As a result, the Enercon steam turbine efficiency penalty estimates range from a factor of 30× high on Unit 4 to nearly a factor of 100× high on Units 5 and 6 compared to the 0.2 percent annual retrofit cooling tower steam turbine efficiency penalties determined for Jeffries Generating Station and Danskammer.[41]

Steam passing through the steam turbine must be condensed back to water to prior to return to the boiler. This condensation takes place on the outer surface of the surface condenser. Circulating cooling water flows inside the condenser tubes. Steam condensation temperature is driven by three values: 1) the cold water temperature entering the surface condenser, 2) the cooling water temperature rise across the surface condenser, and 3) the “terminal temperature difference – TTD,” which is the different between the surface condenser outlet warm water temperature and the steam condensation temperature on the outer surface of the condenser tubes.

A typical mid-range TTD would be 7 ^{o}F.[42] Enercon proposes no change in the surface condenser circulating cooling water flowrate between the existing once-through cooled configuration and

---

[37] Ibid, p. 4-2.
[38] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 51.
[39] Ibid, Appendix 3, Tables 3-1, 3-2, and 3-3, pp. 4-5.
[40] Ibid, p. 51.
[41] Ibid, Attachment 3, Tables 3-2, 3-3, and 3-4. Average steam turbine efficiency penalty on Unit 4 = 3.2 MW (6.7%); on Unit 5 = 9.5 MW (19.8%); on Unit 6 = 9.2 MW (19.2%). Annual average stream turbine efficiency penalty determined for Jeffries Generating Station and Danskammer was approximately 0.2% (~0.1 MW).
[42] California Energy Commission, *Performance, Cost, and Environmental Effects of Saltwater Cooling Towers,* January 2010, p. 10. “Condenser terminal temperature difference (TTD), $T_{cond} – T_h$: 6 ^{o}F to 8 ^{o}F.”

the retrofit cooling tower configuration.[43] Enercon identifies the design temperature rise across the surface condenser for the retrofit cooling tower as 19 ^oF.[44] As noted, Enercon identifies the maximum inlet cold water temperature entering the surface condensers at Schiller Station is 82 ^oF.[45] Therefore the maximum steam condensation temperature of the existing once through cooling configuration is: 82 ^oF + 19 ^oF + 7 ^oF = 108 ^oF. A 108 ^oF steam condensation temperature is equivalent to a steam turbine backpressure of approximately 2.5 inches Hg.[46]

The retrofit cooling tower proposed by Enercon will produce an almost identical worst case summer steam turbine backpressure as the existing once-through cooled system. The design wet bulb temperature for Schiller Station is 75 ^oF.[47] Enercon proposes a conservatively designed retrofit cooling tower with an approach temperature of 8 ^oF. The design range is 19 ^oF. The assumed condenser TTD would be the same as it is for the once-though cooled basecase, 7 ^oF. Therefore, at summer design conditions, the steam condensation temperature of the retrofit cooling tower proposed by Enercon would be: 75 ^oF + 8 ^oF + 19 ^oF + 7 ^oF = 109 ^oF. A 109 ^oF steam condensation temperature is equivalent to a steam turbine backpressure of approximately 2.5 inches Hg.[48]

There is almost no difference in the steam turbine backpressure at worst case conditions between the existing once through cooling system at Schiller Station and the retrofit cooling tower proposed by Enercon. This result contradicts Enercon's claim that a retrofit cooling tower retrofit would result in very high steam turbine backpressure efficiency losses on Schiller Station Units 4, 5, and 6.

B. Closed-Cycle Cooling Pump and Fan Power Demand

The 6-cell plume-abated cooling tower for Units 4, 5, and 6 will use 250 horsepower (hp) fan motors.[49] The cooling tower will be located at an elevation of approximately 5 feet.[50] It is assumed for calculation purposes that the cooling tower booster pumps will be necessary only to meet the cooling tower hydraulic head requirement of 35 feet.[51,52] The cooling tower circulating

---

[43] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 42 and p. 44.
[44] Ibid, p. 42.
[45] Ibid, p. 51.
[46] R. Sonntag, G. Van Wylen, *Introduction to Thermodynamics: Classical and Statistical*, 1971, Table B.1.1 – Saturated Steam: Temperature Table, p. 739.
[47] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 42. Powers Engineering comment - Enercon adds a 2 ^oF performance penalty for cooling tower recirculation at p. 42, with no basis or explanation. The retrofit cooling tower configuration proposed by Enercon will be inline and short (4 active cells), an ideal configuration to avoid any significant recirculation..
[48] R. Sonntag, G. Van Wylen, *Introduction to Thermodynamics: Classical and Statistical*, 1971, Table B.1.1 – Saturated Steam: Temperature Table, p. 739.
[49] P. Lindahl - SPX, e-mail to B. Powers of Powers Engineering regarding fan horsepower requirement - ClearSky™ plume-abated cooling tower, November 18, 2011. .
[50] Enercon Service, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, p. 45.
[51] Ibid, p. 44. "... any of the above (cooling tower) configurations would require significantly increased pump head to pump the circulating water up to the elevated cooling tower spray headers and dry heat exchanger coils and overcome the significant internal flow resistance of the cooling tower. As the existing circulating water pumps are

water flowate is 75,900 gpm. The combined rated capacity of Units 4, 5, and 6 is 144 MW (144,000 kW). The calculated fan energy penalty and booster pump energy penalty for the 6-cell plume-abated cooling tower for Units 4, 5, and 6 are provided in Table 2.

Table 2. Pump and Fan Power Penalty for 6-Cell Cooling Tower at Schiller Station[53,54]

Fan power energy (%)	Pump power energy (%)	Total pump and fan power energy (%)
0.77	0.44	1.21

The estimated cooling tower pump and fan energy penalty for the 6-cell plume abated cooling tower evaluated by Powers Engineering would be 1.2 percent.

Although Enercon correctly identifies a reasonably accurate plume-abated tower booster pump head requirement of 36 to 40 feet, Enercon incorrectly uses a booster pump head requirement of 85 feet when calculating a booster pump horsepower requirement of 900 hp. Three booster pumps would be utilized. The booster pump horsepower requirement is 370 hp when the correct pump head requirement of 35 feet is used.[55]

C. Total Annual Average Energy Penalty for Cooling Tower Retrofit

The total annual average energy penalty for the plume-abated cooling tower, including the 0.2 percent average steam turbine efficiency penalty, would be: 1.2 percent + 0.2 percent = 1.4 percent.

IV. Closed-Cycle Cooling Retrofits Have Been Performed on a Number of U.S. Power Plants

The U.S. EPA reviewed closed-cycle cooling retrofits performed at a number of U.S. power plants in the 316b Phase II TDD the agency prepared for existing facilities rule in 2002. The results of the EPA review are summarized in Table 3.[56] In early 2003, subsequent to the

---

designed for 28 feet of head, the new (cooling tower) booster pumps would be required to produce approximately 36 to 40 feet of head."

52 P. Lindahl - SPX, e-mail to B. Powers of Powers Engineering regarding pump head requirement - ClearSky™ plume-abated cooling tower, June 14, 2011. "A large back-to-back (plume-abated) tower might be about 35 ft. of H_2O pump head."

53 Fan load: 6 × 250 hp × (0.746 kW/hp) = 1,112 kW (1.11 MW). Therefore fan penalty = 1.11 MW/144 MW = 0.0077 (0.77 percent).

54 Pump efficiency is assumed to be 80 percent at design point, per Attachment 1, Section 2 "Circulating Water Pumps" to Enercon Service, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth*, *New Hampshire*, submitted by Public Service of New Hampshire, October 2008. Booster pump load = (gpm × head)/(3,960 × η) = 75,900 gpm × 35 feet)/(3,960 × 0.80) = 838 hp. 838 hp × (0.746 kW/hp) = 625 kW (0.63 MW). Therefore booster pump penalty = 0.63 MW/144 MW = 0.0043 (0.44 percent).

55 This assumes a pump effiency of 70 percent. When 80 percent design point pump efficiency is used, consistent with the design point pump efficiency for circulating water pumps in use at Schiller Station, the booster pump horsepower requirement drops from 370 hp to 324 hp.

56 U.S. EPA, *Technical Development Document (TDD) for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002. Chapter 4, *Cooling System Conversions at Existing Facilities*, p. 4-5 and p. 4-6.

publication of the 2002 316(b) TDD, cost information became available for the Plant Yates cooling tower conversion in Georgia.[57] This information is also provided in Table 3.

It is important to note that the Plant Yates cooling tower is very conservatively designed, with an approach temperature of 6 ^{o}F.[58] A cooling tower with a 6 ^{o}F approach temperature would be about 60 percent larger than a cooling with a 12 ^{o}F approach temperature in the same application.[59]

Table 3. Cost of Closed-Cycle Retrofits at Selected U.S. Sites

Site	MW	Flowrate (gpm)	Cost of Retrofit[a]		
			($MM)	($/kW)	($/gpm)
Palisades Nuclear	800	410,000	55.9	70	136
Pittsburg Unit 7	751	352,000	34.4	46	98
Yates Units 1-5	550	460,000	83.0	151	180
Canadys Station	490		Not available		
Jeffries Station	346		Not available[c]		

a) Retrofit costs for Palisades Nuclear and Pittsburg Unit 7 are in 1999 dollars. Yates 1-5 cooling tower cost is in 2002 dollars.
b) The U.S. Army Corps of Engineers (COE) paid for the cooling tower retrofit and owns the cooling towers. COE diversion of river water was the reason that the retrofit needed to be carried-out.

In addition, two retrofit natural draft hyperbolic cooling towers were completed at the 1,500 MW Brayton Point Station coal- and gas-fired power plant near Fall River, Massachusetts in 2012.[60] These cooling towers have a design circulating water flow rate of 400,000 gpm (each).[61] The cooling towers are 500 feet tall and 406 feet in diameter at the base.[62] A photograph of the cooling towers at Brayton Point Station is provided in Figure 3. Brayton Point is the most recent example of cooling towers being retrofit at an existing coal-fired power plant.

[57] T. Cheek - Geosyntec Consultants, Inc. and B. Evans – Georgia Power Company, *Thermal Load, Dissolved Oxygen, and Assimilative Capacity: Is 316(a) Becoming Irrelevant? – The Georgia Power Experience*, presentation to the EPRI Workshop on Advanced Thermal Electric Cooling Technologies, July 8, 2008, p. 18. Installed cost = $83 million.
[58] D. Houlihan – EPA Region 1, *Phone Memorandum – Conversion of Two Coal-Fired Power Plants Located (sic) Owned by Georgia Power*, January 7, 2003.
[59] SPX Cooling Technologies, *Cooling Tower Performance - Basic Theory and Practice*, 1986, p. 5.
[60] EastBayRI.com, *Brayton Point towers picking up steam*, October 25, 2011. See: http://www.eastbayri.com/news/2011/oct/25/brayton-point-towers-picking-steam/.
[61] U.S. EPA Fact Sheet, *Dominion Energy Brayton Point, LLC Closed Cycle Cooling Tower and Unit 3 Dry Scrubber/Fabric Filter Projects*, p. 6. See: http://www.epa.gov/region1/communities/pdf/braytonpoint/FactSheet.pdf
[62] Fall River (MA) Herald News, *Brayton Point's twin 500-foot cooling towers taking shape*, September 1, 2009.

Figure 3. Natural Draft Hyperbolic Cooling Towers at Brayton Point Station[63]

V. Operational Plume-Abated Cooling Towers at U.S. Power Plants

Plume-abated cooling towers, both inline and back-to-back, are in commercial use in the U.S. Photos of operational inline and back-to-back plume-abated cooling towers, and a ClearSky™ plume-abated cooling tower cell in operation in New Mexico, are provided in Figure 4.

Figure 4. Examples of Operational U.S. Plume-Abated Cooling Towers[64,65,66]

Metcalf Energy Center, San Jose, CA

PSEG Bethlehem, Albany, NY

Bergen Generating Station, New Jersey

ClearSky™ cell, New Mexico (far left)

---

[63] See Brayton Point webpage: https://www.dom.com/about/stations/fossil/brayton-point-power-station.jsp.
[64] Power Magazine, *Bethlehem Energy Center, Glenmont, New York*, August 15, 2006.
[65] Bergen Station photo – Google Earth. Text added by B. Powers, Powers Engineering.
[66] P. Lindahl, K. Mortensen – SPX Cooling Technologies, *Plume Abatement – The Next Generation*, Cooling Technologies Institute Journal, Vol. 31, No. 2, Summer 2010, pp. 8-23.

Multiple cooling tower manufacturers make inline plume-abated cooling towers. ClearSky™ is a recent plume-abated cooling tower option developed by SPX and designed to reduce the operations and maintenance complexities of plume-abated inline cooling towers, either in inline or back-to-back configurations.

VI. Examples of Cooling Tower Retrofit Construction Issues

It is not uncommon to encounter some construction challenges during a cooling tower retrofit. It is for this reason that a cost premium is assumed for a retrofit compared to new construction. Some of the cooling tower retrofits listed in Table 3 encountered space limitations and all retrofits incorporated to a degree some components of the existing once-through cooling system. A brief description of the details of each of the closed-cycle retrofits examined by the EPA is provided in Table 4.[67]

Table 4. Issues Encountered on U.S. Closed-Cycle Cooling Retrofits

Site	Issues
Pittsburg Unit 7	Cooling towers replaced spray canal system. Towers constructed on narrow strip of land between canals, no modifications to condenser. Hookup time not reported.
Yates Units 1-5	Back-to-back 2×20 cell cooling tower. 1,050 feet long, 92 feet wide, 60 feet tall. Design approach is 6 ^{o}F. Cooling tower return pipes discharge into existing intake tunnels. Circulating pumps replaced with units capable of overcoming head loss in cooling tower. Condenser water boxes reinforced to withstand higher system hydraulic pressure. Existing discharge tunnels blocked. New concrete pipes connect to discharge tunnels and transport warm water to cooling tower.
Canadys Station	Distance from condensers to towers ranges from 650 to 1,700 feet. No modifications to condensers. Hookup completed in 4 weeks.
Jefferies Station	Distance from condensers to wet towers is 1,700 feet. No modifications to condensers. Two small booster pumps added. Hookup completed in 1 week.

VII. Closed-Cycle Retrofits Do Not Require Extended Unscheduled Outages

Much of the work related to a closed-cycle retrofit can be carried out while the power generation units are online. Hook-up of the cooling tower requires an outage. The duration of the two retrofits for which detailed information is available, Canadys and Jefferies Station, was four weeks or less. The Yates Unit 1-5 conversion was accomplished without any additional outage time for the retrofit. However, the retrofit was apparently carried out during a time of low power demand when Units 1-5 can be offline for extended periods without impacting the dispatch schedule of the plant.[68]

[67] U.S. EPA, *Technical Development Document (TDD) for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002. Chapter 4, "Cooling System Conversions at Existing Facilities."

[68] EPA Region 1, memorandums on conversion of Yates Plant Units 1-5 to closed-cycle cooling, January and February 2003.

The EPA establishes one month as a reasonable and conservative outage time period for a coal-fired plant retrofit cooling tower hook-up in the 2002 316(b) Phase II TDD, stating:[69]

> p. 4-6: Based on the information provided to the Agency (including the late Palisades submission), the estimate of one-month could in some cases over- and others under-estimate the expected outage duration for a cooling system conversion.
>
> p. 4-6, p. 4-7: The Agency also consulted a detailed historical proposal for a Roseton Generating Station cooling system conversion (Central Hudson Gas & Electric, 1977). The report estimates a gross outage period of one-month for the final pipe connections for the recirculating system. The report estimates the net outage as 10 days for one of the two units and no downtime for the second. The reason given for the short estimates of downtime is the coincidence of the connection process with planned winter maintenance outages. Unlike the projection in the 1999 DEIS described above, this 1977 projection was accompanied by a relatively detailed description of the expected level of effort and engineering expectations for connecting the recirculating system to existing equipment.
>
> p. 4-9: "The Agency located a reference for a project where four condenser waterboxes and tube bundles were removed and replaced at a large nuclear plant (Arkansas Nuclear One). The full project lasted approximately 2 days. The facility, based on experience, had estimated the full condenser replacement to occur over the course of 8 days. Even though the scope of condenser replacements differ from potential cooling system conversions, the regulatory options considered for flow reduction commensurate with wet cooling anticipate that a subset of conversions would precipitate condenser tube replacements. As such, the condenser replacement schedule is important to the consideration of select cooling system conversions."
>
> p. 2-19: "The Agency estimates for the flow-reduction regulatory options considered that the typical process of adjoining the recirculating system to the existing condenser unit and the refurbishment of the existing condenser (when necessary) would last approximately two months. Because the Agency analyzed flexible compliance dates (extended over a five-year compliance period), the Agency estimated that plants under the flow reduction regulatory options could plan the cooling system conversion to coincide with periodic scheduled outages, as was the case for the example cases.

In the 2011 draft 316b Phase II TDD, the EPA estimates a net four weeks of outage for a cooling tower hook-up.[70]

The 12-week outage time per cooling tower projected by Enercon for cooling tower conversions at Schiller Station is not credible in light of actual outage times where such conversions have occurred.[71] Also, the capacity factor of Schiller Station in recent years has averaged in the range

[69] U.S. EPA, *Technical Development Document (TDD) for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002.
[70] U.S. EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, March 28, 2011, pp. 8-26 and 8-27.
[71] Enercon Services, Inc., *Response to the U.S. EPA CWA Section 308 Letter, PSNH Schiller Station, Portsmouth, New Hampshire*, submitted by Public Service of New Hampshire, October 2008, pp. 53-54.

of 50 percent. Schiller is not operating continuously in baseload duty. This means that, in addition to coordinating a cooling tower hook-up with the scheduled annual maintenance outage, Schiller has the option to schedule the cooling tower hook-up during periods of the year when low usage is anticipated.[72]

VIII. Economic Impact of Retrofit Cooling Tower Energy Penalty

The total annual energy efficiency penalty of a cooling tower retrofit at Schiller Station would be 1.4 percent. The 2010 capacity factor of Schiller Station was 50 percent. Therefore, the amount of electricity not available for offsite sale as a result of the cooling tower retrofit, assuming the 2011 actual capacity factor, would be:

Electricity not available for offsite sale = 0.014 × 0.50 × 144 MW × 8,760 hr/yr = 8,830 MWh

Assume the average 2012 wholesale price of electricity in the New England Independent System Operator control area was $36/MWh.[73] Therefore, lost power sales opportunity associated with closed-cycle cooling at Schiller Station = 8,830 MWh × $36/MWh = $317,880/yr.

IX. Closed-Cycle Cooling Will Not Increase Air Emissions Significantly

The switch from once-through cooling to closed-cycle cooling will cause a very minor loss in electricity production efficiency, approximately 1.4 percent on average. Output would thus be reduced by about 2 MW at rated capacity as a result of the conversion to a cooling tower at 144 MW Schiller Station.[74] If this 2 MW is generated by a natural gas-fired combined-cycle plant, the annual NO_x and PM_{10} emissions from this output would be a modest 0.3 tons per year and 0.2 tons per year, respectively, assuming a 50 percent plant capacity factor for Schiller Station.[75,76]

---

[72] Synapse Energy Economics, *Economic Analysis of Schiller Station Coal Units*, July 27, 2011, p. 5. "Schiller units 4 and 6 were run far less frequently in 2009 and 2010 as compared to 2008, as shown by capacity factors of 83% in 2008, 58% in 2009, and 52% in 2010."

[73] New England Independent System Operator , *Press Release - 2012 Wholesale Electricity Prices in New England Fell to Lowest Level Since 2003*, January 23, 2013.

[74] For example, the measured annual efficiency penalty at the 346 MW Jeffries Station in South Carolina – which converted its cooling system to a mechanical-draft system after many years of operation utilizing a once-through system – is 0.16%. The cooling tower pump and fan energy demand for steam plants is estimated by EPA at 0.73%. Thus, the total energy penalty (the sum of those two numbers) would be approximately 0.9%. See: U.S. EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule*, April 2002, Chapter 5, Sections 5.6.1 to 5.6.3, pp. 5-34 to 5-36. In fact, there is a similar loss in efficiency when power plants stacks are fitted with baghouses or scrubbers and other equipment to reduce $PM_{2.5}$, NO_x and SO_2.

[75] California Air Resources Board, *Guidance for the Permitting of Electric Generation Technologies*, Stationary Source Division, July 2002, p. 9 (NO_x emission factor = 0.07 lb/MW-hr combined-cycle plants). Replacement power NO_x emissions: 8,760 hr/yr × 0.50 × 2 MW × (0.07 lb/MW-hr ÷ 2,000 lb/ton) = 0.3 tons/yr.

[76] San Diego County Air Pollution Control District (APCD), Otay Mesa Power Project (air-cooled combined cycle plant), Authority To Construct 973881, 18 lb/hr particulate without duct firing (510 MW output), equals ~ 0.04 lb/MW-hr. Replacement power particulate emissions: 8,760 hr/yr × 0.50 × 2 MW × (0.04 lb/MW-hr ÷ 2,000 lb/ton) = 0.2 tons/yr.

X. Use of Treated Effluent for Cooling Water Makeup for Schiller Would Eliminate Cooling Water Withdrawals from the Lower Piscataqua River

Using grey water for cooling water makeup at power plants using closed-cycle has been successfully accomplished in many locations. The 3,800 MW Palo Verde nuclear plant in Arizona is the largest nuclear power plant in the U.S. and uses grey water as the makeup cooling water supply. All three Palo Verde units utilize water from the Phoenix Municipal Waste Treatment System, which is processed, treated, and stored in a makeup water supply lake onsite.[77] Bergen Station, a natural gas-fired power plant in New Jersey formerly withdrew 400 million mgd of river water through its once-through cooling system. Bergen Station has eliminated those withdrawals, and all entrainment and impingement, by retrofitting with a plume abated closed-cycle cooling tower and running a pipeline under the river to a sewage treatment plant from which it draws treated effluent for makeup cooling water supply.[78]

The City of Portmouth's Peirce Island Wastewater Treatment Plant discharges an average of 2.7 million gallons per day (excluding wet weather flows) to the Lower Piscataqua River and is located about 2 miles downstream of Schiller Station.[79] Assuming a maximum 2 percent makeup water flow rate for a retrofit cooling tower at Schiller Station, the makeup water requirement would be: 75,900 gpm × 0.02 × 60 min/hr × 24 hr/day = 2.2 million gallons per day. There is more than sufficient grey water capacity at the Peirce Island Wastewater Treatment Plant to meet the makeup water requirements of a retrofit cooling tower(s) at Schiller Station.

Supplying Schiller Station with 2.2 million gallons per day of make-up water from the Peirce Island Wastewater Treatment Plant would require a dedicated pipeline of no more than 12 inches diameter.[80] The capital cost of 12-inch diameter, 2-mile pipeline from the Peirce Island Wastewater Treatment Plant to Schiller Station, assuming construction in a mix of rock and soil in an urban setting, would be approximately one million dollars.[81]

XI. Conclusion

A closed-cycle cooling system is the most effective alternative available to minimize the adverse environmental impact of the Schiller Station's intake structure. It would be technically feasible and cost-effective to retrofit Schiller Station to closed-cycle cooling. There is adequate space between the railroad tracks and the coal pile drainage pond for the cooling tower(s). Use of treated grey water as the closed-cycle cooling makeup water supply would eliminate cooling water withdrawals from the Piscataqua River for Schiller Station.

---

[77] http://www.nucleartourist.com/us/pvngs.htm

[78] http://www.bcua.org/WPC_VT_WasteWaterReUse.htm

[79] Brown and Caldwell, *City of Portsmouth, New Hampshire Wastewater Master Plan*, June 12, 2008. Table 3-38, p. 50. 2010 average annual sanitary flow at Peirce Island WWT = 2.68 mgd.

[80] A 2.2 million gallon per day make-up water flowrate is equivalent to a flowrate of 3.4 cubic feet per second. The velocity of a 3.4 cubic feet per second flowrate through a 12-inch diameter pipeline = 4.3 feet per second.

[81] HDR, Inc., *2011 South Central Texas Regional Water Plan, Volume II, Appendix A Cost Estimation Procedures South Central Texas Region*, September 2010, p. 6. Cost per foot of 12-inch diameter water pipeline laid in a combination of soil and rock in an urban environment = $96/foot. Two miles = 10,560 feet. Therefore, capital cost of 2-mile long, 12-inch pipeline = $96/foot × 10,560 feet = $1,013,760.

A retrofit to closed-cycle cooling reduces consumptive water use compared to once-through cooling by approximately 95 percent.[82] A closed-cycle cooling retrofit at Schiller Station would achieve similar reduction in fish larvae entrainment impacts, and large reductions in fish impingement impacts as well.[83] No other mechanisms can reduce the aquatic impacts to a level commensurate with closed-cycle cooling.[84]

Signed,

Bill Powers, P.E.

Bill Powers, P.E.

[82] EPA, *Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule,* March 28, 2011, p. 2-19. "To better reflect the advances in cooling tower design, EPA now estimates that freshwater cooling towers and saltwater cooling towers reduce impingement mortality and entrainment by 97.5 percent and 94.9 percent, respectively."

[83] TetraTech, *California's Coastal Power Plants: Alternative Cooling System Analysis,* Chapter 4 – Closed-Cycle Cooling Systems, February 2008, p. 4-8.

[84] As EPA has explained, "[c]losed-cycle cooling systems … are the *most effective* means of protecting organisms from I&E [impingement and entrainment]." U.S. EPA Office of Science and Technology Engineering and Analysis Division, Economic and Benefits Analysis of Proposed Section 316(b) Phase II Existing Facilities Rule § A2-2.1(a), at p. A2-5, available at http://www.epa.gov/waterscience/316b/econbenefits/a2.pdf (emphasis added).

Attachment A

BILL POWERS, P.E.

PROFESSIONAL HISTORY

Powers Engineering, San Diego, CA 1994-
ENSR Consulting and Engineering, Camarillo, CA 1989-93
Naval Energy and Environmental Support Activity, Port Hueneme, CA 1982-87
U.S. Environmental Protection Agency, Research Triangle Park, NC 1980-81

EDUCATION

Master of Public Health – Environmental Sciences, University of North Carolina
Bachelor of Science – Mechanical Engineering, Duke University

PROFESSIONAL AFFILIATIONS

Registered Professional Mechanical Engineer, California (Certificate M24518)
American Society of Mechanical Engineers
Air & Waste Management Association

TECHNICAL SPECIALTIES

Thirty years of experience in:

- Power plant air emission control system and cooling system assessments
- Combustion equipment permitting, testing and monitoring
- Air pollution control equipment retrofit design/performance testing
- Distributed solar photovoltaics (PV) siting and regional renewable energy planning
- Petroleum refinery air engineering and testing
- Latin America environmental project experience

POWER PLANT EMISSION CONTROL AND COOLING SYSTEM CONVERSION ASSESSMENTS

Biomass Plant NO_x and CO Air Emissions Control Evaluation. Lead engineer for evaluation of available nitrogen oxide (NO_x) and carbon monoxide (CO) controls for a 45 MW Aspen Power biomass plant in Texas where proponent had identified selective non-catalytic reduction (SNCR) for NO_x and good combustion practices for CO as BACT. Identified the use of tail-end SCR for NO_x control at several operational U.S. biomass plants, and oxidation catalyst in use at two of these plants for CO and VOC control, as BACT for the proposed biomass plant. Administrative law judge concurred in decision that SCR and oxidation catalyst is BACT. Developer added SCR and oxidation catalyst to project in subsequent settlement agreement.

Biomass Plant Air Emissions Control Consulting. Lead expert on biomass air emissions control systems for landowners that will be impacted by a proposed 50 MW biomass to be built by the local East Texas power cooperative. Public utility agreed to meet current BACT for biomass plants in Texas, SCR for NOx and oxidation catalyst for CO, in settlement agreement with local landowners.

Combined-Cycle Power Plant Startup and Shutdown Emissions. Lead engineer for analysis of air permit startup and shutdown emissions minimization for combined-cycle power plant proposed for the San Francisco Bay Area. Original equipment was specified for baseload operation prior to suspension of project in early 2000s. Operational profile described in revised air permit was load following with potential for daily start/stop. Recommended that either fast start turbine technology be employed to minimize start/stop emissions or that "demonstrated in practice" operational and control software modifications be employed to minimize startup/shutdown emissions.

IGCC as BACT for Air Emissions from Proposed 960 MW Coal Plant. Presented testimony on IGCC as BACT for air emissions reduction from 960 MW coal plant. Applicant received air permit for a pulverized coal plant to be equipped with a baghouse, wet scrubber, and wet ESP for air emissions control. Use of IGCC technology at the emission rates permitted for two recently proposed U.S. IGCC projects, and demonstrated in practice at a Japanese IGCC plant firing Chinese bituminous coal, would substantially reduce potential emissions of NO_x, SO_2, and PM. The estimated control cost-effectiveness of substituting IGCC for pulverized coal technology in this case was approximately $3,000/ton.

Analysis of Proposed Air Emission Limits for 600 MW Pulverized Coal Plant. Project engineer tasked with evaluating sufficiency of air emissions limits and control technologies for proposed 600 MW coal plant Arkansas. Determined that the applicant had: 1) not properly identified SO_2, sulfuric acid mist, and PM BACT control levels for the plant, and 2) improperly utilized an incremental cost effectiveness analysis to justify air emission control levels that did not represent BACT.

Eight Pulverized Coal Fired 900 MW Boilers – IGCC Alternative with Air Cooling. Provided testimony on integrated gasification combined cycle (IGCC) as a fully commercial coal-burning alternative to the pulverized coal (PC) technology proposed by TXU for eight 900 MW boilers in East Texas, and East Texas as an ideal location for CO2 sequestration due to presence of mature oilfield CO2 enhanced oil recovery opportunities and a deep saline aquifer underlying the entire region. Also presented testimony on the major increase in regional consumptive water use that would be caused by the evaporative cooling towers proposed for use in the PC plants, and that consumptive water use could be lowered by using IGCC with evaporative cooling towers or by using air-cooled condensers with PC or IGCC technology. TXU ultimately dropped plans to build the eight PC plants as a condition of a corporate buy-out.

Utility Boilers – Conversion of Existing Once-Through Cooled Boilers to Wet Towers, Parallel Wet-Dry Cooling, or Dry Cooling. Provided expert testimony and preliminary design for the conversion of four natural gas and/or coal-fired utility boilers (Unit 4, 235 MW; Unit 3, 135 MW; Unit 2, 65 MW; and Unit 1,65 MW) from once-through river water cooling to wet cooling towers, parallel wet-dry cooling, and dry cooling. Major design constraints were available land for location of retrofit cooling systems and need to maintain maximum steam turbine backpressure at or below 5.5 inches mercury to match performance capabilities of existing equipment. Approach temperatures of 12 ^{o}F and 13 ^{o}F were used for the wet towers. SPX Cooling Technologies F-488 plume-abated wet cells with six feet of packing were used to achieve approach temperatures of 12 ^{o}F and 13 ^{o}F. Annual energy penalty of wet tower retrofit designs is approximately 1 percent. Parallel wet-dry or dry cooling was determined to be technically feasible for Unit 3 based on straightforward access to the Unit 3 surface condenser and available land adjacent to the boiler.

Utility Boiler – Assessment of Air Cooling and Integrated Gasification/Combined Cycle for Proposed 500 MW Coal-Fired Plant. Provided expert testimony on the performance of air-cooling and IGCC relative to the conventional closed-cycle wet cooled, supercritical pulverized coal boiler proposed by the applicant. Steam Pro™ coal-fired power plant design software was used to model the proposed plant and evaluate the impacts on performance of air cooling and plume-abated wet cooling. Results indicated that a conservatively designed air-cooled condenser could maintain rated power output at the design ambient temperature of 90 ^{o}F. The IGCC comparative analysis indicated that unit reliability comparable to a conventional pulverized coal unit could be achieved by including a spare gasifier in the IGCC design, and that the slightly higher capital cost of IGCC was offset by greater thermal efficiency and reduced water demand and air emissions.

Utility Boiler – Assessment of Closed-Cycle Cooling Retrofit Cost for 1,200 MW Oil-Fired Plant. Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 1,200 MW Roseton Generating Station. Determined that the cost to retrofit the Roseton plant with plume-abated closed-cycle wet cooling was well established based on cooling tower retrofit studies performed by the original owner (Central Hudson Gas & Electric Corp.) and subsequent regulatory agency critique of the cost estimate.

Also determined that elimination of redundant and/or excessive budgetary line items in owners cost estimate brings the closed-cycle retrofit in line with expected costs for comparable new or retrofit plume-abated cooling tower applications.

Nuclear Power Plant – Assessment of Closed-Cycle Cooling Retrofit Cost for 2,000 MW Plant. Prepared an assessment of the cost and feasibility of a closed-cycle wet tower retrofit for the 2,000 MW Indian Point Generating Station. Determined that the most appropriate arrangement for the hilly site would be an inline plume-abated wet tower instead of the round tower configuration analyzed by the owner. Use of the inline configuration would allow placement of the towers at numerous sites on the property with little or need for blasting of bedrock, greatly reducing the cost of the retrofit. Also proposed an alternative circulating cooling water piping configuration to avoid the extensive downtime projected by the owner for modifications to the existing discharge channel.

Kentucky Coal-Fired Power Plant – Pulverized Coal vs IGCC. Expert witness in Sierra Club lawsuit against Peabody Coal Company's plan to construct a 1,500 MW pulverized-coal fired power plant in Kentucky. Presented case that Integrated Gasification Combined Cycle (IGCC) is a superior method for producing power from coal, from environmental and energy efficiency perspective, than the proposed pulverized-coal plant. Presented evidence that IGCC is technically feasible and cost competitive with pulverized coal.

Power Plant Dry Cooling Symposium – Chair and Organizer. Chair and organizer of the first symposium held in the U.S. (May 2002) that focused exclusively on dry cooling technology for power plants. Sessions included basic principles of wet and dry cooling systems, performance capabilities of dry cooling systems, case studies of specific installations, and reasons why dry cooling is the predominant form of cooling specified in certain regions of North America (Massachusetts, Nevada, northern Mexico).

Utility Boiler – Best Available NO_x Control System for 525 MW Coal-Fired Circulating Fluidized Bed Boiler Plant. Expert witness in dispute over whether 50 percent NO_x control using selective non-catalytic reduction (SNCR) constituted BACT for a proposed 525 MW circulating fluidized bed (CFB) boiler plant. Presented testimony that SNCR was capable of continuous NO_x reduction of greater than 70 percent on a CFB unit and that tail-end selective catalytic reduction (SCR) was technically feasible and could achieve greater than 90 percent NO_x reduction.

Utility Boilers – Evaluation of Correlation Between Opacity and PM_{10} Emissions at Coal-Fired Plant. Provided expert testimony on whether correlation existed between mass PM_{10} emissions and opacity during opacity excursions at large coal-fired boiler in Georgia. EPA and EPRI technical studies were reviewed to assess the correlation of opacity and mass emissions during opacity levels below and above 20 percent. A strong correlation between opacity and mass emissions was apparent at a sister plant at opacities less than 20 percent. The correlation suggests that the opacity monitor correlation underestimates mass emissions at opacities greater than 20 percent, but may continue to exhibit a good correlation for the component of mass emissions in the PM_{10} size range.

Utility Boilers – Retrofit of SCR and FGD to Existing Coal-Fired Units.
Expert witness in successful effort to compel an existing coal-fired power plant located in Massachusetts to meet an accelerated NO_x and SO_2 emission control system retrofit schedule. Plant owner argued the installation of advanced NO_x and SO_2 control systems would generate > 1 ton/year of ancillary emissions, such as sulfuric acid mist, and that under Massachusetts Dept. of Environmental Protection regulation ancillary emissions > 1 ton/year would require a BACT evaluation and a two-year extension to retrofit schedule. Successfully demonstrated that no ancillary emissions would be generated if the retrofit NO_x and SO_2 control systems were properly sized and optimized. Plant owner committed to accelerated compliance schedule in settlement agreement.

Utility Boilers – Retrofit of SCR to Existing Natural Gas-Fired Units.
Lead engineer in successful representation of interests of California coastal city to prevent weakening of an existing countywide utility boiler NO_x rule. Weakening of NO_x rule would have allowed a merchant utility boiler plant located in the city to operate without installing selective catalytic reduction (SCR) NO_x control systems. This project required numerous appearances before the county air pollution control hearing board to successfully defend the existing utility boiler NO_x rule.

COMBUSTION EQUIPMENT PERMITTING, TESTING AND MONITORING

EPRI Gas Turbine Power Plant Permitting Documents – Co-Author.
Co-authored two Electric Power Research Institute (EPRI) gas turbine power plant siting documents. Responsibilities included chapter on state-of-the-art air emission control systems for simple-cycle and combined-cycle gas turbines, and authorship of sections on dry cooling and zero liquid discharge systems.

Air Permits for 50 MW Peaker Gas Turbines – Six Sites Throughout California.
Responsible for preparing all aspects of air permit applications for five 50 MW FT-8 simple-cycle turbine installations at sites around California in response to emergency request by California state government for additional peaking power. Units were designed to meet 2.0 ppm NO_x using standard temperature SCR and innovative dilution air system to maintain exhaust gas temperature within acceptable SCR range. Oxidation catalyst is also used to maintain CO below 6.0 ppm.

Kauai 27 MW Cogeneration Plant – Air Emission Control System Analysis. Project manager to evaluate technical feasibility of SCR for 27 MW naphtha-fired turbine with once-through heat recovery steam generator. Permit action was stalled due to questions of SCR feasibility. Extensive analysis of the performance of existing oil-fired turbines equipped with SCR, and bench-scale tests of SCR applied to naphtha-fired turbines, indicated that SCR would perform adequately. Urea was selected as the SCR reagent given the wide availability of urea on the island. Unit is first known application of urea-injected SCR on a naphtha-fired turbine.

Microturbines – Ronald Reagan Library, Ventura County, California.
Project manager and lead engineer or preparation of air permit applications for microturbines and standby boilers. The microturbines drive the heating and cooling system for the library. The microturbines are certified by the manufacturer to meet the 9 ppm NO_x emission limit for this equipment. Low-NO_x burners are BACT for the standby boilers.

Hospital Cogeneration Microturbines – South Coast Air Quality Management District.
Project manager and lead engineer for preparation of air permit application for three microturbines at hospital cogeneration plant installation. The draft Authority To Construct (ATC) for this project was obtained two weeks after submittal of the ATC application. 30-day public notification was required due to the proximity of the facility to nearby schools. The final ATC was issued two months after the application was submitted, including the 30-day public notification period.

Gas Turbine Cogeneration – South Coast Air Quality Management District. Project manager and lead engineer for preparation of air permit application for two 5.5 MW gas turbines in cogeneration configuration for county government center. The turbines will be equipped with selective catalytic reduction (SCR) and oxidation catalyst to comply with SCAQMD BACT requirements. Aqueous urea will be used as the SCR reagent to avoid trigger hazardous material storage requirements. A separate permit will be obtained for the NO_x and CO continuous emissions monitoring systems. The ATCs is pending.

Industrial Boilers – NO_x BACT Evaluation for San Diego County Boilers.
Project manager and lead engineer for preparation of Best Available Control Technology (BACT) evaluation for three industrial boilers to be located in San Diego County. The BACT included the review of low NO_x burners, FGR, SCR, and low temperature oxidation (LTO). State-of-the-art ultra low NO_x burners with a 9 ppm emissions guarantee were selected as NO_x BACT for these units.

Peaker Gas Turbines – Evaluation of NO_x Control Options for Installations in San Diego County. Lead engineer for evaluation of NO_x control options available for 1970s vintage simple-cycle gas turbines proposed for peaker sites in San Diego County. Dry low-NO_x (DLN) combustors, catalytic combustors, high-temperature SCR, and NO_x absorption/conversion ($SCONO_x$) were evaluated for each candidate turbine make/model. High-temperature SCR was selected as the NOx control option to meet a 5 ppm NO_x emission requirement.

Hospital Cogeneration Plant Gas Turbines – San Joaquin Valley Unified Air Pollution Control District. Project manager and lead engineer for preparation of air permit application and Best Available Control Technology (BACT) evaluation for hospital cogeneration plant installation. The BACT included the review of DLN combustors, catalytic combustors, high-temperature SCR and $SCONO_x$. DLN combustion followed by high temperature SCR was selected as the NO_x control system for this installation. The high temperature SCR is located upstream of the heat recovery steam generator (HRSG) to allow the diversion of exhaust gas around the HRSG without compromising the effectiveness of the NO_x control system.

1,000 MW Coastal Combined-Cycle Power Plant – Feasibility of Dry Cooling. Expert witness in on-going effort to require use of dry cooling on proposed 1,000 MW combined-cycle "repower" project at site of an existing 1,000 MW utility boiler plant. Project proponent argued that site was two small for properly sized air-cooled condenser (ACC) and that use of ACC would cause 12-month construction delay. Demonstrated that ACC could easily be located on the site by splitting total of up to 80 cells between two available locations at the site. Also demonstrated that an ACC optimized for low height and low noise would minimize or eliminate proponent claims of negative visual and noise impacts.

Industrial Cogeneration Plant Gas Turbines – Upgrade of Turbine Power Output. Project manager and lead engineer for preparation of Best Available Control Technology (BACT) evaluation for proposed gas turbine upgrade. The BACT included the review of DLN combustors, catalytic combustors, high-, standard-, and low-temperature SCR, and $SCONO_x$. Successfully negotiated air permit that allowed facility to initially install DLN combustors and operate under a NO_x plantwide "cap." Within two major turbine overhauls, or approximately eight years, the NO_x emissions per turbine must be at or below the equivalent of 5 ppm. The 5 ppm NO_x target will be achieved through technological in-combustor NO_x control such as catalytic combustion, or SCR or SCR equivalent end-of-pipe NO_x control technologies if catalytic combustion is not available.

Gas Turbines – Modification of RATA Procedures for Time-Share CEM. Project manager and lead engineer for the development of alternate CO continuous emission monitor (CEM) Relative Accuracy Test Audit (RATA) procedures for time-share CEM system serving three 7.9 MW turbines located in San Diego. Close interaction with San Diego APCD and EPA Region 9 engineers was required to receive approval for the alternate CO RATA standard. The time-share CEM passed the subsequent annual RATA without problems as a result of changes to some of the CEM hardware and the more flexible CO RATA standard.

Gas Turbines – Evaluation of NO_x Control Technology Performance. Lead engineer for performance review of dry low-NO_x combustors, catalytic combustors, high-, standard-, and low-temperature selective catalytic reduction (SCR), and NO_x absorption/conversion ($SCONO_x$). Major turbine manufacturers and major manufacturers of end-of-pipe NO_x control systems for gas turbines were contacted to determine current cost and performance of NO_x control systems. A comparison of 1993 to 1999 "\$/kwh" and "\$/ton" cost of these control systems was developed in the evaluation.

Gas Turbines – Evaluation of Proposed NO_x Control System to Achieve 3 ppm Limit.

Lead engineer for evaluation for proposed combined cycle gas turbine NO_x and CO control systems. Project was in litigation over contract terms, and there was concern that the GE Frame 7FA turbine could not meet the 3 ppm NO_x permit limit using a conventional combustor with water injection followed by SCR. Operations personnel at GE Frame 7FA installatins around the country were interviewed, along with principal SCR vendors, to corroborate that the installation could continuously meet the 3 ppm NO_x limit.

Gas Turbines – Title V "Presumptively Approvable" Compliance Assurance Monitoring Protocol. Project manager and lead engineer for the development of a "presumptively approval" NO_x parametric emissions monitoring system (PEMS) protocol for industrial gas turbines. "Presumptively approvable" means that any gas turbine operator selecting this monitoring protocol can presume it is acceptable to the U.S. EPA. Close interaction with the gas turbine manufacturer's design engineering staff and the U.S. EPA Emissions Measurement Branch (Research Triangle Park, NC) was required to determine modifications necessary to the current PEMS to upgrade it to "presumptively approvable" status.

Environmental Due Diligence Review of Gas Turbine Sites – Mexico. Task leader to prepare regulatory compliance due diligence review of Mexican requirements for gas turbine power plants. Project involves eleven potential sites across Mexico, three of which are under construction. Scope involves identification of all environmental, energy sales, land use, and transportation corridor requirements for power projects in Mexico. Coordinator of Mexican environmental subcontractors gathering on-site information for each site, and translator of Spanish supporting documentation to English.

Development of Air Emission Standards for Gas Turbines - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian gas turbine power plants. All major gas turbine power plants in Peru are currently using water injection to increase turbine power output. Recommended that 42 ppm on natural gas and 65 ppm on diesel (corrected to 15% O_2) be established as the NO_x limit for existing gas turbine power plants. These limits reflect NO_x levels readily achievable using water injection at high load. Also recommended that new gas turbine sources be subject to a BACT review requirement.

Gas Turbines – Title V Permit Templates. Lead engineer for the development of standardized permit templates for approximately 100 gas turbines operated by the oil and gas industry in the San Joaquin Valley. Emissions limits and monitoring requirements were defined for units ranging from GE Frame 7 to Solar Saturn turbines. Stand-alone templates were developed based on turbine size and NO_x control equipment. NO_x utilized in the target turbine population ranged from water injection alone to water injection combined with SCR.

Gas Turbines – Evaluation of NO_x, SO_2 and PM Emission Profiles. Performed a comparative evaluation of the NO_x, SO_2 and particulate (PM) emission profiles of principal utility-scale gas turbines for an independent power producer evaluating project opportunities in Latin America. All gas turbine models in the 40 MW to 240 MW range manufactured by General Electric, Westinghouse, Siemens and ABB were included in the evaluation.

Stationary Internal Combustion Engine (ICE) RACT/BARCT Evaluation. Lead engineer for evaluation of retrofit NO_x control options available for the oil and gas production industry gas-fired ICE population in the San Joaquin Valley affected by proposed RACT and BARCT emission limits. Evaluation centered on lean-burn compressor engines under 500 bhp, and rich-burn constant and cyclically loaded (rod pump) engines under 200 bhp. The results of the evaluation indicated that rich burn cyclically-loaded rod pump engines comprised 50 percent of the affected ICE population, though these ICEs accounted for only 5 percent of the uncontrolled gas-fired stationary ICE NO_x emissions. Recommended retrofit NO_x control strategies included: air/fuel ratio adjustment for rod pump ICEs, Non-selective catalytic reduction (NSCR) for rich-burn, constant load ICEs, and "low emission" combustion modifications for lean burn ICEs.

Development of Air Emission Standards for Stationary ICEs - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian stationary ICE power plants. Draft 1997 World Bank NO_x and particulate emission limits for stationary ICE power plants served as the basis for proposed MEM emission limits. A detailed review of ICE emissions data provided in PAMAs submitted to the MEM was performed to determine the level of effort that would be required by Peruvian industry to meet the proposed NO_x and particulate emission limits. The draft 1997 WB emission limits were revised to reflect reasonably achievable NO_x and particulate emission limits for ICEs currently in operation in Peru.

Air Toxics Testing of Natural Gas-Fired ICEs. Project manager for test plan/test program to measure volatile and semi-volatile organic air toxics compounds from fourteen gas-fired ICEs used in a variety of oil and gas production applications. Test data was utilized by oil and gas production facility owners throughout California to develop accurate ICE air toxics emission inventories.

AIR ENGINEERING/AIR TESTING PROJECT EXPERIENCE – GENERAL

Reverse Air Fabric Filter Retrofit Evaluation – Coal-Fired Boiler. Lead engineer for upgrade of reverse air fabric filters serving coal-fired industrial boilers. Fluorescent dye injected to pinpoint broken bags and damper leaks. Corrosion of pneumatic actuators serving reverse air valves and inadequate insulation identified as principal causes of degraded performance.

Pulse-Jet Fabric Filter Performance Evaluation – Gold Mine. Lead engineer on upgrade of pulse-jet fabric filter and associated exhaust ventilation system serving an ore-crushing facility at a gold mine. Fluorescent dye used to identify bag collar leaks, and modifications were made to pulse air cycle time and duration. This marginal source was in compliance at 20 percent of emission limit following completion of repair work.

Pulse-Jet Fabric Filter Retrofit - Gypsum Calciner. Lead engineer on upgrade of pulse-jet fabric filter controlling particulate emissions from a gypsum calciner. Recommendations included a modified bag clamping mechanism, modified hopper evacuation valve assembly, and changes to pulse air cycle time and pulse duration.

Wet Scrubber Retrofit – Plating Shop. Project engineer on retrofit evaluation of plating shop packed-bed wet scrubbers failing to meet performance guarantees during acceptance trials, due to excessive mist carryover. Recommendations included relocation of the mist eliminator (ME), substitution of the original chevron blade ME with a mesh pad ME, and use of higher density packing material to improve exhaust gas distribution. Wet scrubbers passed acceptance trials following completion of recommended modifications.

Electrostatic Precipitator (ESP) Retrofit Evaluation – MSW Boiler. Lead engineer for retrofit evaluation of single field ESP on a municipal solid waste (MSW) boiler. Recommendations included addition of automated power controller, inlet duct turning vanes, and improved collecting plate rapping system.

ESP Electric Coil Rapper Vibration Analysis Testing - Coal-Fired Boiler. Lead engineer for evaluation of ESP rapper effectiveness test program on three field ESP equipped with "magnetically induced gravity return" (MIGR) rappers. Accelerometers were placed in a grid pattern on ESP collecting plates to determine maximum instantaneous plate acceleration at a variety of rapper power setpoints. Testing showed that the rappers met performance specification requirements.

Aluminum Remelt Furnace Particulate Emissions Testing. Project manager and lead engineer for high temperature (1,600 ^oF) particulate sampling of a natural gas-fired remelt furnace at a major aluminum rolling mill. Objectives of test program were to: 1) determine if condensable particulate was present in stack gases, and 2) to validate the accuracy of the in-stack continuous opacity monitor (COM). Designed and constructed a customized high temperature (inconel) PM_{10}/Mtd 17 sampling assembly for test program. An onsite natural gas-fired boiler was also tested to provide comparative data for the condensable particulate portion of the test program. Test results showed that no significant levels of condensable particulate in the remelt furnace exhaust gas, and indicated that the remelt furnace and boiler had similar particulate emission rates. Test results also showed that the COM was accurate.

Aluminum Remelt Furnace CO and NO_x Testing. Project manager and lead engineer for continuous week-long testing of CO and NO_x emissions from aluminum remelt furnace. Objective of test program was to characterize CO and NO_x emissions from representative remelt furnace for use in the facility's criteria pollution emissions inventory. A TECO Model 48 CO analyzer and a TECO Model 10 NO_x analyzer were utilized during the test program to provide $\pm$1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system.

DISTRIBUTED SOLAR PV SITING AND REGIONAL RENEWABLE ENERGY PLANNING

Bay Area Smart Energy 2020 Plan . Author of the March 2012 *Bay Area Smart Energy 2020* strategic energy plan for the nine-county region surrounding San Francisco Bay. This plan uses the zero net energy building targets in the *California Energy Efficiency Strategic Plan* as a framework to achieve a 60 percent reduction in GHG emissions from Bay Area electricity usage, and a 50 percent reduction in peak demand for grid electricity, by 2020. The 2020 targets in the plan include: 25 percent of detached homes and 20 percent of commercial buildings achieving zero net energy, adding 200 MW of community-scale microgrid battery storage and 400 MW of utility-scale battery storage, reduction in air conditioner loads by 50 percent through air conditioner cycling and targeted incentive funds to assure highest efficiency replacement units, and cooling system modifications to increase power output from The Geysers geothermal production zone in Sonoma County. Report is available online at: http://pacificenvironment.org/-1-87.

Solar PV technology selection and siting for SDG&E Solar San Diego project. Served as PV technology expert in California Public Utilities Commission proceeding to define PV technology and sites to be used in San Diego Gas & Electric (SDG&E) $250 million "Solar San Diego" project. Recommendations included: 1) prioritize use of roof-mounted thin-film PV arrays similar to the SCE urban PV program to maximize the installed PV capacity, 2) avoid tracking ground-mounted PV arrays due to high cost and relative lack of available land in the urban/suburban core, 3) and incorporate limited storage in fixed rooftop PV arrays to maximizing output during peak demand periods. Suitable land next to SDG&E substations capable of supporting 5 to 40 MW of PV (each) was also identified by Powers Engineering as a component of this project.

Rooftop PV alternative to natural gas-fired peaking gas turbines, Chula Vista. Served as PV technology expert in California Energy Commission (CEC) proceeding regarding the application of MMC Energy to build a 100 MW peaking gas turbine power plant in Chula Vista. Presented testimony that 100 MW of PV arrays in the Chula Vista area could provide the same level of electrical reliability on hot summer days as an equivalent amount of peaking gas turbine capacity at approximately the same cost of energy. The preliminary decision issued by the presiding CEC commissioner in the case recommended denial of the application in part due to failure of the applicant or CEC staff to thoroughly evaluate the PV alternative to the proposed turbines. No final decision has yet been issued in the proceeding (as of May 2009).

San Diego Smart Energy 2020 Plan. Author of October 2007 "San Diego Smart Energy 2020," an energy plan that focuses on meeting the San Diego region's electric energy needs through accelerated integration of renewable and non-renewable distributed generation, in the form of combined heat and power (CHP) systems and solar photovoltaic (PV) systems. PV would meet approximately 28 percent of the San Diego region's electric energy demand in 2020. Annual energy demand would drop 20 percent in 2020 relative to 2003 through use all cost-effective energy efficiency measures. Existing utility-scale gas-fired generation would continue to be utilized to provide power at night, during cloudy whether, and for grid reliability support. Report at: http://www.etechinternational.org/new_pdfs/smartenergy/52008_SmE2020_2nd.pdf

Development of San Diego Regional Energy Strategy 2030. Participant in the 18-month process in the 2002-2003 timeframe that led to the development of the San Diego Regional Energy Strategy 2030. This document was adopted by the SANDAG Board of Directors in July 2003 and defines strategic energy objectives for the

San Diego region, including: 1) in-region power generation increase from 65% of peak demand in 2010 to 75% of peak demand in 2020, 2) 40% renewable power by 2030 with at least half of this power generated in-county, 3) reinforcement of transmission capacity as needed to achieve these objectives. The SANDAG Board of Directors voted unanimously on Nov. 17, 2006 to take no position on the Sunrise Powerlink proposal primarily because it conflicts the Regional Energy Strategy 2030 objective of increased in-region power generation. The Regional Energy Strategy 2030 is online at: http://www.energycenter.org/uploads/Regional_Energy_Strategy_Final_07_16_03.pdf

PETROLEUM REFINERY AIR ENGINEERING/TESTING EXPERIENCE

Big West Refinery Expansion EIS. Lead engineer on comparative cost analysis of proposed wet cooling tower and fin-fan air cooler for process cooling water for the proposed clean fuels expansion project at the Big West Refinery in Bakersfield, California. Selection of the fin-fin air-cooler would eliminate all consumptive water use and wastewater disposal associated with the cooling tower. Air emissions of VOC and PM_{10} would be reduced with the fin-fan air-cooler even though power demand of the air-cooler is incrementally higher than that of the cooling tower. Fin-fan air-coolers with approach temperatures of 10 ^oF and 20 ^oF were evaluated. The annualized cost of the fin-fin air-cooler with a 20 ^oF approach temperature is essentially the same as that of the cooling tower when the cost of all ancillary cooling tower systems are considered.

Criteria and Air Toxic Pollutant Emissions Inventory for Proposed Refinery Modifications. Project manager and technical lead for development of baseline and future refinery air emissions inventories for process modifications required to produce oxygenated gasoline and desulfurized diesel fuel at a California refinery. State of the art criteria and air toxic pollutant emissions inventories for refinery point, fugitive and mobile sources were developed. Point source emissions estimates were generated using onsite criteria pollutant test data, onsite air toxics test data, and the latest air toxics emission factors from the statewide refinery air toxics inventory database. The fugitive volatile organic compound (VOC) emissions inventories were developed using the refinery's most recent inspection and maintenance (I&M) monitoring program test data to develop site-specific component VOC emission rates. These VOC emission rates were combined with speciated air toxics test results for the principal refinery process streams to produce fugitive VOC air toxics emission rates. The environmental impact report (EIR) that utilized this emission inventory data was the first refinery "Clean Fuels" EIR approved in California.

Development of Air Emission Standards for Petroleum Refinery Equipment - Peru. Served as principal technical consultant to the Peruvian Ministry of Energy in Mines (MEM) for the development of air emission standards for Peruvian petroleum refineries. The sources included in the scope of this project included: 1) SO_2 and NO_x refinery heaters and boilers, 2) desulfurization of crude oil, particulate and SO_2 controls for fluid catalytic cracking units (FCCU), 3) VOC and CO emissions from flares, 4) vapor recovery systems for marine unloading, truck loading, and crude oil/refined products storage tanks, and 5) VOC emissions from process fugitive sources such as pressure relief valves, pumps, compressors and flanges. Proposed emission limits were developed for new and existing refineries based on a thorough evaluation of the available air emission control technologies for the affected refinery sources. Leading vendors of refinery control technology, such as John Zink and Exxon Research, provided estimates of retrofit costs for the largest Peruvian refinery, La Pampilla, located in Lima. Meetings were held in Lima with refinery operators and MEM staff to discuss the proposed emission limits and incorporate mutually agreed upon revisions to the proposed limits for existing Peruvian refineries.

Air Toxic Pollutant Emissions Inventory for Existing Refinery. Project manager and technical lead for air toxic pollutant emissions inventory at major California refinery. Emission factors were developed for refinery heaters, boilers, flares, sulfur recovery units, coker deheading, IC engines, storage tanks, process fugitives, and catalyst regeneration units. Onsite source test results were utilized to characterize emissions from refinery combustion devices. Where representative source test results were not available, AP-42 VOC emission factors were combined with available VOC air toxics speciation profiles to estimate VOC air toxic emission rates. A risk assessment based on this emissions inventory indicated a relatively low health risk associated with refinery operations. Benzene, 1,3-butadiene and PAHs were the principal health risk related pollutants emitted.

Air Toxics Testing of Refinery Combustion Sources. Project manager for comprehensive air toxics testing program at a major California refinery. Metals, Cr^{+6}, PAHs, H_2S and speciated VOC emissions were measured from refinery combustion sources. High temperature Cr^{+6} stack testing using the EPA Cr^{+6} test method was performed for the first time in California during this test program. Representatives from the California Air Resources Board source test team performed simultaneous testing using ARB Method 425 (Cr^{+6}) to compare the results of EPA and ARB Cr^{+6} test methodologies. The ARB approved the test results generated using the high temperature EPA Cr^{+6} test method.

Air Toxics Testing of Refinery Fugitive Sources. Project manager for test program to characterize air toxic fugitive VOC emissions from fifteen distinct process units at major California refinery. Gas, light liquid, and heavy liquid process streams were sampled. BTXE, 1,3-butadiene and propylene concentrations were quantified in gas samples, while BTXE, cresol and phenol concentrations were measured in liquid samples. Test results were combined with AP-42 fugitive VOC emission factors for valves, fittings, compressors, pumps and PRVs to calculate fugitive air toxics VOC emission rates.

OIL AND GAS PRODUCTION AIR ENGINEERING/TESTING EXPERIENCE

Air Toxics Testing of Oil and Gas Production Sources. Project manager and lead engineer for test plan/test program to determine VOC removal efficiency of packed tower scrubber controlling sulfur dioxide emissions from a crude oil-fired steam generator. Ratfisch 55 VOC analyzers were used to measure the packed tower scrubber VOC removal efficiency. Tedlar bag samples were collected simultaneously to correlate BTX removal efficiency to VOC removal efficiency. This test was one of hundreds of air toxics tests performed during this test program for oil and gas production facilities from 1990 to 1992. The majority of the volatile air toxics analyses were performed at in-house laboratory. Project staff developed thorough familiarity with the applications and limitations of GC/MS, GC/PID, GC/FID, GC/ECD and GC/FPD. Tedlar bags, canisters, sorbent tubes and impingers were used during sampling, along with isokinetic tests methods for multiple metals and PAHs.

Air Toxics Testing of Glycol Reboiler – Gas Processing Plant. Project manager for test program to determine emissions of BTXE from glycol reboiler vent at gas processing facility handling 12 MM/cfd of produced gas. Developed innovative test methods to accurately quantify BTXE emissions in reboiler vent gas.

Air Toxics Emissions Inventory Plan. Lead engineer for the development of generic air toxics emission estimating techniques (EETs) for oil and gas production equipment. This project was performed for the Western States Petroleum Association in response to the requirements of the California Air Toxics "Hot Spots" Act. EETs were developed for all point and fugitive oil and gas production sources of air toxics, and the specific air toxics associated with each source were identified. A pooled source emission test methodology was also developed to moderate the cost of source testing required by the Act.

Fugitive NMHC Emissions from TEOR Production Field. Project manager for the quantification of fugitive Nonmethane hydrocarbon (NMHC) emissions from a thermally enhanced oil recovery (TEOR) oil production field in Kern County, CA. This program included direct measurement of NMHC concentrations in storage tank vapor headspace and the modification of available NMHC emission factors for NMHC-emitting devices in TEOR produced gas service, such as wellheads, vapor trunklines, heat exchangers, and compressors. Modification of the existing NMHC emission factors was necessary due to the high concentration of CO_2 and water vapor in TEOR produced gases.

Fugitive Air Emissions Testing of Oil and Gas Production Fields. Project manager for test plan/test program to determine VOC and air toxics emissions from oil storage tanks, wastewater storage tanks and produced gas lines. Test results were utilized to develop comprehensive air toxics emissions inventories for oil and gas production companies participating in the test program.

Oil and Gas Production Field – Air Emissions Inventory and Air Modeling. Project manager for oil and gas production field risk assessment. Project included review and revision of the existing air toxics emission inventory, air dispersion modeling, and calculation of the acute health risk, chronic non-carcinogenic risk and carcinogenic risk of facility operations. Results indicated that fugitive H_2S emissions from facility operations posed a potential health risk at the facility fenceline.

TITLE V PERMIT APPLICATION/MONITORING PLAN EXPERIENCE

Title V Permit Application – San Diego County Industrial Facility. Project engineer tasked with preparing streamlined Title V operating permit for U.S. Navy facilities in San Diego. Principal emission units included chrome plating, lead furnaces, IC engines, solvent usage, aerospace coating and marine coating operations. For each device category in use at the facility, federal MACT requirements were integrated with District requirements in user friendly tables that summarized permit conditions and compliance status.

Title V Permit Application Device Templates - Oil and Gas Production Industry. Project manager and lead engineer to prepare Title V permit application "templates" for the Western States Petroleum Association (WSPA). The template approach was chosen by WSPA to minimize the administrative burden associated with listing permit conditions for a large number of similar devices located at the same oil and gas production facility. Templates are being developed for device types common to oil and gas production operations. Device types include: boilers, steam generators, process heaters, gas turbines, IC engines, fixed-roof storage tanks, fugitive components, flares, and cooling towers. These templates will serve as the core of Title V permit applications prepared for oil and gas production operations in California.

Title V Permit Application - Aluminum Rolling Mill. Project manager and lead engineer for Title V permit application prepared for largest aluminum rolling mill in the western U.S. Responsible for the overall direction of the permit application project, development of a monitoring plan for significant emission units, and development of a hazardous air pollutant (HAP) emissions inventory. The project involved extensive onsite data gathering, frequent interaction with the plant's technical and operating staff, and coordination with legal counsel and subcontractors. The permit application was completed on time and in budget.

Title V Model Permit - Oil and Gas Production Industry. Project manager and lead engineer for the comparative analysis of regional and federal requirements affecting oil and gas production industry sources located in the San Joaquin Valley. Sources included gas turbines, IC engines, steam generators, storage tanks, and process fugitives. From this analysis, a model applicable requirements table was developed for a sample device type (storage tanks) that covered the entire population of storage tanks operated by the industry. The U.S. EPA has tentatively approved this model permit approach, and work is ongoing to develop comprehensive applicable requirements tables for each major category of sources operated by the oil and gas industry in the San Joaquin Valley.

Title V Enhanced Monitoring Evaluation of Oil and Gas Production Sources. Lead engineer to identify differences in proposed EPA Title V enhanced monitoring protocols and the current monitoring requirements for oil and gas production sources in the San Joaquin Valley. The device types evaluated included: steam generators, stationary ICEs, gas turbines, fugitives, fixed roof storage tanks, and thermally enhanced oil recovery (TEOR) well vents. Principal areas of difference included: more stringent Title V O&M requirements for parameter monitors (such as temperature, fuel flow, and O_2), and more extensive Title V recordkeeping requirements.

RACT/BARCT/BACT EVALUATIONS

BACT Evaluation of Wool Fiberglass Insulation Production Line. Project manager and lead engineer for BACT evaluation of a wool fiberglass insulation production facility. The BACT evaluation was performed as a component of a PSD permit application. The BACT evaluation included a detailed analysis of the available control options for forming, curing and cooling sections of the production line. Binder formulations, wet electrostatic precipitators, wet scrubbers, and thermal oxidizers were evaluated as potential PM_{10} and VOC control options. Low NO_x burner options and combustion control modifications were examined as potential NO_x control techniques for the curing oven burners. Recommendations included use of a proprietary binder formulation to achieve PM_{10} and VOC BACT, and use of low-NO_x burners in the curing ovens to achieve NO_x BACT. The PSD application is currently undergoing review by EPA Region 9.

RACT/BARCT Reverse Jet Scrubber/Fiberbed Mist Eliminator Retrofit Evaluation. Project manager and lead engineer on project to address the inability of existing wet electrostatic precipitators (ESPs) and atomized mist scrubbers to adequately remove low concentration submicron particulate from high volume recovery boiler exhaust gas at the Alaska Pulp Corporation mill in Sitka, AK. The project involved thorough on-site inspections of existing control equipment, detailed review of maintenance and performance records, and a detailed evaluation of potential replacement technologies. These technologies included a wide variety of scrubbing technologies where manufacturers claimed high removal efficiencies on submicron particulate in high humidity exhaust gas. Packed tower scrubbers, venturi scrubbers, reverse jet scrubbers, fiberbed mist eliminators and wet ESPs were evaluated. Final recommendations included replacement of atomized mist scrubber with reverse jet scrubber and upgrading of the existing wet ESPs. The paper describing this project was published in the May 1992 TAPPI Journal.

Aluminum Smelter RACT Evaluation - Prebake. Project manager and technical lead for CO and PM_{10} RACT evaluation for prebake facility. Retrofit control options for CO emissions from the anode bake furnace, potline dry scrubbers and the potroom roof vents were evaluated. PM_{10} emissions from the coke kiln, potline dry scrubbers, potroom roof vents, and miscellaneous potroom fugitive sources were addressed. Four CO control technologies were identified as technologically feasible for potline CO emissions: potline current efficiency improvement through the addition of underhung busswork and automated puncher/feeders, catalytic incineration, recuperative incineration and regenerative incineration. Current efficiency improvement was identified as probable CO RACT if onsite test program demonstrated the effectiveness of this approach. Five PM_{10} control technologies were identified as technologically feasible: increased potline hooding efficiency through redesign of shields, the addition of a dense-phase conveying system, increased potline air evacuation rate, wet scrubbing of roof vent emissions, and fabric filter control of roof vent emissions. The cost of these potential PM_{10} RACT controls exceeded regulatory guidelines for cost effectiveness, though testing of modified shield configurations and dense-phase conveying is being conducted under a separate regulatory compliance order.

RACT/BACT Testing/Evaluation of PM_{10} Mist Eliminators on Five-Stand Cold Mill. Project manager and lead engineer for fiberbed mist eliminator and mesh pad mist eliminator comparative pilot test program on mixed phase aerosol (PM_{10})/gaseous hydrocarbon emissions from aluminum high speed cold rolling mill. Utilized modified EPA Method 5 sampling train with portion of sample gas diverted (after particulate filter) to Ratfisch 55 VOC analyzer. This was done to permit simultaneous quantification of aerosol and gaseous hydrocarbon emissions in the exhaust gas. The mesh pad mist eliminator demonstrated good control of PM_{10} emissions, though test results indicated that the majority of captured PM_{10} evaporated in the mesh pad and was emitted as VOC.

Aluminum Remelt Furnace/Rolling Mill RACT Evaluations. Lead engineer for comprehensive CO and PM_{10} RACT evaluation for the largest aluminum sheet and plate rolling mill in western U.S. Significant sources of CO emissions from the facility included the remelt furnaces and the coater line. The potential CO RACT options for the remelt furnaces included: enhanced maintenance practices, preheating combustion air, installation of fully automated combustion controls, and energy efficiency modifications. The coater line was equipped with an afterburner for VOC and CO destruction prior to the initiation of the RACT study. It was determined that the afterburner meets or exceeds RACT requirements for the coater line. Significant sources of PM_{10} emissions included the remelt furnaces and the 80-inch hot rolling mill. Chlorine fluxing in the melting and holding furnaces was identified as the principal source of PM_{10} emissions from the remelt furnaces. The facility is in the process of minimizing/eliminating fluxing in the melting furnaces, and exhaust gases generated in holding furnaces during fluxing will be ducted to a baghouse for PM_{10} control. These modifications are being performed under a separate compliance order, and were determined to exceed RACT requirements. A water-based emulsion coolant and inertial separators are currently in use on the 80-inch hot mill for PM_{10} control. Current practices were determined to meet/exceed PM_{10} RACT for the hot mill. Tray tower absorption/recovery systems were also evaluated to control PM_{10} emissions from the hot mill, though it was determined that the technical/cost feasibility of using this approach on an emulsion-based coolant had not yet been adequately demonstrated.

BARCT Low NO_x Burner Conversion – Industrial Boilers. Lead engineer for evaluation of low NO_x burner options for natural gas-fired industrial boilers. Also evaluated methanol and propane as stand-by fuels to replace existing diesel stand-by fuel system. Evaluated replacement of steam boilers with gas turbine co-generation system.

BACT Packed Tower Scrubber/Mist Eliminator Performance Evaluations. Project manager and lead engineer for Navy-wide plating shop air pollution control technology evaluation and emissions testing program. Mist eliminators and packed tower scrubbers controlling metal plating processes, which included hard chrome, nickel, copper, cadmium and precious metals plating, were extensively tested at three Navy plating shops. Chemical cleaning and stripping tanks, including hydrochloric acid, sulfuric acid, chromic acid and caustic, were also tested. The final product of this program was a military design specification for plating and chemical cleaning shop air pollution control systems. The hydrochloric acid mist sampling procedure developed during this program received a protected patent.

BACT Packed Tower Scrubber/UV Oxidation System Pilot Test Program. Technical advisor for pilot test program of packed tower scrubber/ultraviolet (UV) light VOC oxidation system controlling VOC emissions from microchip manufacturing facility in Los Angeles. The testing was sponsored in part by the SCAQMD's Innovative Technology Demonstration Program, to demonstrate this innovative control technology as BACT for microchip manufacturing operations. The target compounds were acetone, methylethylketone (MEK) and 1,1,1-trichloroethane, and compound concentrations ranged from 10-100 ppmv. The single stage packed tower scrubber consistently achieved greater than 90% removal efficiency on the target compounds. The residence time required in the UV oxidation system for effective oxidation of the target compounds proved significantly longer than the residence time predicted by the manufacturer.

BACT Pilot Testing of Venturi Scrubber on Gas/Aerosol VOC Emission Source. Technical advisor for project to evaluate venturi scrubber as BACT for mixed phase aerosol/gaseous hydrocarbon emissions from deep fat fryer. Venturi scrubber demonstrated high removal efficiency on aerosol, low efficiency on VOC emissions. A number of VOC tests indicated negative removal efficiency. This anomaly was traced to a high hydrocarbon concentration in the scrubber water. The pilot unit had been shipped directly to the jobsite from another test location by the manufacturer without any cleaning or inspection of the pilot unit.

Pulp Mill Recovery Boiler BACT Evaluation. Lead engineer for BACT analysis for control of SO_2, NO_x, CO, TNMHC, TRS and particulate emissions from the proposed addition of a new recovery furnace at a kraft pulp mill in Washington. A "top down" approach was used to evaluate potential control technologies for each of the pollutants considered in the evaluation.

Air Pollution Control Equipment Design Specification Development. Lead engineer for the development of detailed Navy design specifications for wet scrubbers and mist eliminators. Design specifications were based on field performance evaluations conducted at the Long Beach Naval Shipyard, Norfolk Naval Shipyard, and Jacksonville Naval Air Station. This work was performed for the U.S. Navy to provide generic design specifications to assist naval facility engineering divisions with air pollution control equipment selection. Also served as project engineer for the development of Navy design specifications for ESPs and fabric filters.

CONTINUOUS EMISSION MONITOR (CEM) PROJECT EXPERIENCE

Process Heater CO and NO_x CEM Relative Accuracy Testing. Project manager and lead engineer for process heater CO and NO_x analyzer relative accuracy test program at petrochemical manufacturing facility. Objective of test program was to demonstrate that performance of onsite CO and NO_x CEMs was in compliance with U.S. EPA "Boiler and Industrial Furnace" hazardous waste co-firing regulations. A TECO Model 48 CO analyzer and a TECO Model 10 NO_x analyzer were utilized during the test program to provide $\pm$1 ppm measurement accuracy, and all test data was recorded by an automated data acquisition system. One of the two process heater CEM systems tested failed the initial test due to leaks in the gas conditioning system. Troubleshooting was performed using O_2 analyzers, and the leaking component was identified and replaced. This CEM system met all CEM relative accuracy requirements during the subsequent retest.

Performance Audit of NO_x and SO_2 CEMs at Coal-Fired Power Plant. Lead engineer on system audit and challenge gas performance audit of NO_x and SO_2 CEMs at a coal-fired power plant in southern Nevada. Dynamic and instrument calibration checks were performed on the CEMs. A detailed visual inspection of the CEM system, from the gas sampling probes at the stack to the CEM sample gas outlet tubing in the CEM trailer, was also conducted. The CEMs passed the dynamic and instrument calibration requirements specified in EPA's Performance Specification Test - 2 (NO_x and SO_2) alternative relative accuracy requirements.

LATIN AMERICA ENVIRONMENTAL PROJECT EXPERIENCE

Preliminary Design of Ambient Air Quality Monitoring Network – Lima, Peru. Project leader for project to prepare specifications for a fourteen station ambient air quality monitoring network for the municipality of Lima, Peru. Network includes four complete gaseous pollutant, particulate, and meteorological parameter monitoring stations, as well as eight PM_{10} and TSP monitoring stations.

Evaluation of Proposed Ambient Air Quality Network Modernization Project – Venezuela. Analyzed a plan to modernize and expand the ambient air monitoring network in Venezuela. Project was performed for the U.S. Trade and Development Agency. Direct interaction with policy makers at the Ministerio del Ambiente y de los Recursos Naturales Renovables (MARNR) in Caracas was a major component of this project.

Evaluation of U.S.-Mexico Border Region Copper Smelter Compliance with Treaty Obligations – Mexico. Project manager and lead engineer to evaluate compliance of U.S. and Mexican border region copper smelters with the SO_2 monitoring, recordkeeping and reporting requirements in Annex IV [Copper Smelters] of the La Paz Environmental Treaty. Identified potential problems with current ambient and stack monitoring practices that could result in underestimating the impact of SO_2 emissions from some of these copper smelters. Identified additional source types, including hazardous waste incinerators and power plants, that should be considered for inclusion in the La Paz Treaty process.

Development of Air Emission Limits for ICE Cogeneration Plant - Panamá. Lead engineer assisting U.S. cogeneration plant developer to permit an ICE cogeneration plant at a hotel/casino complex in Panama. Recommended the use of modified draft World Bank NO_x and PM limits for ICE power plants. The modification consisted of adding a thermal efficiency factor adjustment to the draft World Bank NO_x and PM limits. These proposed ICE emission limits are currently being reviewed by Panamanian environmental authorities.

Mercury Emissions Inventory for Stationary Sources in Northern Mexico. Project manager and lead engineer to estimate mercury emissions from stationary sources in Northern Mexico. Major potential sources of mercury emissions include solid- and liquid-fueled power plants, cement kilns co-firing hazardous waste, and non-ferrous metal smelters. Emission estimates were provided for approximately eighty of these sources located in Northern Mexico. Coordinated efforts of two Mexican subcontractors, located in Mexico City and Hermosillo, to obtain process throughput data for each source included in the inventory.

Translation of U.S. EPA Scrap Tire Combustion Emissions Estimation Document – Mexico. Evaluated the Translated a U.S. EPA scrap tire combustion emissions estimation document from English to Spanish for use by Latin American environmental professionals.

Environmental Audit of Aluminum Production Facilities – Venezuela. Evaluated the capabilities of existing air, wastewater and solid/hazardous waste control systems used by the aluminum industry in eastern Venezuela. This industry will be privatized in the near future. Estimated the cost to bring these control systems into compliance with air, wastewater and solid/hazardous waste standards recently promulgated in Venezuela. Also served as technical translator for team of U.S. environmental engineers involved in the due diligence assessment.

Assessment of Environmental Improvement Projects – Chile and Peru. Evaluated potential air, water, soil remediation and waste recycling projects in Lima, Peru and Santiago, Chile for feasibility study funding by the U.S. Trade and Development Agency. Project required onsite interaction with in-country decisionmakers (in Spanish). Projects recommended for feasibility study funding included: 1) an air quality technical support project for the Santiago, Chile region, and 2) soil remediation/metals recovery projects at two copper mine/smelter sites in Peru.

Air Pollution Control Training Course – Mexico. Conducted two-day Spanish language air quality training course for environmental managers of assembly plants in Mexicali, Mexico. Spanish-language course manual prepared by Powers Engineering. Practical laboratory included training in use of combustion gas analyzer, flame ionization detector (FID), photoionization detector (PID), and occupational sampling.

Stationary Source Emissions Inventory – Mexico. Developed a comprehensive air emissions inventory for stationary sources in Nogales, Sonora. This project requires frequent interaction with Mexican state and federal environmental authorities. The principal Powers Engineering subcontractor on this project is a Mexican firm located in Hermosillo, Sonora.

VOC Measurement Program – Mexico. Performed a comprehensive volatile organic compound (VOC) measurements program at a health products fabrication plant in Mexicali, Mexico. An FID and PID were used to quantify VOCs from five processes at the facility. Occupational exposures were also measured. Worker exposure levels were above allowable levels at several points in the main assembly area.

Renewable Energy Resource Assessment Proposal – Panama. Translated and managed winning bid to evaluate wind energy potential in Panama. Direct interaction with the director of development at the national utility monopoly (IRHE) was a key component of this project.

Comprehensive Air Emissions Testing at Assembly Plant – Mexico. Project manager and field supervisor of emissions testing for particulates, NO_x, SO_2 and CO at turbocharger/air cooler assembly plant in Mexicali, Mexico. Source specific emission rates were developed for each point source at the facility during the test program. Translated test report into Spanish for review by the Mexican federal environmental agency (SEMARNAP).

Air Pollution Control Equipment Retrofit Evaluation – Mexico. Project manager and lead engineer for comprehensive evaluation of air pollution control equipment and industrial ventilation systems in use at assembly plant consisting of four major facilities. Equipment evaluated included fabric filters controlling blast booth emissions, electrostatic precipitator controlling welding fumes, and industrial ventilation systems controlling welding fumes, chemical cleaning tank emissions, and hot combustion gas emissions. Recommendations included modifications to fabric filter cleaning cycle, preventative maintenance program for the electrostatic precipitator, and redesign of the industrial ventilation system exhaust hoods to improve capture efficiency.

Comprehensive Air Emissions Testing at Assembly Plant – Mexico. Project manager and field supervisor of emissions testing for particulates, NO_x, SO_2 and CO at automotive components assembly plant in Acuña, Mexico. Source-specific emission rates were developed for each point source at the facility during the test program. Translated test report into Spanish.

Fluent in Spanish. Studied at the Universidad de Michoacán in Morelia, Mexico, 1993, and at the Colegio de España in Salamanca, Spain, 1987-88. Have lectured (in Spanish) on air monitoring and control equipment at the Instituto Tecnológico de Tijuana. Maintain contact with Comisión Federal de Electricidad engineers responsible for operation of wind and geothermal power plants in Mexico, and am comfortable operating in the Mexican business environment.

PUBLICATIONS

Bill Powers, "*More Distributed Solar Means Fewer New Combustion Turbines*," Natural Gas & Electricity Journal, Vol. 29, Number 2, September 2012, pp. 17-20.

Bill Powers, "*Bay Area Smart Energy 2020,*" March 2012. See: http://pacificenvironment.org/-1-87

Bill Powers, "*Federal Government Betting on Wrong Solar Horse*," Natural Gas & Electricity Journal, Vol. 27, Number 5, December 2010,

Bill Powers, "*Today's California Renewable Energy Strategy—Maximize Complexity and Expense*," Natural Gas & Electricity Journal, Vol. 27, Number 2, September 2010, pp. 19-26.

Bill Powers, "*Environmental Problem Solving Itself Rapidly Through Lower Gas Costs*," Natural Gas & Electricity Journal, Vol. 26, Number 4, November 2009, pp. 9-14.

Bill Powers, "*PV Pulling Ahead, but Why Pay Transmission Costs?*" Natural Gas & Electricity Journal, Vol. 26, Number 3, October 2009, pp. 19-22.

Bill Powers, "*Unused Turbines, Ample Gas Supply, and PV to Solve RPS Issues*," Natural Gas & Electricity Journal, Vol. 26, Number 2, September 2009, pp. 1-7.

Bill Powers, "*CEC Cancels Gas-Fed Peaker, Suggesting Rooftop Photovoltaic Equally Cost-Effective*," Natural Gas & Electricity Journal, Vol. 26, Number 1, August 2009, pp. 8-13.

Bill Powers, "*San Diego Smart Energy 2020 – The 21st Century Alternative*," San Diego, October 2007.

Bill Powers, "*Energy, the Environment, and the California – Baja California Border Region*," Electricity Journal, Vol. 18, Issue 6, July 2005, pp. 77-84.

W.E. Powers, *"Peak and Annual Average Energy Efficiency Penalty of Optimized Air-Cooled Condenser on 515 MW Fossil Fuel-Fired Utility Boiler,"* presented at California Energy Commission/Electric Power Research Institute Advanced Cooling Technologies Symposium, Sacramento, California, June 2005.

W.E. Powers, R. Wydrum, P. Morris, *"Design and Performance of Optimized Air-Cooled Condenser at Crockett Cogeneration Plant,"* presented at EPA Symposium on Technologies for Protecting Aquatic Organisms from Cooling Water Intake Structures, Washington, DC, May 2003.

P. Pai, D. Niemi, W.E. Powers, *"A North American Anthropogenic Inventory of Mercury Emissions,"* presented at Air & Waste Management Association Annual Conference in Salt Lake City, UT, June 2000.

P.J. Blau and W.E. Powers, *"Control of Hazardous Air Emissions from Secondary Aluminum Casting Furnace Operations Through a Combination of: Upstream Pollution Prevention Measures, Process Modifications and*

End-of-Pipe Controls," presented at 1997 AWMA/EPA Emerging Solutions to VOC & Air Toxics Control Conference, San Diego, CA, February 1997.

W.E. Powers, et. al., *"Hazardous Air Pollutant Emission Inventory for Stationary Sources in Nogales, Sonora, Mexico ,"* presented at 1995 AWMA/EPA Emissions Inventory Specialty Conference, RTP, NC, October 1995.

W.E. Powers, *"Develop of a Parametric Emissions Monitoring System to Predict NO_x Emissions from Industrial Gas Turbines,"* presented at 1995 AWMA Golden West Chapter Air Pollution Control Specialty Conference, Ventura, California, March 1995.

W. E. Powers, et. al., *"Retrofit Control Options for Particulate Emissions from Magnesium Sulfite Recovery Boilers,"* presented at 1992 TAPPI Envr. Conference, April 1992. Published in *TAPPI Journal*, July 1992.

S. S. Parmar, M. Short, W. E. Powers, *"Determination of Total Gaseous Hydrocarbon Emissions from an Aluminum Rolling Mill Using Methods 25, 25A, and an Oxidation Technique,"* presented at U.S. EPA Measurement of Toxic and Related Air Pollutants Conference, May 1992.

N. Meeks, W. E. Powers, *"Air Toxics Emissions from Gas-Fired Internal Combustion Engines,"* presented at AIChE Summer Meeting, August 1990.

W. E. Powers, *"Air Pollution Control of Plating Shop Processes,"* presented at 7th AES/EPA Conference on Pollution Control in the Electroplating Industry, January 1986. Published in *Plating and Surface Finishing* magazine, July 1986.

H. M. Davenport, W. E. Powers, *"Affect of Low Cost Modifications on the Performance of an Undersized Electrostatic Precipitator,"* presented at 79th Air Pollution Control Association Conference, June 1986.

AWARDS

Engineer of the Year, 1991 – ENSR Consulting and Engineering, Camarillo
Engineer of the Year, 1986 – Naval Energy and Environmental Support Activity, Port Hueneme
Productivity Excellence Award, 1985 – U. S. Department of Defense

PATENTS

Sedimentation Chamber for Sizing Acid Mist, Navy Case Number 70094

Attachment B

Nuclear Plant Retrofit Comparison for Powers Engineering 9-June-2009

	Case 1A	Case 2A	Case 1B	Case 2B
Water	Salt	Salt	Fresh	Fresh
Type	ClearSky BTB	Wet BTB	ClearSky BTB	Wet BTB
Cells	3x22=66	3x18=54	3x20=60	3x18=54
Footprint	3@529x109	3@433x109	3@481x109	3@433x109
Rough Budget	$115.6 million	$38.6	$109.1	$36.4

Basis: 830,000 gpm at 108-88-76. Plume point is assumed at 50 DB/90% RH.

Low clog film type fill is used for all of the selections, assuming any fresh water used would likely be reclaimed water of some sort. Low clog fill has been used successfully in various sea water applications. Intake screens would be required for the make-up sea water to limit shells, etc. Make-up for the ClearSky tower would be approximately 80-85% of the wet tower make-up on an annual basis. Budget is tower only, not including basins. Infrastructure cost is estimated by some at 3 times the cost of the wet tower, including such things as site prep, basins, piping, electrical wiring and controls, etc. Sub-surface foundations such as piling can add significantly, and may be necessary for a seacoast location. The estimates above are adjusted for premium hardware and California seismic requirements, which are a factor in the taller back-to-back (BTB) designs both for wet and ClearSky. These are approximate comparisons. Both the wet towers and ClearSky towers could likely be optimized more than what has been estimated here, and may have to be tailored to actual site space in any event. ClearSky has pump head like a wet tower, is piped like a wet tower, and has higher fan power than a wet tower to accommodate the increased air flow and pressure drop.

Coil type wet dry towers would cost significantly more, with premium tube (titanium for sea water, and possibly for reclaimed water) and header materials. An appropriate plenum mixing design has yet to be developed, but would also require non-corrosive materials and high pressure drop on the air side. No coil type BTB wet dry towers are likely to be proposed.

Bill Powers

From: PAUL.LINDAHL@ct.spx.com

Sent: Tuesday, June 09, 2009 9:27 AM

To: bpowers@powersengineering.com

Subject: Nuclear Comparison

Bill,

A comparison of wet and ClearSky back to back towers for a reference duty is included in the attached summary.

Paul Lindahl, LEED AP
Director, Market Development
SPX Thermal Equipment & Services
7401 W 129th St
Overland Park, KS 66213
TEL 913.664.7588
MOB 913.522.4254
paul.lindahl@spx.com
www.spxcooling.com
www.balcke-duerr.com/

Attachment C

Refined Calculations on Closed-Cycle Conversion Effect on Steam Cycle Thermal Efficiency

A. Estimated Steam Turbine Backpressure for Once-Thru Cooling on Unit 4 at Summertime Peak/Average Conditions:

1. Peak day backpressure 8/15/02: load = 235 MW, water in T = 83 °F, water out T = 99 °F, steam sat. T = 105 °F.
Backpressure = **2.25 inches Hg**.

2. Actual average Unit 4 spring, summer, fall steam turbine backpressure:

Parameter	May	June	July	August	Sept.	October	
average load, MW	196	201	211	219	217	224	Average MW Unit 4 load 2001-2004 for month indicated. Rated load is 235 MW per NYDEC air permit.
average cooling water flowrate, gpm	150,000	150,000	150,000	150,000	150,000	125,000	All three C.W. pumps in operation in May, June, July, August, and September. Assume only two pumps online beginning in second half of October.
average monthly river temperature, °F	59	69	80	82	77	67	Source of information is "Danskammer Circulating Cooling Water System Daily Operating Report," January - Dec. 2002.
average temperature increase across condenser, °F	13	14	14	15	15	16	Source of information is "Danskammer Circulating Cooling Water System Daily Operating Report," January - Dec. 2002.
TTD between warm water out and steam saturation T, °F	6	6	6	6	6	6	6 °F is surface condenser terminal temperature difference (TTD) identified in Micheletti and Burns paper presented at EPA *Symposium on Technologies for Protecting Aquatic Organisms from Cooling Water Intake Structures*, May 2003, Arlington, VA.
steam saturation temperature, °F	78	89	100	103	98	89	Sum of cooling water temperature into condenser, cooling water T increase across condenser, and delta T between warm cooling water out temperature and steam saturation temperature.
average steam turbine backpressure, in. Hg	**1.0**	**1.4**	**1.9**	**2.1**	**1.8**	**1.5**	Conversion of steam saturation temperature to steam turbine backpressure per steam tables for saturated steam.

Refined Calculations on Closed-Cycle Conversion Effect on Steam Cycle Thermal Efficiency

B. Estimated Steam Turbine Backpressure with Wet Tower Retrofit on Unit 4 at Summertime Peak/Average Conditions:

1. Backpressure at design conditions : load = 235 MW, WB = 76 °F, approach T = 13 °F, range = 20 °F, TTD = 6 °F, steam saturation T = 115 °F. Backpressure = **3.0 inches Hg**.

2. Projected actual average Unit 4 spring, summer, fall backpressure with closed-cycle wet tower.

Parameter	May	June	July	August	Sept.	October	
average load, MW	196	201	211	219	217	224	Average MW Unit 4 load 2001-2004 for month indicated. Rated load is 235 MW per NYDEC air permit.
average monthly cooling water flowrate, gpm	110,000	110,000	110,000	110,000	110,000	110,000	Six F-488-6.0-6 plume-abated wet cells at 110,000 gpm per Marley SPX 10/11/05 and 10/12/05 clarifications.
mean monthly wet bulb temperature, °F	52	62	67	66	59	48	These are mean monthly wet bulb temperature for Newburgh, NY, period of record 1973-1995.
Effective approach temperature, °F	22	17.5	16	16.5	19.5	26	Marley SPX estimates 13 °F approach temperature for six F488-6.0-6 cells with 9-bladed fans with 250 hp motors for 1,100 MMBtu/hr heat rejection duty at 235 MW output. Effective approach temperature at 200 MW is 12 °F per 11/1/05 Marley wet bulb vs. range vs. approach temperature graph for Unit 4 cooling tower. Approach temperature increases as wet bulb temperature drops per Marley 11/1/05 graph (attached).
increase in cooling water temperature across condenser (range)	16.5	17	18	18.5	18.5	19	Unit 4 rated output is 235 MW (2,512 MMBtu/hr heat input). The range is 20 oF when heat rejection duty is 1,100 MMBtu/hr at 235 MW. Range is proportionate lower as load and heat duty drop (as long as tower flowrate is maintained at 110,000 gpm).
TTD between warm water out and steam saturation T, °F	6	6	6	6	6	6	6 oF is surface condenser terminal temperature difference (TTD) identified in Micheletti and Burns paper presented at EPA *Symposium on Technologies for Protecting Aquatic Organisms from Cooling Water Intake Structures*, May 2003, Arlington, VA.
steam condensation temperature, °F	96.5	102.5	107	107	103	99	Sum of cooling water temperature into condenser, cooling water T increase across condenser, and delta T between warm water out temperature and steam saturation temperature.
average steam turbine backpressure, in. Hg	**1.7**	**2.1**	**2.4**	**2.4**	**2.1**	**1.9**	Conversion of steam condensation temperature to steam turbine backpressure per steam tables for saturated steam.

Refined Calculations on Closed-Cycle Conversion Effect on Steam Cycle Thermal Efficiency

C. Annual Unit 4 Turbine Heat Rate (Efficiency) Penalty Resulting from Conversion to Closed-Cycle Wet Cooling:
(from GE exhaust pressure correction factor graph, Attachment B-2, Chp. 5, proposed Phase II TDD)

Month	Existing once-through cooling steam turbine backpressure		Closed-cycle wet cooling steam turbine backpressure		Net efficiency penalty of closed-cycle cooling (%)
	Backpressure (inches Hg)	Efficiency penalty (%)	Backpressure (inches Hg)	Efficiency penalty (%)	
January	<1.5	0.0	<1.5	0.0	0.0
February	<1.5	0.0	<1.5	0.0	0.0
March	<1.5	0.0	<1.5	0.0	0.0
April	<1.5	0.0	1.7	0.2	0.2
May	1.0	0.0	1.7	0.2	0.2
June	1.4	0.0	2.1	0.6	0.6
July	1.9	0.4	2.4	1.0	0.6
August	2.1	0.6	2.4	1.0	0.4
September	1.8	0.3	2.1	0.6	0.3
October	1.5	0.0	1.9	0.4	0.4
November	<1.5	0.0	<1.5	0.0	0.0
December	<1.5	0.0	<1.5	0.0	0.0
				Annual average:	**0.2**

Note: GE exhaust pressure correction factors for a fossil fuel steam turbine indicate maximum heat rate (turbine efficiency) is achieved between 1.0 and 1.5 inches Hg backpressure. Turbine efficiency degrades below 1.0 inch Hg and above 1.5 inches Hg following the flattest exhaust pressure correction factor curve for fossil fuel plant steam turbines (attached).

Refined Calculations on Closed-Cycle Conversion Effect on Steam Cycle Thermal Efficiency

D. Peak Unit 4 Turbine Heat Rate Penalty Resulting from Conversion to Closed-Cycle Wet Cooling:
(from GE exhaust pressure correction factor graph, Attachment B-2, Chp. 5, proposed Phase II TDD)

Peak once-through cooling steam turbine backpressure		**Peak closed-cycle wet cooling steam turbine backpressure**		
Backpressure (inches Hg)	Efficiency penalty (%)	Backpressure (inches Hg)	Efficiency penalty (%)	**Peak efficiency penalty of closed-cycle cooling (%)**
2.25	0.75	3.0	2.25	**1.5**

Attachment B

Marley BEST™ Version 2.41
Product Data: 6/27/2005

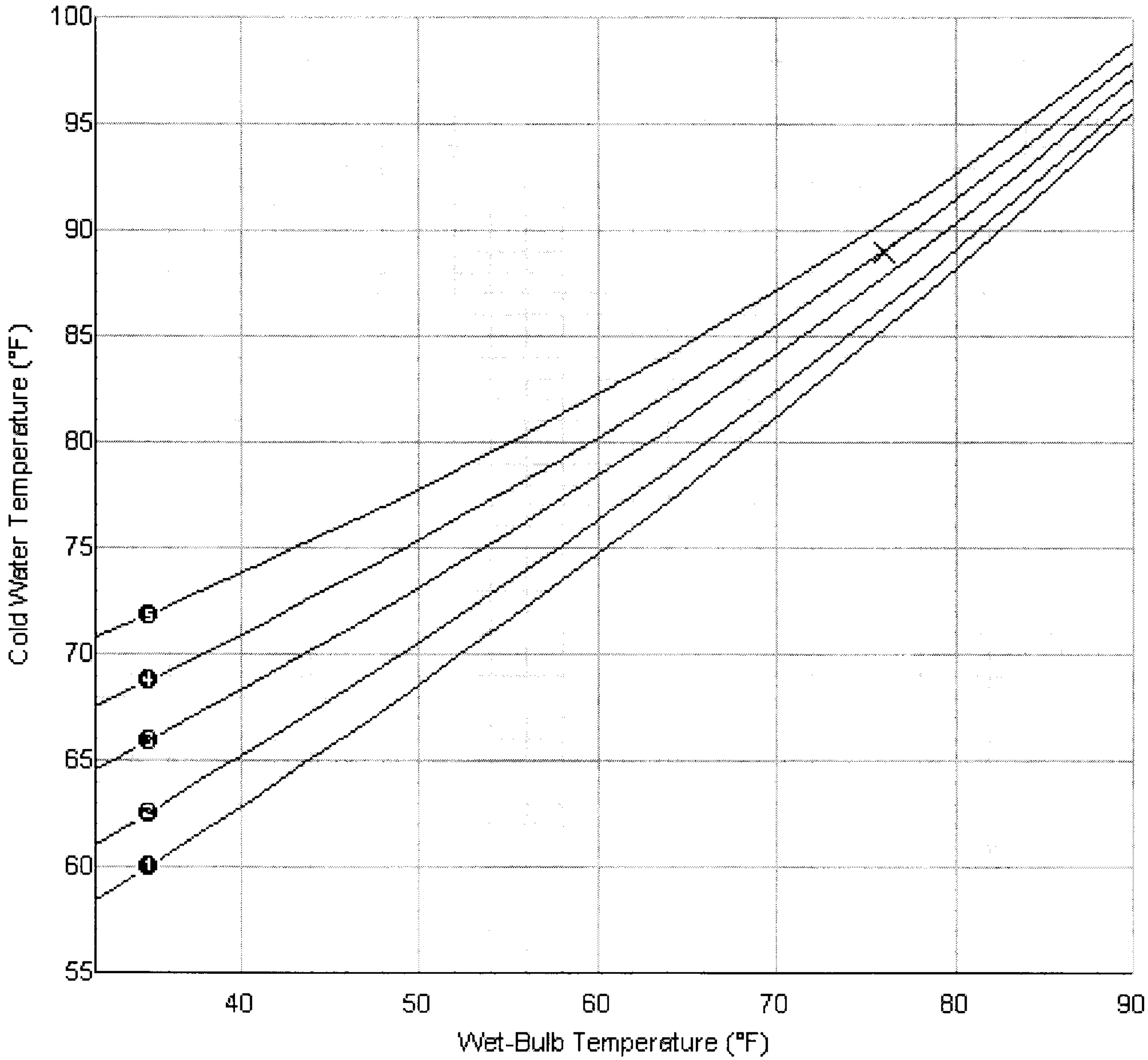
Optimization 1.opt
Revised 11/1/2005 10:05:12 AM by Joe Padilla

Customer

Contact

Marley Cooling Technolgies, Inc.
P.O. Box 4605
El Dorado Hills, CA
joseph.padilla@marleyct.spx.com

Joe Padilla
Tel 916-941-1232
Fax 916-941-1240



Definition

Model (ID 13)	F489A-4.0-6		
Fill	MC75 Log-4.0		
Eliminator	TU12C		
Louver	No louvers		
Fan	336HP7-9		
Stack	336'x14' Rflx/V Rib		
Speed Reducer	4000, 13.24:1		
Drive	301 Shaft		
Motor	1800 rpm, TEFC		
Closed Sides	0	Partitions	Yes
Closed Ends	2	Wind Walls	Yes
Air Inlet Guide	No		
Effective Air Inlet Ht.	10.00 ft		
Plenum Height	7.69 ft		

Design Conditions

Tower Water Flow	110000 gpm
Hot Water Temperature	109.00 °F
Cold Water Temperature	89.00 °F
Wet-Bulb Temperature	76.00 °F
Relative Humidity	50 %
Total Dissolved Solids	0 ppm
Altitude	0 ft
Inlet P.D. Vel. Heads	0
Outlet P.D. Vel. Heads	0
Motor Output	241 BHp

Curve Conditions

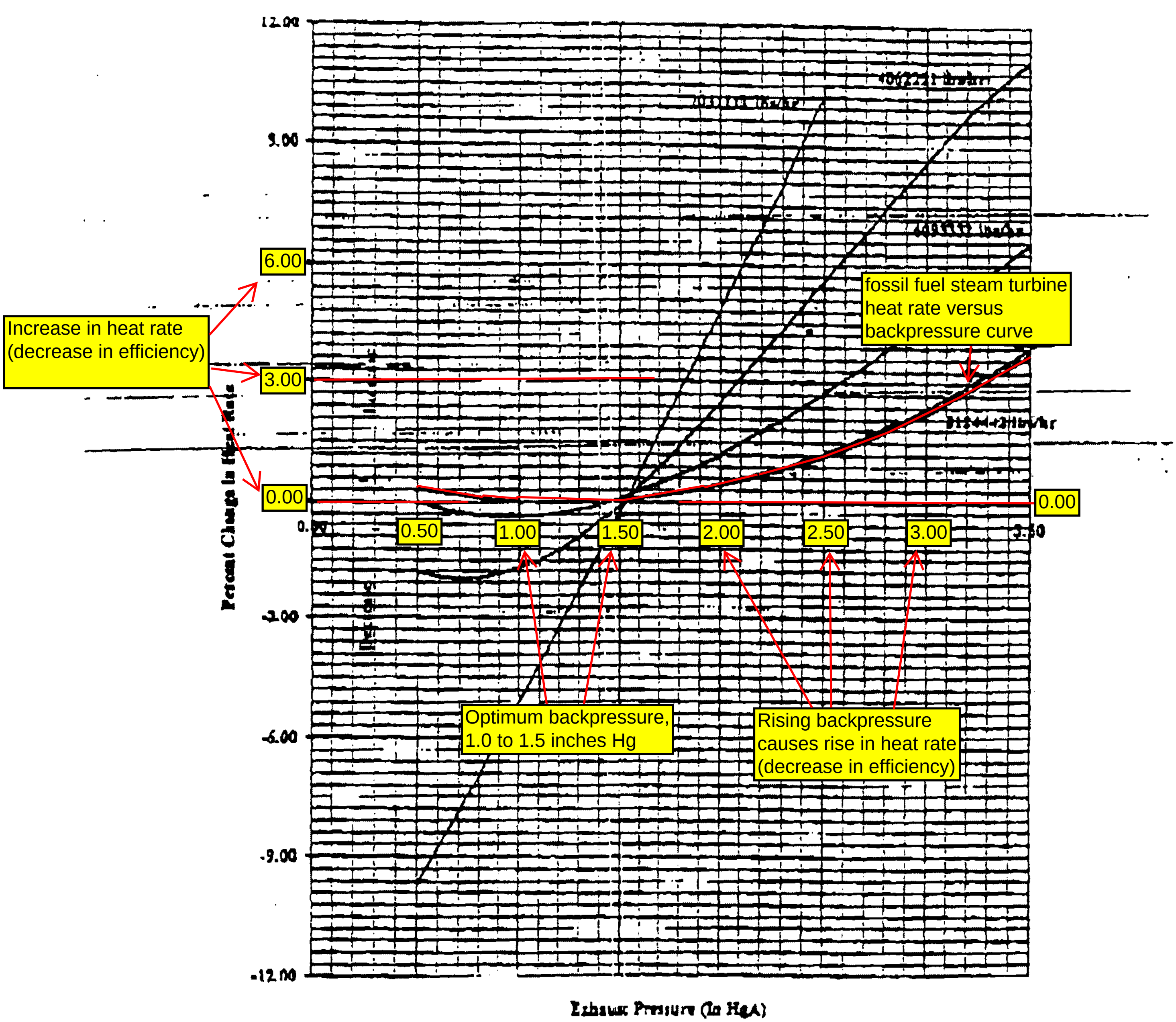
Tower Water Flow (100 %)	110000 gpm
Fan Speed (100 %)	134 rpm
Motor Output	241 BHp

Legend

1 12 °F Range
2 14 °F Range
3 17 °F Range
4 20 °F Range
5 24 °F Range
X Design Point

Fossil Fuel Steam Turbine Exhaust Pressure Correction Factor Curve from: Proposed 316(b) Phase II Technical Development Document, Chapter 5, Attachment B-2

Exhaust Pressure Correction Factors

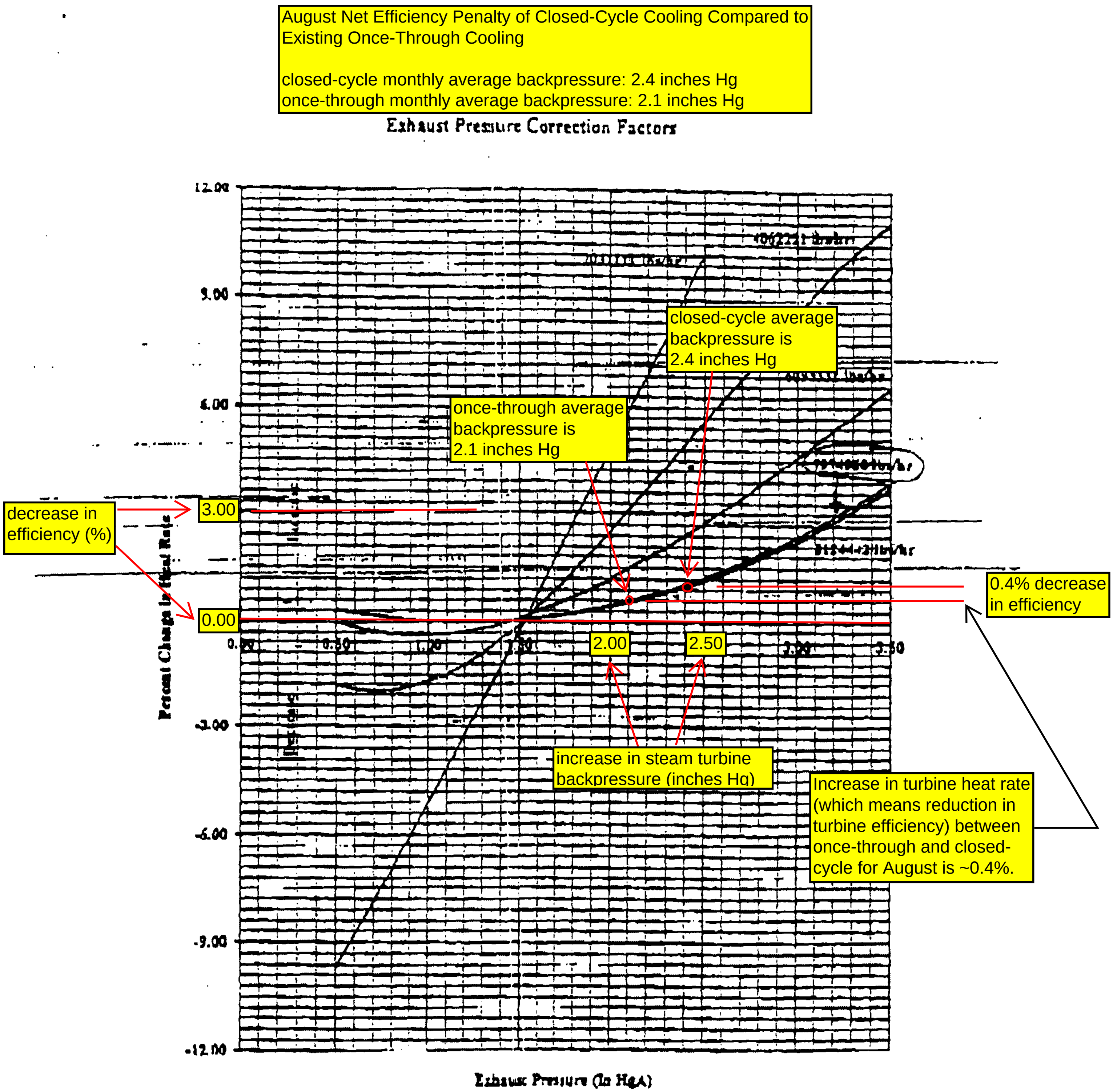


Method of Using Curve

Flows near curves are throttle flows at 987 psia and 1191.2 Btu/lb. These correction factors assume constant control valve opening. Apply the corrections to heat rates and kW loads at 1.5 In HgA and 0.5% MU.
The percent change in kW load for various exhaust pressures is equal to:

$$\frac{(\text{Minus \% Change in Heat Rate})100}{(100 + \text{\% Change in Heat Rate})}$$

These correction factors are not guaranteed.
GE, Schenectady, New York TB # 170X341 367HB259 Rev 1 1/25/94



Method of Using Curve

Flows near curves are throttle flows at 987 psia and 1191.2 Btu/lb. These correction factors assume constant control valve opening. Apply the corrections to heat rates and kW loads at 1.5 In HgA and 0.5% MU.
The percent change in kW load for various exhaust pressures is equal to:

$$\frac{(\text{Minus \% Change in Heat Rate})100}{(100 + \text{\% Change in Heat Rate})}$$

These correction factors are not guaranteed.
GE, Schenectady, New York TB # 170X341 367HB259 Rev 1 1/25/94

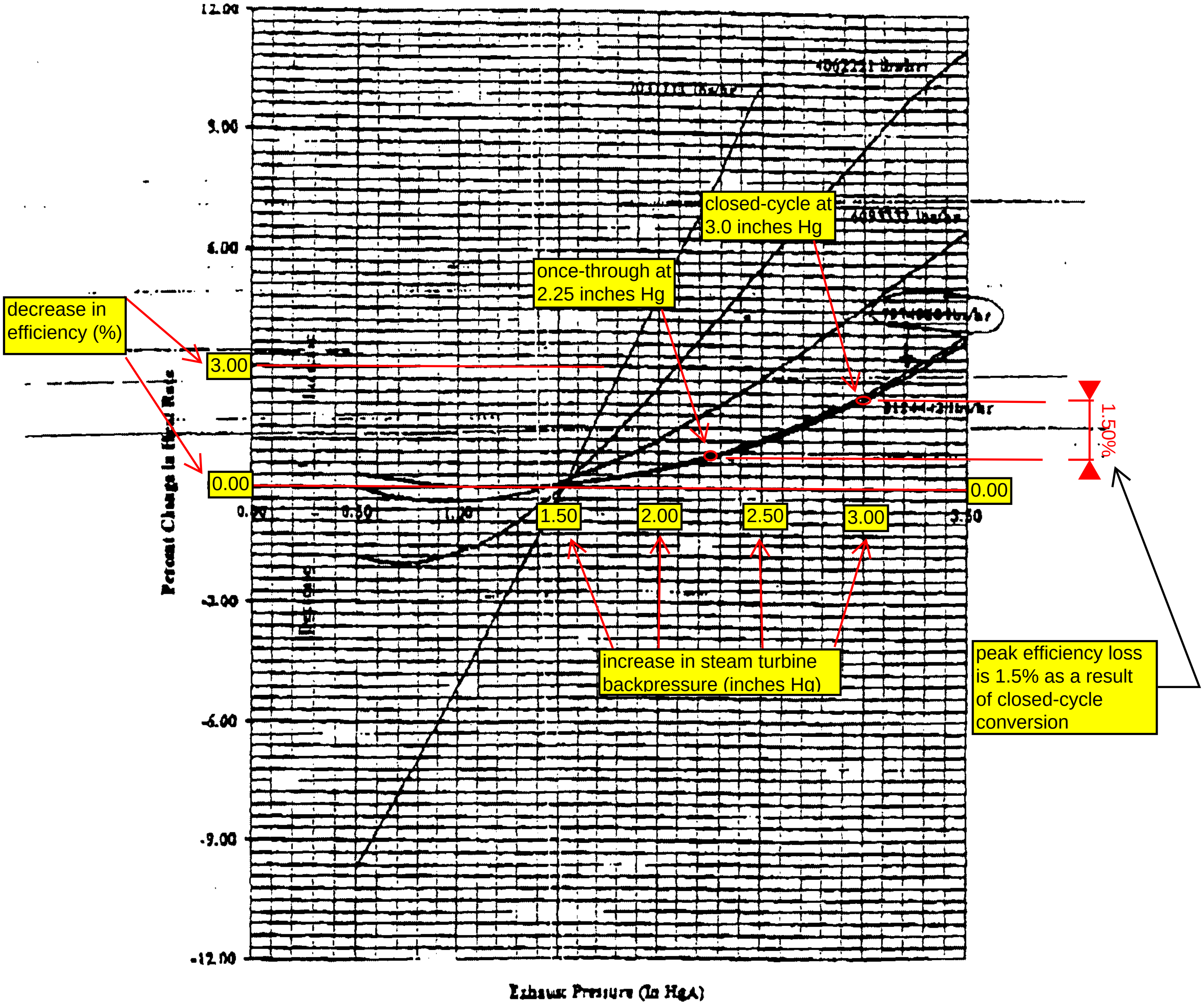
MAR 05 2001 13:20 FR TETR ... 84646 P.27/27
FILE No.537 03/01 '01 10:35

Peak Efficiency Penalty of Closed-Cycle Cooling Compared to Existing Once-Through Cooling

August 15, 2002

closed-cycle backpressure: 3.0 inches Hg
once-through backpressure: 2.25 inches Hg

Exhaust Pressure Correction Factors



Method of Using Curve

Flows near curves are throttle flows at 987 psia and 1191.2 Btu/lb. These correction factors assume constant control valve opening. Apply the corrections to heat rates and kW loads at 1.5 In HgA and 0.5% MU.
The percent change in kW load for various exhaust pressures is equal to:

$$\frac{(\textit{Minus \% Change in Heat Rate})100}{(100 + \% \textit{ Change in Heat Rate})}$$

These correction factors are not guaranteed.
GE, Schenectady, New York TB # 170X341 367HB259 Rev 1 1/25/94

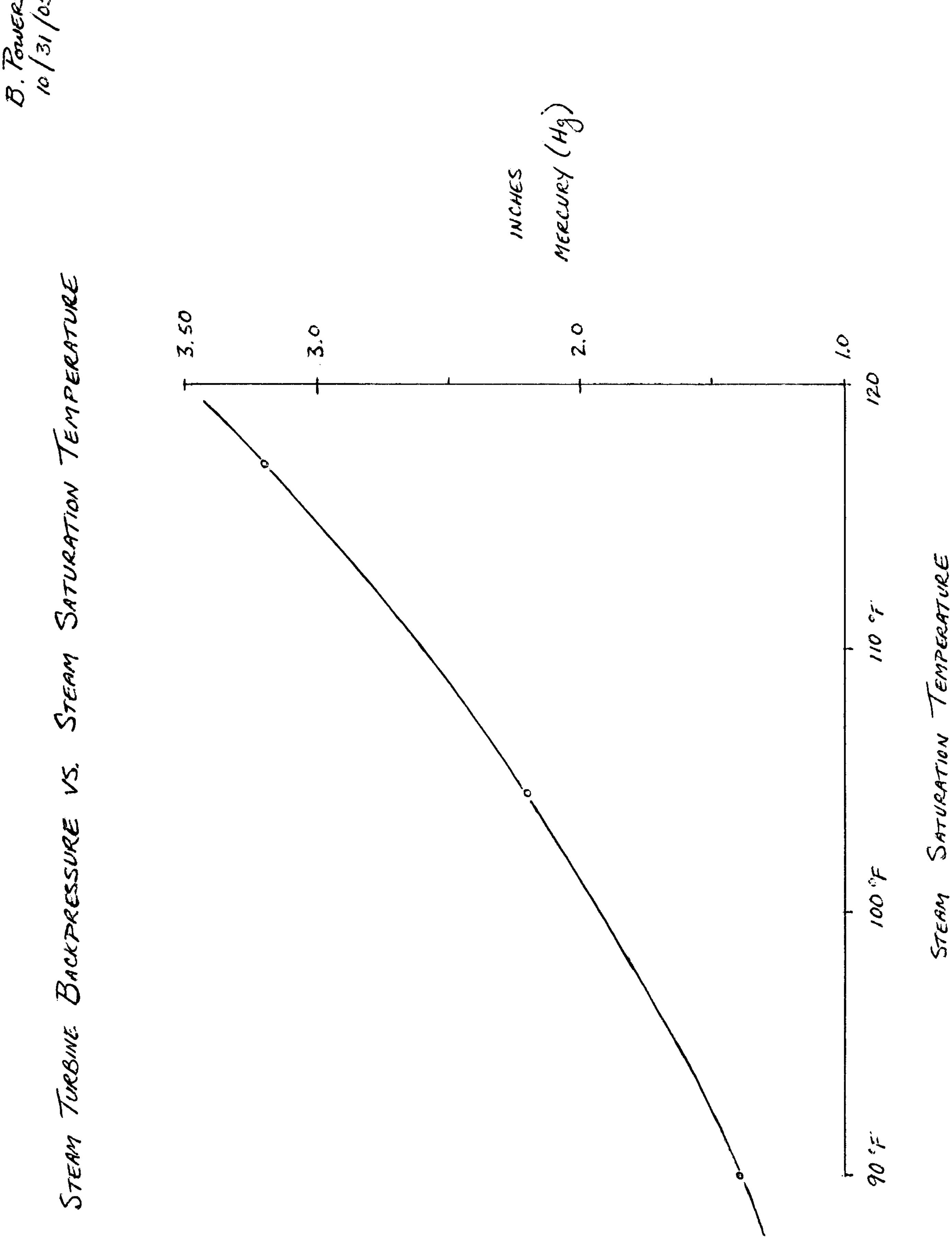

B. Powers
10/31/05
Steam Turbine Backpressure vs. Steam Saturation Temperature
Inches
Mercury (Hg)
3.50
3.0
2.0
1.0
120
110 °F
100 °F
90 °F
Steam Saturation Temperature

Exhibit 2

Synapse Energy Economics Report

Memorandum

TO: SIERRA CLUB

FROM: FRANK ACKERMAN

DATE: JANUARY 20, 2016

RE: COMMENTS ON DRAFT NPDES PERMIT FOR SCHILLER STATION

Introduction

EPA has issued a draft authorization for Schiller Station to discharge effluent into the Piscataqua River, under the National Pollutant Discharge Elimination System (NPDES). As part of the authorization, EPA proposes a determination that the Best Technology Available (BTA) for Schiller's cooling water intake structures (CWIS) is a wedgewire screen system, combined with other minor measures (limiting the through-screen water velocity, shutting down intake pumps when a generating unit is not operating, and scheduling annual maintenance outages to maximize reduction in entrainment methodology). EPA also considered closed-cycle cooling, but declined to designate this alternative as BTA.

This memorandum comments on several aspects of EPA's arguments in support of its BTA decision, focusing on Sections 10 – 10.4 (pages 148 – 167) of the EPA fact sheet supporting the draft authorization. Those sections present EPA's approach to the costs and benefits of CWIS options for Schiller, and explain the decision in favor of wedgewire screens.

The conclusion of this memorandum is that EPA has failed to justify its BTA decision. A re-examination of EPA's data and arguments, combined with analysis of other available documents, demonstrates that closed-cycle cooling is a superior alternative, offering much greater reduction in entrainment of aquatic organisms at an entirely affordable price. Three topics are addressed here: EPA's illogical "cost-cost" analysis; public-domain estimates of the likely cost of cooling towers at Schiller; and the best available estimates of the monetary value of the benefits of reduction in entrainment and impingement mortality.

EPA's "cost-cost" analysis is illogical

The analysis of BTA options in the EPA fact sheet is centrally concerned with costs and benefits. Indeed, the critical Section 10 of the fact sheet is titled "Consideration of BTA Option Costs, Cost-Effectiveness, and Comparison of Relative Costs and Benefits". Yet the analysis is written with at least one hand tied behind the analyst's back, since "PSNH has designated the technology cost information to be confidential business information" (fact sheet, 150). As a result, EPA offers no actual dollar figures, only ratios of one cost to another. Since there is extensive public information on the costs of these technologies, the discussion would have been better served by attempting to estimate costs from public documents.

Despite the nearly complete lack of relevant dollar figures, EPA's decision is based on details of the costs and benefits, making it difficult for others to evaluate. On the crucial judgment, the decision to favor wedgewire screens over closed-cycle cooling, EPA notes that the closed-cycle cooling option "is estimated to cost nearly 40 times more than any of the wedgewire screen options", while achieving only twice as much reduction in fish eggs and larvae entrainment mortality (fact sheet, 155). The conclusion drawn from this about closed-cycle cooling is that "its far greater costs, as compared to the fine-mesh wedgewire screen option, are not warranted by the additional margin of reduction in adverse environmental effects that it could achieve (fact sheet, 157).

This is not a logical deduction from the cost ratios and benefit ratios that EPA has presented. Rather, it makes a strong but implicit judgment about the low value of the environmental benefits at stake. Consider two monetary options, with the same cost and benefit profiles identified in this discussion. Plan A requires spending $1 on some protective measure to avoid $100 of damages; Plan B requires spending $40 to avoid $200 of damages. It is true that Plan B costs 40 times as much but saves only twice as much. It is also true that Plan A has a net value of $99 while Plan B has a net value of $160, making the more expensive plan a much better deal.

The only way to determine whether the Plan A / Plan B story applies to the Schiller CWIS options is to estimate actual dollar values for costs and benefits. In the absence of such estimates, nothing can be concluded from EPA's examination of relative costs. A "cost-cost" analysis of this type is normally inconclusive, in the absence of hard information about the relevant costs and benefits.

Cooling towers at Schiller might cost $28 - $34 million

Attached at the end of this document is a 2014 memorandum which I and my colleagues prepared for Sierra Club, estimating the cost of cooling towers at Schiller. Our estimate of $26 - $31 million was expressed in 2009 dollars; adjusting for inflation with the consumer price index, this is equivalent to $28 - $34 million in 2013 dollars, the standard used in EPA's analysis (fact sheet, 149). Our analysis is entirely based on documents in the public domain, which are available to EPA and other interested parties.

Combined with EPA's 40-to-1 cost ratio, our estimate implies that the fine-mesh wedgewire screen option would cost $700,000 - $850,000 in 2013 dollars. This can be compared to the one wisp of cost data in EPA's analysis, the statement that the price tag for "the fine-mesh wedgewire screen options (along with the specified BMPs)" is "a low seven-figure cost" (fact sheet, 158) – that is, more than $1 million, but perhaps not much more. Unless the BMPs are relatively expensive, this suggests that our estimate may be slightly lower than EPA's, but in the same ballpark.

As we explain in our 2014 memorandum, Public Service of New Hampshire, the owner of Schiller, is a subsidiary of Northeast Utilities, a large multi-state company. In 2012 its investments in plant and equipment were in the low *ten* figures (more than $1 *billion*), making it clear that cooling towers at Schiller were well within their means. Since then, only the names have changed: "The most visible change will be the new logos",[1] as both PSNH and its parent company have rebranded themselves Eversource Energy.

The fish are worth at least as much as the cost of cooling towers

On the benefits side, the principal difference between the cooling tower option and the best of the wedgewire screen options examined by EPA is that cooling towers lead to a reduction in fish and macrocrustacean entrainment mortality of about 80 million organisms per year (calculated from Table 10-B, fact sheet, 153). Any judgment about whether the costs of cooling towers are justified is, implicitly or explicitly, a judgment about the value of saving an additional 80 million organisms per year over and above the number saved by wedgewire screens.

As EPA accurately notes, the cost of a monetized assessment of benefits, meeting professional standards in environmental economics, would be prohibitive for a case of this magnitude (fact sheet, 161). However, to address exactly such questions, EPA launched a multi-year, national research project to assess the monetized value of fish affected by CWIS. Partial results, and a request for comments, were published in 2012.[2] That survey encountered extraordinary hostility from industry representatives, who alleged (unpersuasively, in my view) that, despite the elaborately careful academic preparation for the survey, EPA had somehow committed fatal methodological errors. As a result, EPA never converted the nearly-complete draft results released in 2012 into a final assessment.

In my comments on the draft survey, I pointed out that it was easy to fill in the blanks, completing the last few steps of the survey calculations on the assumption that the remaining data resembled the already-published parts.[3] The resulting national estimate of willingness to pay for reduced fish mortality can be expressed in terms of age-1 equivalents (A1E), as $5.00 per A1E using EPA's assumptions throughout, or $10.00 - $12.50 per A1E on modified versions of the calculation that I recommended.[4]

---

[1] Allie Morris, "Public Service of New Hampshire is now Eversource Energy", Concord (NH) Monitor, February 3, 2015, http://www.concordmonitor.com/news/work/business/15508210-95/public-service-of-new-hampshire-is-now-eversource-energy.

[2] See Federal Register 77, no. 113 (June 12, 2012), pages 34927-34931.

[3] My comments are available at www.regulation.gov, Docket ID no. EPA-HQ-OW-2008-0667-3021.

[4] These numbers do not appear in my comments, but are easily calculated as the ratio of total willingness to pay for policy options, divided by the reduction in A1E mortality achieved by those options. Monetary amounts were expressed in 2011 dollars, and should be increased by 3.6 percent to convert to 2013 dollars.

This is clearly not a finalized value, and could benefit from additional research. On the other hand, due to the abrupt halt in work on the EPA survey, this is the only available estimate at this time. It is clearly superior to a default estimate of zero, in the absence of an established value; it is also preferable to vague guesses about values, which do not necessarily rest on objective data or reproducible calculations. Until a substantial research effort creates a better value, my calculation remains the best available estimate.

In the current case, EPA expresses entrainment mortality in terms of total organisms. Entrainment and impingement studies performed at Schiller for PSNH in 2006-2007 found that in the 17 fish taxa that comprised 99 percent of entrainment, the annual entrainment was 143.9 million individuals, representing 673,725 adult equivalents.[5] In other words, there was 1 adult equivalent for every 214 individuals.

Using this ratio, the annual entrainment mortality reduction of 80 million individuals achieved by cooling towers rather than the best wedgewire screen option at Schiller would represent about 370,000 adult equivalents. Using my completion of the EPA willingness to pay survey, this mortality reduction would have a value in 2013 dollars of $1.9 million using EPA's assumptions, or $3.8 - $4.8 million using my preferred versions. The present value of 30 years of entrainment mortality reduction at these rates, using EPA's 5.3 percent real discount rate, is $30 million using the EPA assumptions, or $60 - $75 million using my alternatives. (The discount rate and the 30 year horizon are from the fact sheet, 150.)

In other words, the monetized value of reduced entrainment mortality is roughly equal to the cost of cooling towers, at the conservative valuation of fish (and additional non-monetized benefits of reduced fish mortality should tip the balance toward cooling towers). At my recommended valuation of fish, the net monetized benefit of cooling towers far exceeds the net benefit of wedgewire screens. There is no basis for EPA's undocumented certainty that the costs of cooling towers are clearly excessive in comparison to the benefits they achieve. Based on a hard look at the missing numbers, EPA should reconsider its decision and declare cooling towers to be BTA at Schiller.

---

[5] Normandeau Associates (2008), "Entrainment and Impingement Studies Performed at Schiller Generating Station from September 2006 through September 2007", page 54.

Memorandum

To: Sierra Club

From: Frank Ackerman, Tyler Comings, and Tommy Vitolo

Date: March 4, 2014

Re: Cost Analysis for Cooling Towers at Schiller Station

Introduction

This memo presents cost estimates for cooling towers at Schiller Station, and discusses economic achievability and other economic issues relevant to a "Best Technology Available" analysis under Section 316(b) of the U.S. Clean Water Act.

Cooling tower costs are calculated for Schiller operating at a capacity factor of 68 percent, the actual capacity factor at the time of the biological modeling cited below (October 2006 – September 2007). Operation of Schiller as a baseload power plant could lead to a higher level of energy-production, with proportionate increases in some (but not all) costs discussed here – and with impacts on aquatic organisms up to roughly 20 percent greater than those described below. Although a higher capacity factor does not appear likely in the near term, no enforceable limitations on Schiller operations have been proposed in the plant's permit application; if the permit is granted, much higher levels of output could resume at any time. Actual operations and costs could vary in either direction—for instance, the analysis by Bill Powers assumes a capacity factor of 50%.

The discussion of impacts, costs, and benefits of cooling towers is based on several sources: an engineering report prepared by Bill Powers, P.E.[1]; a biological report prepared by Dr. Paul H. Patrick[2]; and other previous research, in the context of 316(b) regulation.

Cooling Tower Cost Estimates

Our cost estimates include capital costs, operating and maintenance costs, construction outage costs and energy penalty.Table 1 summarizes our estimates for the net present value cost of conventional and plume-abated cooling towers at Schiller units 4, 5, and 6; the total costs range from $26 million (in 2009

[1] Bill Powers, P.E., "Declaration on Feasibility and Cost-Effectiveness of Cooling Tower Retrofits at Schiller Station," May 29, 2013.
[2] Petrudev, "Cooling Water Intake and Discharge Evaluations for Schiller Station," October 2013.

dollars) for conventional cooling towers to $31 million for plume-abated towers. (Powers notes that plume abatement would probably be required at Schiller.) The principal difference between the two estimates is the greater capital cost requirement for plume-abated towers.

We assumed that construction of the cooling towers would take place in 2013 with operation beginning in 2014. This unrealistically accelerated schedule is a worst case scenario for costs, in present-value terms. In reality, permitting and construction would require several years, so that the present value of costs would be lower. We calculate net present value for a 21-year period, including one year for construction (2013) and 20 years of operation (2014-2033). Tax depreciation was calculated on a 15-year straight-line basis. Further detail on the cost components is provided below.

Table 1: Net Present Value Cost of Cooling Towers at Schiller

NPV (2009$ millions, 2014-2034)	**Schiller 4-6, at 68% capacity factor**	
	Conventional	**Plume-abated**
Capital revenue requirement	$21	$26
Tax depreciation	($6)	($7)
Cooling O&M costs	$5	$5
Construction outage costs	$1	$1
Energy penalty	$6	$6
Total	$26	$31

Capital Costs

The engineering cost estimate for a cooling tower at Schiller is $25 million for a plume-abated tower and $20 million for a conventional tower.[3] We amortized these costs over the 20-year useful life of the towers. The resulting present value of amortized capital costs, using a nominal discount rate of 7.6 percent,[4] is $26 million for plume-abated towers and $21 million for conventional towers.[5] Since capital costs are independent of the level of production, these costs apply at any capacity factor. The after-tax

[3] Powers, p. 5.
[4] Kleinschmidt. Response to EPA Information Request: FirstLight Power Resources LLC, Mt. Tom Station. May 2011, p.17.
[5] All results are presented in 2009 dollars unless otherwise specified.

present value cost is $15 million for conventional and $19 million for plume-abated towers (i.e., capital cost net of depreciation, combining the first two lines of Table 1.)

Operating Costs

The operation and maintenance (O&M) costs of the cooling towers were based on an analysis of the Schiller Station performed for the Public Service Company of New Hampshire (PSNH), provided to the EPA, and used as a primary source in EPA's estimates for the Merrimack Station, also owned by PSNH,[6] converted to 2009 dollars.[7] The present value of O&M costs was estimated at $5 million over the 20-year life of the tower. As these are fixed O&M costs related to inspection and light maintenance performed at set intervals, they apply at any capacity factor.

Table 2: Annual Operation and Maintenance Costs (2009$)

	Costs
Years 1-5	$303,000
Years 6-15	$354,000
Years 16-20	$529,000

Source: PSNH, Synapse calculations

Construction Outage Costs

Much of the construction of a cooling tower can occur alongside an operating coal-fired power plant. Connecting the cooling tower to the plant, however, requires an outage period, during which the plant cannot generate electricity. If this connection process does not coincide with a previously scheduled outage, the operator forgoes revenue on the reduced generation and loses capacity payments, while avoiding the corresponding fuel and variable O&M costs.

Assuming one month of outage for connection,[8] we estimated that the plant would lose one month's capacity payment by going off-line for an additional month. The after-tax value of that payment is $232,000. There would also be lost generation, estimated at about 84,100 MWh. Avoided O&M at the plant was valued based on the generic variable non-fuel O&M costs of coal units of similar sizes to Schiller 4, 5, and 6 ($5.20 per MWh) and Schiller's reported fuel costs ($37 per MWh).[9] Energy market revenue

[6] EPA – New England, "Clean Water Act NPDES Permitting Determinations for the Thermal Discharge and Cooling Water Intake Structures at Merrimack Station in Bow, New Hampshire, NPDES Permit No. NH 0001465," Table 7-4, p. 153.
[7] Public Service Company of New Hampshire (PSNH EPA). Response to US EPA CWA §308 Letter. October 2008, p. 55-58.
[8] U.S. EPA, "Technical Development Document (TDD) for the Proposed Section 316(b) Phase II Existing Facilities Rule," April 2002, p. 4-6, 4-7.
[9] Coal costs are from EIA 923 data from 2012. Variable O&M costs are from North American Electric Reliability Corporation (NERC) Assessment for EPA in 2010. Expressed in 2009 dollars.

was valued at the Annual Energy Outlook 2013 (AEO 2013) forecasted wholesale price for the Northeast region, $48 per MWh.

The projected revenue exceeds O&M costs by approximately $6 per MWh, providing an estimate of the pre-tax net revenue that would have accrued to PSNH, in the absence of the construction outage. However, PSNH would also have paid taxes on that profit at their marginal rate (40.5%).[10] Shown in **Error! Reference source not found.**, these elements combine for an estimated after-tax cost of $684,000 due to the cooling tower construction outage. These construction outage costs are the same in present value terms since they are assumed to occur at once and are not discounted.

These estimates assume that cooling tower construction at Schiller would require an additional one-month outage. If the Company can time the construction to coincide with an outage that was already planned, there might be no new construction outage costs of any sort. Since construction outage costs are the smallest category shown in Table 1, this would have only a minor impact on the overall costs of cooling towers at Schiller.

Table 3: Construction Outage Costs (2009$)

Construction Outage	
Lost revenue	$4,435,000
Avoided O&M	$3,284,000
Pre-tax loss (lost revenue – avoided O&M)	$1,151,000
Net cost (after-tax loss)	**$684,000**

Source: PSNH, Abt Associates, EIA, NERC

Energy Penalty Costs

The installation of cooling towers leads to a small loss of net generation at the plant for two reasons: first, the increased temperature of condenser water leads to a loss of boiler efficiency or "energy conversion penalty," and second, additional energy is required to run the cooling towers themselves, called "parasitic loss." Bill Powers' engineering analysis projected average parasitic losses of 1.21 percent, equal to 1.7 MW.[11] The energy conversion penalty was projected to lower net generation by 0.2 percent on average and 1.5 percent during peak summer months (0.3 MW and 2.2 MW, respectively).[12]

[10] Abt Associates. Cost and Affordability Analysis of Cooling Water System Technology Options at Merrimack Station. September 14, 2011.
[11] Powers, p. 9.
[12] *Ibid.*

Table 4: Energy Penalty

	Annual Average MW	Summer Peak MW
Energy conversion penalty	0.3	2.2
Parasitic loss	1.7	1.7
Total energy penalty	**2.0**	**3.9**

Source: Bill Powers, P.E., "Declaration on Feasibility and Cost-Effectiveness of Cooling Tower Retrofits at Schiller Station," May 29, 2013.

This energy penalty leads to revenue losses, as shown in Table 1. There are losses of both capacity and energy revenue. For capacity revenue, the energy penalty means a reduction in the capacity that Schiller could bid into the New England Forward Capacity Market (FCM). In order to estimate the change in capacity market revenue, we applied the summer peak capacity reduction (from Table 4) year-round, multiplied by an assumed price of $2.79 per kW-month for each year (in 2009 dollars), which is consistent with the latest FCM auction results.[13]

For energy revenue, we converted the energy penalty capacity reduction (from Table 4) to MWh by assuming an annual capacity factor of 68 percent. That is, the reduction in generation is assumed to be proportional to the reduction in capacity, under either scenario. The annual generation penalty was then multiplied by the wholesale electricity price projections for the Northeast from AEO 2013 to estimate the lost revenue recovered by the plant.

Once the cooling towers are operational, the plant must burn the same amount of fuel and incur all other variable O&M costs as before the retrofit when operating, even though the energy penalty has reduced its capacity. As a result, the plant's pre-tax profits will decrease by the full amount of the lost capacity and energy market revenues, since the same amount of fuel and other variable O&M costs would be required to recover the lower amount of revenue. As with the reduced generation during the construction outage, the after-tax losses are somewhat smaller, because the Company also avoids the taxes that would have been paid on the lost profits. The energy penalty costs are over $500,000 per year, on average, and amount to $6 million in net present value at a 68 percent capacity factor (Table 1).

[13] ISO-New England Forward Capacity Market results: http://www.iso-ne.com/markets/othrmkts_data/fcm/cal_results/. These were adjusted from delivery years (e.g. 2016/2017) to calendar years and for inflation.

Economic Achievability of Costs of Cooling Towers

The cost of cooling towers at all three Schiller units is an estimated $26 million (conventional) - $31 million (plume-abated) in NPV, spread over the next 20 years (Table 1, above). Schiller is owned by PSNH, a regulated utility, whose corporate parent is Northeast Utilities (NU).

NU also owns Connecticut Light and Power, NSTAR, and Western Massachusetts Electric Company, making it the largest electricity distributor in New England. In 2012, the company held $28.3 billion in assets, received operating revenues of $6.3 billion and invested $1.47 billion in plant and equipment.[14] For the year, NU reported net income of $533 million, and issued debt totaling $850 million.[15] In 2012, PSNH alone had revenues of over $1 billion.[16] Thus the costs of cooling towers at Schiller are clearly affordable for NU or even for PSNH alone. It seems clear that a company of this magnitude can afford the $31 million (or less) net present value cost of a cooling tower at Schiller; that cost is less than half of one percent of the company's annual revenues. If financed entirely through debt, the annual interest costs would be $2 million – $3 million.

This discussion does not address the question of the overall profitability of Schiller. For this analysis we are assuming that PSNH is interested in continuing to operate the Schiller facility. Under that assumption, cooling towers are obviously affordable for the plant's owner.

Since Schiller is operated by a regulated utility, the costs of cooling towers would be passed on to ratepayers in PSNH's territory. However, these costs would result in only a very small rate increase. Based on PSNH's 2012 retail revenue of $946 million, the increase in annualized costs (including capital, O&M, energy penalty and construction outage costs) would mean a rate increase of no more than 0.3 - 0.4 percent for PSNH customers. For example, a customer bill that previously amounted to $100.00 would rise to $100.30 - $100.40. Concerns have been raised about the broader impact of current PSNH rates on its customers, an issue beyond the scope of this memo. It is clear, however, that the minor expense of cooling towers at Schiller, for a company of this size, would cause only a minimal change in rates, and hence only a minimal change in customer response to PSNH rates.

Cost-effectiveness of Cooling Towers

EPA uses the term "cost-effectiveness" to refer to two different kinds of analyses: (1) whether a selected option is the least expensive way of getting to the same (or nearly the same) performance goal; and (2) a comparative assessment of the cost per unit of performance by different options.[17] In this case, EPA has

[14] Northeast Utilities Form 10K, United States Securities and Exchange Commission, Fiscal Year 2012.
[15] *Ibid.*
[16] *Ibid.*
[17] EPA, NPDES Determinations for Merrimack, p.129.

already determined that closed-cycle cooling systems "are the most effective means of protecting organisms from I&E [impingement and entrainment]."[18] As Bill Powers concludes,

> "Adding closed-cycle cooling will cut aquatic mortality associated with Schiller Station by approximately 95 percent. No other mechanisms short of plant outage during entrainment season can reduce the aquatic impacts to a level commensurate with closed-cycle cooling."[19]

This conclusion precludes a formal analysis of cost-effectiveness: Powers reports that there are no other mechanisms that achieve nearly the same performance, and hence there is no scope for comparative assessment of the cost per unit of performance by different options.

Thus it does not appear necessary or appropriate to conduct a formal analysis of cost-effectiveness. There are no other options that get close to the same results; this was the basis for EPA's decision that cost-effectiveness would not be a useful criterion at Merrimack.[20] As the discussion of economic achievability, above, shows, if PSNH chooses to continue operating Schiller station, then it can clearly afford the cost of cooling towers – which EPA has declared to be the most effective means of protection of aquatic life. Moreover, the impacts on electricity rates will be minimal.

Comparison of Costs and Benefits

The costs of cooling towers, and their economic achievability, are documented above. The benefits of cooling towers are, according to the EPA, a 97.5 percent reduction in aquatic impingement and a 95 percent reduction in entrainment mortality.[21] The best estimates of aquatic mortality at Schiller, and the mortality that would be avoided by cooling towers, are shown in **Table 5**.

Table 5. Avoidable I&E Mortality Compared to Cooling Tower Costs, Schiller

Cooling Tower Type	Fish impinged	Fish entrained	Macrocrustaceans impinged	Macrocrustaceans entrained	Net Present Value of Cooling Towers ($2009 millions)
Conventional	5,231	138,131,000	12,333	1,242,690,000	26
Plume-abated	5,231	138,131,000	12,333	1,242,690,000	31

Source: Petrudev 2013. NPV of cooling towers from Table 1; entrainment estimates are rounded to 6 significant figures.

[18] EPA, Economic and Benefits Analysis of Proposed Section 316(b) Phase II Existing Facilities Rule, as quoted in Powers, op.cit., p.13, n.46.
[19] Powers, p.16.
[20] EPA, NPDES Determinations for Merrimack, p.168.

[21] EPA, Technical Development Document for the Proposed Section 316(b) Phase II Existing Facilities Rule, March 28, 2011, p. 2-19.

Entrainment accounts for the vast majority of affected organisms, including well over 100 million fish, and more than 1 billion macrocrustaceans (lobster and several species of crabs).

Thus the 97.5 percent of impingement and 95 percent of entrainment mortality that would be saved by cooling towers amount to more than 1.3 billion total organisms. The cooling towers analyzed in this memo would presumably save this number of fish and crustaceans each year, for at least the 20-year assumed lifetime of the investment: more than 26 billion total organisms. The comparison of costs and benefits, therefore, consists of a comparison of a NPV cost of $26-31 million on the one hand, and avoided mortality of 26 billion fish and crustaceans, on the other hand.

Comments on EPA's Section 316(b) Stated Preference Survey

Dr. Frank Ackerman
Stockholm Environment Institute-US Center, Tufts University
July 10, 2012

EPA's proposed standards for cooling water intake structures at existing facilities, published in 2011, were based on an incomplete quantification of costs and benefits of regulatory proposals. Although relatively complete data were developed for costs of regulatory options, the description of many important benefits, including most non-use benefits, was only qualitative.

In order to extend the quantification of benefits, EPA has undertaken a stated preference survey, estimating willingness to pay (WTP) for improved protection of fisheries affected by cooling water intake structures. Survey results were released in June 2012, described in detail in the "Survey Support Document - in Support of Section 316(b) Stated Preference Survey Notice of Data Availability" (Support Document).

In these comments I discuss the implications of the stated preference survey for regulatory analysis and evaluation of proposals. The principal points I will make are:

- With this survey, EPA has taken an important step forward in evaluation of costs and benefits of cooling water intake regulations.
- It is more appropriate to use the national, rather than regional, estimates from the survey.
- Baseline mortality at out-of-scope facilities should not be included in evaluation of the effectiveness of regulation at in-scope facilities.
- The survey results suggest that all four regulatory options considered in 2011 have benefits that exceed their costs by billions of dollars.
- The more protective regulatory choices, Options 2 and 3, have much greater net benefits than the looser regulations of Options 1 and 4.
- The favorable benefit-cost comparison for these regulatory options weakens the case for site-specific analyses at each facility. If site-specific analyses are required, EPA should create default estimates of WTP for such analyses, based on this survey.

The importance of the survey

EPA's analysis of cooling water intake regulation in 2011 attempted to compare costs and benefits of the proposed options. Yet despite detailed documentation and calculation, it exhibited a common weakness of such cost-benefit comparisons: the cost estimates were relatively complete, but the quantified benefit estimates were fragmentary. This is not surprising, since the two sides of the balance are inherently asymmetrical. Costs often involve equipment purchases and construction, areas in which engineering and economic calculations can yield meaningful answers. Benefits, in contrast, often involve protection of life, health, natural ecosystems, biodiversity, and other important but priceless values.[1]

In such circumstances, there is little significance to the finding that the (relatively complete) estimates of costs exceed the (extremely incomplete) quantified, monetized estimates of benefits – as was the case with EPA's 2011 analysis of cooling water intake regulation. Such an asymmetrical bottom line cannot tell us whether complete costs exceed complete benefits, or whether hard-to-quantify benefits are more important than costs.

The stated preference survey is a giant step forward in this respect. It does not necessarily resolve all the questions about quantifying environmental benefits, but it provides a valuable new data source describing key aspects of public sentiment and preferences about fisheries protection. The survey estimates of WTP allow a less asymmetrical comparison of costs and benefits. Despite some differences of approach that are discussed below, the most important comment on the stated preference survey is that EPA should be commended for advancing the state of knowledge on the issue.

National rather than regional estimates should be used

The survey develops both national and regional estimates of WTP for four attributes of fisheries protection. The national estimates should be used for policy analysis, for several reasons.

First, it is conceptually and analytically simpler to use a single set of estimates, and the regional differences in WTP are generally not statistically significant. Exhibit II-10 of the support document presents 16 regional "prices" (for four attributes in four regions), of which only one is outside the 90% confidence interval for the corresponding national price – namely, the high value for fish saved in the Pacific region.

Second, the benefit of protecting ecosystems and wildlife is not a strictly local or regional matter. In a study of the geographic scope of non-use value, John Loomis found that

> While benefits per household do exhibit a statistically significant decrease with distance from the wildlife habitat, aggregate benefits are still substantial at 1,000 miles from the public good … on average, measuring only the benefits at the state level would result in just 13 percent of the national total public good benefits…[2]

The non-local nature of environmental preferences and beliefs is evident in many contexts. The Exxon Valdez accident mattered to people far beyond Alaska; concern about the Deepwater Horizon oil well blowout was not limited to states bordering the Gulf of Mexico; appreciation of the Grand Canyon is not restricted to Arizona. As Loomis makes clear, non-use benefits decline only slowly with distance, and remain important across long distances and state boundaries.

[1] Frank Ackerman and Lisa Heinzerling, *Priceless: On Knowing the Price of Everything and the Value of Nothing* (New York: The New Press, 2004).
[2] John B. Loomis, "Vertically Summing Public Good Demand Curves: An Empirical Comparison of Economic versus Political Jurisdictions." *Land Economics* 76(2), 2000, pages 312-21; quote from pages 319-29.

Finally, the regional boundaries used in the stated preference survey do not correspond to the regions used in EPA's 2011 analyses, despite the misleading similarity of names in some cases. Therefore, regional valuations from the survey cannot be directly compared to regional costs developed in the earlier analyses.

In the data and documents developed by EPA to support the ruling in 2011, in-scope facilities were assigned to one of seven regions. Five coastal regions "include facilities that withdraw cooling water from estuaries, tidal rivers and ocean facilities" (EEBA[3], p. 1-3). The Great Lakes region includes facilities withdrawing cooling water from the Great Lakes and connecting channels (such as the Detroit River or the Saint Lawrence River). The Inland region "includes all in-scope facilities that withdraw water from all inland waterbodies (excluding those included within the Great lakes Region) regardless of geographical location. There are 669 such facilities in 39 states…" (EEBA, p.1-4).

The coastal regions were based on National Marine Fisheries Service regions: North Atlantic stretches from Maine through Connecticut; Mid-Atlantic includes New York through Virginia; South Atlantic is North Carolina through the east coast of Florida; Gulf of Mexico is the west coast of Florida through Texas; "California" includes California, Oregon, Washington and Hawaii (Alaska is excluded from the analysis.) In practice, the only in-scope facilities in "California" are manufacturing facilities in the state of California and four facilities in Hawaii (EEBA, p.1-3). California's coastal power plants are covered by state regulation and hence excluded from this analysis, and there are no in-scope coastal facilities in the Northwest that are expected to remain in operation under the new regulations.

For the stated preference survey, in contrast, regions were defined by state rather than by source of cooling water (Support Document, Exhibit II-3). The Northeast includes coastal states from Maine through Maryland and the District of Columbia, plus Vermont. The Southeast includes coastal states from Virginia through Texas. The Pacific region is California, Oregon, and Washington (Hawaii and Alaska were excluded). The Inland region is the remaining 25 states of the contiguous United States, i.e. those that have no ocean coasts (excluding Vermont).

Thus the natural-sounding identifications between the two sets of regions are not strictly accurate. The survey's Inland region might appear comparable to the EEBA's Inland plus Great Lakes regions – but these EEBA regions include all non-coastal facilities, including those in coastal states. The survey's Inland region consists of 25 states, while EEBA's Inland region includes facilities in 39 states.

In terms of state boundaries, the survey's Northeast region corresponds to EEBA's North Atlantic plus Mid-Atlantic regions, with two exceptions: the survey's Northeast excludes Virginia and includes Vermont, while EEBA does the opposite. Likewise, the survey's Southeast region almost corresponds to EEBA's South Atlantic plus Gulf of Mexico, except that Virginia is Southeast in the survey and Mid-Atlantic in EEBA. In addition, the survey's Northeast and Southeast regions include plants classified as Inland in EEBA, as noted above.

---

[3] *Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule*, EPA 821-R-11-002, March 28, 2011.

The mismatch of regions between the two documents may be most extreme in the Pacific. The survey's Pacific region consists of the states of California, Oregon, and Washington; the principal in-scope facilities in the EEBA's "California" region are located in Hawaii, a state that was excluded from the survey. An additional issue involving data for the Pacific region is discussed in the next section.

As a result of these differences in definition, the baseline mortality by region differs significantly between the two documents, as shown in Table 1.

Table 1. Baseline mortality - 2012 survey vs EEBA					
Units: millions of A1E					
Survey regions			*EEBA regions*		*Difference*
Northeast	964.87		North Atlantic, Mid-Atlantic	1050.06	-85.19
Southeast	722.97		South Atlantic, Gulf of Mexico	169.04	553.93
Pacific	385.99		California	36.83	349.16
Inland	462.29		Inland, Great Lakes	932.99	-470.70
Total	2536.12		Total	2188.92	347.20
Sources: Survey Document, Exhibit II-11; EEBA, Tables 3-1, 3-3, 3-5, 3-7, 3-9, 3-11, 3-13)					

Note that the redefinition of regions has shifted a large amount of baseline mortality out of Inland, and a smaller amount (perhaps representing coastal Virginia) out of Northeast, into Southeast. Most of the baseline mortality in the survey's Southeast region must fall in the EEBA's Inland region – that is, it occurs at inland facilities in southeastern coastal states. Only half of the baseline mortality in EEBA's Inland and Great Lakes regions occurs in the survey's Inland region.

In developing baseline mortality reductions for the survey's newly defined regions, EPA used estimates based on state-level data on actual intake flow (Support Document, page 38), in effect assuming that the relationship between intake flow and baseline mortality is constant within each region. This underscores the limitations of the regional analysis in the survey, and strengthens the arguments for basing any policy evaluations on the national survey data.

Only in-scope facilities should be included in the analysis

Table 1 also shows that the national totals of baseline mortality are quite different between the two analyses; the difference is almost identical to the change in the Pacific/California region.

The much greater baseline A1E mortality in the Pacific region in the survey, compared to the California region in EEBA, is almost entirely due to a change in classification of coastal California power plants. When calculating the percent of fish saved by the four regulatory options (Support Document, Exhibit II-11), EPA included all Pacific facilities, including coastal power plants in California. According to EPA[4], the survey's estimate of baseline mortality in the Pacific, 385.99 million A1E losses (see Table 1) consists of:

> 347.21 million at coastal California facilities (already covered by state regulation, and hence not in scope for proposed federal regulation);
>
> 36.78 million at other coastal facilities (mainly Hawaii); and
>
> 1.95 million at inland California, Oregon, and Washington facilities.

The second of these categories is almost identical to baseline mortality in EEBA's "California" region, and the third is a consequence of the redefinition of Inland facilities. The dominant factor is the first of these categories, i.e. the large baseline mortality at out-of-scope California coastal power plants. It accounts almost exactly for the difference between the EEBA and the survey document in total national baseline mortality – and it represents almost 14 percent of the national total in the survey version of the data.

The ambiguity in the range of facilities that are included would be less important if WTP were expressed in terms of absolute numbers of fish saved, e.g. WTP per numerical quantity of A1E baseline mortality avoided. Expression of the survey-based estimates as WTP for absolute numbers would also simplify application to regional or local analyses, as discussed below. Since, however, EPA has thus far expressed WTP for mortality reduction in terms of percentages, it becomes necessary to ask: percentages of what?

It makes no sense to include a large quantity of out-of-scope impacts when calculating WTP for a percentage of fish saved by regulatory options. EPA's explanation of this decision says "EPA took a conservative approach to assigning baseline A1E losses to the Pacific region when calculating its preliminary estimates of percent fish saved."[5] This procedure is "conservative" only in the sense of causing a reduction in the percent saved. Under this definition, where 86 percent of baseline mortality occurs at in-scope facilities and 14 percent occurs elsewhere, a regulatory option that saves every fish and reduces in-scope mortality to zero would be misleadingly described as saving only 86 percent of the fish. By the same logic, it would be more conservative to include even more out-of-scope fish mortality, perhaps from Alaska – thus making a perfectly protective regulation that saves every in-scope fish look even less than 86 percent effective.

Common sense and ordinary usage of the English language imply that a regulation saving every affected fish should be described as 100 percent effective, not "conservatively" ratcheted down to an arbitrary figure such as 86 percent. This can be achieved by removing the out-of-scope California baseline mortality from the national total, restoring the EEBA total of 2,189 million A1E. (Note that this total is also used in the Support Document, in Exhibit II-2, p.16.)

The effect of this correction is shown in Table 2, presenting the percent of baseline A1E mortality eliminated by each of the regulatory options. The first column shows mortality reduction as reported by EPA (Support Document, Exhibit II-11); the second column shows the same data recalculated with the corrected national total. That is, the second column shows

[4] E-mail from Erik Helm, June 20, 2012, previewing calculations in a forthcoming EPA memo.
[5] E-mail from Erik Helm, June 20, quoting the relevant paragraph in the forthcoming EPA memo.

mortality reduction as a percentage of in-scope baseline mortality. The numbers in the first column are 14 percent lower than the numbers in the second column; as a result, WTP estimates based on the first column are 14 percent lower than estimates based on the second column. (The third column expresses the effectiveness of each option relative to Option 3, a ratio that is used in calculations below).

Table 2. Baseline A1E losses eliminated by regulatory options

	percentage reduction		
	As reported	Corrected	Ratio to Option 3
Option 1	24.25	28.09	0.305
Option 2	78.13	90.53	0.984
Option 3	79.39	91.99	1.000
Option 4	23.75	27.52	0.299

As reported - Support Document, Exhibit II-11
Corrected - restricted to in-scope facilities (see text)

WTP results imply multi-billion-dollar benefits for all regulatory options

EPA discusses in some detail the methods for estimating WTP (Support Document, pages 32-36), but does not present a numerical estimate of the total dollar value of WTP. Analysis of the survey results leads to "implicit prices" for each of four attributes, defined as average annual household WTP for a one percentage point improvement in that attribute (Support Document, Exhibit II-10).

The four attributes – commercial fish populations, all fish populations, fish saved by a regulatory option, and aquatic ecosystem conditions – need not be correlated with one another, and are modeled as independent outcomes. The survey design ensures that respondents are evaluating each attribute independently of the others (Support Document, pages 33-34). Therefore, the appropriate measure of household WTP for a regulatory option is the sum of the contributions from all four attributes. The contribution of each attribute is the implicit price of the attribute, multiplied by the percent improvement in the attribute due to the option. This is made clear by the equation on page 33 of the Support Document.

EPA then makes a puzzling suggestion, exploring the possibility that WTP could be based solely on one attribute, the percentage of fish saved (Support Document, page 37). As EPA notes in that context, this amounts to assuming that regulatory options have zero effect on the other three attributes – an unlikely assumption that EPA does not attempt to support. It is briefly suggested that this assumption is "conservative" and might perhaps offset other biases in WTP estimates; there is, however, no discussion of the size of this "conservative" truncation of the WTP calculation, or estimation of the size of other biases. As with the inclusion of out-of-scope baseline mortality, discussed above, there is no justification for arbitrary changes in a well-defined methodology in order to seem "conservative." In the absence of any specific justification for this approach, it remains appropriate to estimate WTP for all four attributes. Nonetheless, WTP on EPA's proposed "conservative" basis is calculated below and compared to more appropriate estimates of total WTP.

Two gaps in the analysis prevent a definitive calculation of WTP for each option: EPA has not yet completed the analysis of potential non-response bias in the survey, except for the Northeast region; and EPA has estimated the percent improvement due to regulatory options for only one attribute, the number of fish saved by the option (i.e. reduction in baseline mortality). It is, however, possible to perform illustrative calculations of WTP under plausible assumptions about the missing data.

Non-response bias

Regarding non-response bias – that is, the possibility that households that did not respond to the survey have different preferences and values from the responders – there is no guarantee about the size or direction of this effect. Since non-responders might have either larger or smaller WTP than those who responded, the correction for non-response bias could either raise or lower the estimates. In the Northeast study, non-responders evidently had slightly higher WTP, so correction for this bias raises the estimates of WTP (compare Support Document, Exhibits II-10 and II-13; the key data are reproduced in Table 3 below).

Despite the lack of national data on non-response, there are two plausible hypotheses that are easy to evaluate: either there is no bias (non-responders and responders have identical preferences), or the Northeast's biases are typical (national non-response bias is proportional to Northeast non-response bias).

Implicit prices for the four attributes are shown in Table 3, illustrating the effect of these two hypotheses. In the Northeast, correction for non-response bias raised estimates of WTP for all four attributes, so the no-bias national estimates are lower than the Northeast-bias-corrected national estimates. The calculations presented below use the WTP estimates in the last two columns of Table 3.

Table 3: WTP and non-response bias

Annual average household WTP for one percentage point improvement in attribute

Attribute	*Northeast*			*National*	
	Unweighted	Weighted	Ratio	Unweighted	Weighted
Commercial fish populations	$7.35	$7.55	1.027	$4.93	$5.06
All fish populations	$2.66	$4.75	1.786	$7.04	$12.57
Reduction in baseline mortality	$1.12	$1.40	1.250	$1.13	$1.41
Aquatic ecosystem conditions	$7.66	$9.34	1.219	$3.94	$4.80

Unweighted - no correction for non-response bias, from Support Document, Exhibit II-10
Northeast weighted - corrected for non-response bias, from Support Document, Exhibit II-13
*National weighted = national unweighted * Northeast ratio*

Improvement in other attributes

Among the attributes in the survey, EPA has estimated the percent improvement due to the four regulatory options only for reduction in baseline mortality. In designing the survey, however, EPA made some assessment of possible levels of improvement. As the Support Document emphasizes (pages 13-14), the attribute levels in the survey were chosen to represent "realistic policy scenarios that 'span the range over which we expect respondents to have preferences, and/or are practically achievable'… Allowing the range of variables to vary according to realistic ecological and technological expectations is recommended practice in stated preference design."

For each attribute, EPA used three levels of change in survey questions. The maximum level was 6 percentage points above baseline for commercial fish populations, 4 percentage points for all fish populations, 95 percentage points for fish saved (reduction in mortality), and 4 percent for aquatic ecosystem conditions (Support Document, Exhibit II-1). For reduction in mortality, the maximum change, 95 percentage points, is quite similar to the 92 percent effect of Option 3, the strongest regulatory option (see corrected estimates in Table 2, above).

It seems plausible, therefore, to assume that Option 3 might achieve roughly the maximum improvement considered in the survey for the other attributes, and that the other options would achieve proportionally less: roughly 98 percent as much for Option 2, and 30 percent as much for Options 1 and 4 (see ratios in the last column of Table 2). The assumed levels of improvement in each attribute, by option, are summarized in Table 4.

Table 4. Assumed improvement in attributes, by regulatory option

Percentage points of improvement

	Commercial fish	All fish	Fish saved	Aquatic ecosystem
Option 1	1.83	1.22	28.09	1.22
Option 2	5.90	3.94	90.53	3.94
Option 3	6.00	4.00	91.99	4.00
Option 4	1.80	1.20	27.52	1.20

Fish saved: Table 2 (corrected values)

Other columns: Assumed values for Option 3, scaled by Table 2, last column (see text)

Estimates of total WTP

WTP per household can then be estimated for the four options, as the national prices per percentage point in each attribute (national columns, Table 3) multiplied by the percentage improvement assumptions in Table 4. At the time of the survey there were 111.67 million households in the contiguous United States (Support Document, Exhibit II-3), so per-household estimates can be multiplied by that number to obtain national total WTP. The results are shown for the unweighted values (assuming no non-response bias) in Table 5, and for the weighted values (assuming Northeast non-response bias) in Table 6.

Table 5. National total WTP at unweighted national prices					
Annual WTP, contiguous US, millions of 2011$					
	Commercial fish	All fish	Fish saved	Aquatic ecosystem	Total
Option 1	$1,009	$960	$3,545	$538	$6,052
Option 2	$3,251	$3,095	$11,423	$1,732	$19,501
Option 3	$3,303	$3,145	$11,608	$1,760	$19,815
Option 4	$988	$941	$3,473	$527	$5,928
*Source: Table 4 * national unweighted values, Table 3 * 111.67 million households (see text)*					

Table 6. National total WTP at Northeast-weighted national prices					
Annual WTP, contiguous US, millions of 2011$					
	Commercial fish	All fish	Fish saved	Aquatic ecosystem	Total
Option 1	$1,036	$1,715	$4,431	$655	$7,838
Option 2	$3,339	$5,526	$14,279	$2,112	$25,256
Option 3	$3,393	$5,615	$14,510	$2,146	$25,664
Option 4	$1,015	$1,680	$4,341	$642	$7,678
*Source: Table 4 * national weighted values, Table 3 * 111.67 million households (see text)*					

On the assumptions used in these tables, annual total WTP is $6 billion - $8 billion for Options 1 and 4, and $20 billion - $25 billion for Options 2 and 3. The valuation of fish saved (reduction in baseline mortality) is by far the largest component, but the other three attributes account for more than 40 percent of total WTP in each case.

A much lower but still substantial estimate would be obtained under EPA's "conservative" assumptions. Under this approach, WTP would be based solely on reduction in mortality, and the artificially lowered, as-reported reductions in mortality (Table 2, first column) would be used. Household WTP would be estimated at $1.13 per percentage point reduction in mortality (the unweighted national value; see Table 3). The results are shown in Table 7: WTP is about $3 billion for Options 1 and 4, and about $10 billion for Options 2 and 3.

Table 7. National total WTP using EPA assumptions			
Annual WTP, contiguous US, millions of 2011$			
	Percent reduction in baseline mortality (as reported)		Value of reduction in baseline mortality
Option 1	24.25		$3,060
Option 2	78.13		$9,859
Option 3	79.39		$10,018
Option 4	23.75		$2,997
Source: First column from Table 2			
*Second column = first column * $1.13 * 111.67 million households*			

Net benefits are large for all options, and largest for Options 2 and 3

The annualized present value costs of the regulatory options were estimated in the EBA[6] in 2011, as shown in Table 8.

Table 8: EPA estimates of costs by option		
Millions of 2009$		
	Discount rate	
	3%	7%
Option 1	$384	$459
Option 2	$4,463	$4,699
Option 3	$4,632	$4,862
Option 4	$327	$383
Source: EBA, Tables 12-2, 13-4		

These costs were based on a complex schedule for gradual introduction of the measures required under each option. Major investments such as cooling towers, where required, were assumed to be completed in 2018-2022 for non-nuclear power plants, and in 2023-2027 for nuclear plants.

To approximate this gradual schedule for reductions in cooling water intake, it could be assumed that the benefits estimated above will begin at a fixed date in the future, such as 2024. That is, the benefits might begin 12 years from now, suggesting that the benefit estimates in Tables 5, 6, and 7 might be discounted for 12 years' delay in startup. This amounts to multiplying the benefit estimates presented above by 0.70 at a 3 percent discount rate, or by 0.44 at a 7 percent rate.

The results are shown, for the totals from Table 6 (the maximum benefits estimate developed above) and from Table 7 (the estimate using EPA assumptions) in Table 9. Net benefits are the difference between these figures and Table 8.

Table 9: Discounted benefits					
Present value, millions of 2011$					
	Northeast-weighted totals			EPA assumptions	
Discount rate	3%	7%		3%	7%
Option 1	$5,497	$3,480		$2,146	$1,359
Option 2	$17,714	$11,214		$6,915	$4,378
Option 3	$18,000	$11,395		$7,026	$4,448
Option 4	$5,385	$3,409		$2,102	$1,331
Source: Totals from Tables 6 and 7, discounted for 12 years at indicated rates					

In the worst case – the low estimate of benefits, based on EPA assumptions without any of the corrections presented above, and a 7 percent discount rate – benefits are barely below costs.

[6] *Economic and Benefits Analysis for Proposes Section 316(b) Existing Facilities Rule*, EPA 821-R-11-003, March 28, 2011.

Even in this case, benefits exceed 90 percent of costs, and the difference between benefits and costs is arguably within the margin of error for these calculations. In all other cases, benefits exceed costs by wide margins.

Net benefits are clearly positive for all options at both discount rates, under any one of the three alternative assumptions discussed above: restricting calculations to in-scope baseline mortality; correcting for non-response bias based on the Northeast study results; and including estimates for the other three attributes in the survey. To avoid excessive numerical detail, calculations for the individual alternatives are not shown here; discounted benefit estimates for the combination of all three corrections are presented in the first two columns of Table 9.

Under EPA assumptions at a 3 percent discount rate, and under all other assumptions at both discount rates, net benefits are greatest for Options 2 and 3, the strictest and highest-cost regulatory options. Under EPA assumptions at 3 percent, Options 2 and 3 have net benefits exceeding $2 billion. Under the combination of alternatives examined here, net benefits for Options 2 and 3 are greater than $13 billion at a 3 percent discount rate, and greater than $6 billion at 7 percent (compare Tables 8 and 9).

Thus the interpretations of the survey results discussed here all imply that all four options pass the cost-benefit test with flying colors: benefits are far in excess of costs. Indeed, if maximization of net benefits is the goal of public policy, as economic theory often suggests, then Options 2 and 3 are strongly preferable to Options 1 and 4.

With large net benefits, there is little need for site-specific analyses

Based on the data and analyses available in 2011, EPA's proposed rule included the option of site-specific analyses of costs and benefits at each affected facility.[7] The proposed rule describes in some detail the costs that should be considered in site-specific analyses, but offers only general discussion of benefits, including comments on the difficulty of accurate calculation of benefits.

The option of site-specific analysis is problematical under any circumstances, as Elizabeth Stanton and I explained in our comments last year: the task of estimating costs and benefits, which is challenging even at a national level, would be have to be repeated, typically with very limited resources, in hundreds of local cases in jurisdictions across the country. States would be likely to develop inconsistent or inadequate approaches to the evaluation of costs and benefits – in many cases, simply ignoring non-use values, or in effect, estimating them at zero.

For example, the New York State Department of Environmental Conservation (NYS DEC) believes that site-specific cost-benefit analyses are impossible, and does not intend to perform such analyses. In comments on the proposed rule submitted last year, NYS DEC said,

> The requirement for an undefined social cost-benefit analysis to be conducted to support the decision to require *any* entrainment reduction technologies or operational measures at

[7] 76 Federal Register, April 20, 2011, pages 22261-62.

> an existing facility is unwarranted and overly burdensome… [Because the agency acknowledges the absence of monetized benefit estimates,] EPA is knowingly requiring an impossible task under the proposed rule… Based on the plain facts in the proposed rule, the proposed cost-benefit analysis is impossible to comply with.[8]

The tendency to ignore non-use values in practice is illustrated in PSEG's comprehensive demonstration study for the Mercer power plant in New Jersey. That study argues that the preamble to EPA's 2004 Suspended Final Rule suggests that non-use benefits should be monetized only when there is substantial harm to threatened and endangered species or other major ecological impacts. Therefore, the study concludes that non-use benefits need not be monetized (that is, can be valued at zero) for the Mercer plant, and that costs of cooling towers or other alternatives for the plant are vastly greater than the modest direct-use benefits.[9]

The lack of detailed guidance on benefits calculations makes it particularly likely that jurisdictions will continue to view site-specific cost-benefit analyses as impossible, as NYS DEC does, or will value non-use benefits at zero, as in the Mercer study. In view of the technical complexity of the task, Elizabeth Stanton and I recommended last year that EPA develop clear guidance for local analyses, including default values for non-use values and other difficult-to-estimate benefits.

The purported need for site-specific cost-benefit comparisons was presumably based on the risk that costs might be much greater than benefits at some locations. This risk is greatly diminished by the revised, survey-based benefits estimates I have discussed above. Since benefits exceed costs by many billions of dollars at the national level (and, as noted earlier, WTP is relatively consistent from one region to another), local variation in costs and benefits need not imply that any facilities face an intolerable cost burden. Rather, there could be variation between facilities with greater than average net benefits, and those with smaller than average (but still positive) net benefits.

Therefore, I recommend that EPA withdraw its proposal for site-specific analyses of costs and benefits. It is simply an unnecessary regulatory burden to require hundreds of time-consuming local studies to confirm the overwhelmingly positive net benefits of this rule.

If the final rule does call for site-specific analyses, then EPA should provide detailed guidelines and default values for use in those analyses, including default values for benefits based on WTP as determined in this survey. Although the Notice of Data Availability (NODA) for this survey states that "…these preliminary national and regional results are not directly transferable to site specific assessments,"[10] the survey results are the best estimates of nonuse values available at this time. Until and unless more perfect estimates become available, use of the survey estimates is much better than nothing.

Development of regionally specific estimates – still far from site-specific – is a challenging task, even for EPA with its substantial resources. Local jurisdictions will typically be completely

[8] NYS DEC comments on proposed regulations for Phase I facilities, Docket no. EPA-HQ-OW-2008-0667, August 18, 2011, pages 15-16.
[9] PSEG Services Corporation, Comprehensive Demonstration Study for Mercer Generating Station, NJPDES Permit No. NJ0004995, June 30, 2008, page 44.
[10] 77 Federal Register, June 12, 2012, page 34928.

unable to take this on. Even if the information were available without cost, the needed analysis would be ill-defined. How large an area should be included in valuing each facility's benefits? Is it empirically true that people care only about fish mortality within a certain, short distance from their homes? (Research by Loomis, cited above, suggests that the answer to the last question is no.) Conversely, is it more acceptable for a facility to kill fish if it is done at some distance from major population centers?

In view of the non-local nature of WTP and the similarity of WTP estimates for different parts of the country, EPA should abandon the complex and time-consuming effort to develop regionally specific estimates, and propose a set of national default values. If detailed WTP estimates are available for only one part of the country, WTP in another region is more likely to be the same as in the well-studied region than to be zero. If you are buying an item in a hardware store but do not know the local price, would you expect it to be about the same price as in a different part of the country, or would you expect it to be free because you haven't studied local prices yet?

EPA may be able to develop new, improved national default values for use in local analyses. It is imperative, however, to provide the best (or least bad) available estimates of benefits, in a simple, unambiguous, user-friendly format, as guidance to local, site-specific analyses. The ideal outcome would be for EPA to withdraw the proposal for site-specific analyses. Barring that, guidance to the local analyses must ensure that they can include non-zero benefit estimates with a direct, transparent relationship to the valuable database on WTP that EPA has now created.

Exhibit 3
Petrudev Report

COOLING WATER INTAKE AND DISCHARGE EVALUATIONS FOR SCHILLER STATION

Prepared for:

Sierra Club

Prepared by:

Petrudev Inc.

January 2016

EXECUTIVE SUMMARY

Petrudev was tasked by Sierra Club to provide cooling water intake and discharge evaluations for Schiller Station, a 150 MW electrical generating facility located in Portsmouth, New Hampshire, on the Piscataqua River. Schiller is owned by the Public Service Company of New Hampshire (PSNH) and is seeking renewal of its existing National Pollutant Discharge Elimination System (NPDES) permit (no. NH0001473).

A number of reports and data summaries including Normandeau (2008) and Enercon (2008) were reviewed including impingement, entrainment, cooling water intake, discharge data and technology reports. A summary of findings follows:

- A significant number of fish and macrocrustaceans are removed from the food web especially when entrained (145 million fish eggs and larvae, 1.3 billion macrocrustaceans) and to a lesser extent impinged (5,365 fish, 12,649 macrocrustaceans) at Schiller, including species of commercial and/or recreational interest, those whose populations are in decline, and those who are listed by the National Marine Fisheries Service as species of concern. In addition, cumulative impacts from I&E are possible since Newington Station and Newington Energy Facility are located within miles of Schiller.

- Although overall being a well-designed study with good QA/QC support, there were shortcomings identified in Normandeau (2008) which systematically may have underestimated the extent of impacts from operations at Schiller. These include issues with the entrainment sampling design related to robustness during specific months and entrainment survival studies; comparison of entrainment and source water body densities; impingement survival determination; lack of data on larval head capsule measurements to assist in technology assessments such as wedgewire screens, and characterization of seasonal year-to-year variation in both entrainment and impingement densities. We conducted a preliminary risk assessment on temperature effects of selected species using a screening tool. Overall, exceedances were found at both the reference and plume locations for rainbow smelt (egg/incubation) at mid-depth. For Atlantic herring (juveniles), the exceedances were seen at the plume stations and the north-east reference location (Station 1). These are the minimum, lower bound potential thermal impacts but cannot be better quantified because of lack of data. The assessment would be more complete if more temperature measurements were available during April-July. The existing plume at Schiller seems to be buoyant and the exposure time of fish (including larvae) to thermal effects would likely be of short duration because of the strong tidal induced river velocities. This would minimize any potential thermal effect. Nevertheless, cumulative effects from thermal discharges are possible from many sources including the PSNH Newington Station next door (0.9 mi) of Schiller. Climate change effects were not discussed in the documents reviewed. However, waters in the Piscataqua/Great Bay region are warming and the thermal discharges from Schiller in combination with the higher ambient temperatures are likely to adversely affect fish and macrocrustaceans such as rainbow smelt, Atlantic herring, tautog, Atlantic tomcod, river herring, and American lobster in ways or to an extent not addressed in the Schiller documents reviewed. Furthermore, climate change, combined with potential cumulative thermal effects such as neighboring PSNH Newington Station may result in additional adverse effects on fish and macrocrustaceans.

- There are several impingement technologies which can effectively reduce fish impingement mortality such as a modified fish return system but they are not effective in reducing entrainment. Fine mesh cylindrical wedgewire screens (0.5-1.0 mm) though less effective than cooling towers, still provide considerable entrainment reductions but with a higher degree of uncertainty. Fine mesh cylindrical wedge wire screens with through-slot velocity of 0.5 fps may reduce entrainment up to 75%, while a through screen velocity of 0.2 fps may further reduce entrainment by up to 85%-90%. This is consistent with EPA's recommendation of fine mesh screens in the Draft NPDES Permit (NH0001473) with the noticeable exception of the lower through-slot velocity. The small mesh size and low through- slot velocity (0.2 fps) would address both physical exclusion as well as larval avoidance behavior (by larger size organisms), and also reduce potential larval contact and impingement mortality against the screens. Still, more data regarding post-screen contact survival rates of excluded organisms is necessary to characterize the relationship between entrainment reductions and entrainment <u>mortality</u> reductions for the species most frequently entrained at Schiller. Additional operational changes such as having outages during key entrainment events is also recommended. However, cooling towers will likely still provide the greatest reduction in I&E and thermal load.

TABLE OF CONTENTS

Page No.

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION AND OBJECTIVES 1-1

2.0 IMPINGEMENT AND ENTRAINMENT IMPACTS 2-1
2.1 Entrainment of Fish and Macrocrustaceans 2-4
2.2 Impingement of Fish and Macrocrustaceans 2-11
2.3 Impacts from Entrainment and Impingement Losses 2-15
2.3.1 General Impacts 2-15
2.3.2 Species-Specific Impacts at Schiller 2-18
2.4 Conclusions 2-25

3.0 SHORTCOMINGS IN MONITORING STUDIES 3-1
3.1 Issues with Entrainment Sampling Design 3-1
3.1.1 Sampling Design Not Robust and Not Designed to Detect Species of Low Abundance 3-1
3.1.2 Lack of Data on Larvae Head Capsule Measurements and Its Importance 3-3
3.1.3 Issues with Entrainment Survival Studies 3-5
3.1.4 Conclusions 3-6
3.2 Entrainment Estimates Relative to Source Water Body Densities 3-6
3.3 Issue with Characterization of Seasonal Year-to-Year Variation in Entrainment Densities 3-8
3.4 Issue with Impingement Survival Determination 3-10
3.5 Issue with Characterization of Seasonal Year-to-Year Variation in Impingement Densities 3-10
3.6 Conclusions 3-12

4.0 THERMAL DISCHARGE IMPACTS 4-1
4.1 Discharge Effects 4-1
4.2 Risk Assessment 4-4
4.2.1 Thermal Effects Risk Assessment Methodology 4-4
4.2.2 Selection of Indicator Species 4-8
4.2.3 Temperature Data 4-8
4.2.4 Thermal Effects Criteria 4-9
4.2.5 Results 4-10
4.2.5.1 Hazard Quotient Calculations and Results 4-10
4.2.5.2 Overall Findings 4-14
4.2.6 Conclusions 4-15
4.3 Cumulative Thermal Impacts 4-15

5.0 CLIMATE CHANGE AND THERMAL EFFECTS 5-1

6.0 TECHNOLOGIES FOR REDUCING IMPINGEMENT, ENTRAINMENT AND DISCHARGES 6-1
6.1 Technologies for Reducing I&E at the Intake 6-1
6.2 Technologies for Reducing Thermal Discharges 6-9
6.3 Species at Risk 6-10
6.4 Conclusions 6-10

7.0 REFERENCES 7-1

LIST OF TABLES

Page No.

Table 2.1 Fish Species in the Vicinity of Schiller Station 2-1
Table 2.2 Macrocrustaceans in the Vicinity of Schiller 2-3
Table 2.3 Fish Species and Numbers Entrained Annually (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007....2-5
Table 2.4 Numbers of Ichthyoplankton Entrained Annually by Month (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007 2-5
Table 2.5 Annual Total Adult Equivalent Entrainment Abundance for 17 Fish Taxa Representing 99% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007 2-6
Table 2.6 Annual Total Adult Equivalent Entrainment Abundance by Month for 17 Fish Taxa Representing 99% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007 2-6
Table 2.7 Macrocrustaceans and Numbers Entrained Annually (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007 2-7
Table 2.8 Numbers of Macrocrustaceans Entrained Annually by Month (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007 2-8
Table 2.9 Annual Total Adult Equivalent Entrainment Abundance for 3 Macrocrustacean Taxa Representing 99.6% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007 2-8
Table 2.10 Annual Total Adult Equivalent Entrainment Abundance by Month for 3 Macrocrustacean Taxa Representing 99.6% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007....2-9
Table 2.11 Annual Estimates of Entrained Fish and their Survival, Schiller, October 2, 2006 to September 30, 2007 2-10
Table 2.12 Annual Estimates of Entrained Macrocrustaceans and their Survival, Schiller, October 2, 2006 to September 30, 2007....2-11
Table 2.13 Estimated Annual Fish Impingement (adjusted for collection efficiency) by Species, All Units Combined, October 2, 2006 to September 30, 2007....2-12
Table 2.14 Estimated Annual Fish Impingement (adjusted for collection efficiency) and Survival by Month, October 2, 2006 to September 30, 2007 2-13
Table 2.15 Estimated Annual Adult Equivalent Impingement for the 14 Fish Taxa Comprising 89.6% of Raw Impingement Numbers, October 2, 2006 to September 30, 2007 2-13
Table 2.16 Estimated Annual Impingement of Macrocrustaceans by Species, All Units Combined, October 2, 2006 to September 30, 2007 2-14
Table 2.17 Estimated Annual Impingement and Survival of Macrocrustaceans by Month, All Units Combined, October 2, 2006 to September 30, 2007 2-14

Table 4.1 Summary of HQ Values....4-10

Table 6.1 Selected Characteristics of 15 Ohio River Power Plants Studied during the ORERP Impingement Study, 2005-2007....6-4
Table 6.2 Estimated I&E Reduction (Experience and Literature) 6-11
Table 6.3 Estimated I&E Reduction (Experience and Literature) of Additional Technologies ...6-14

LIST OF FIGURES

Page No.

Figure 2.1 Example of an Estuarine Food Web 2-17

Figure 3.1 Mean Coefficient of Variation of Annual Entrainment Estimates for all Taxa Combined and for 10 Individual Taxa, Based on 100 Iterations of Weekly Sampling Scenarios 2 (1, 2, and 7 Days per Week), 3 (2 Days per Week), and 5 (1 day per Biweek), with 4 Events per Day, 100 m^3 per Sample, applied to Indian Point Entrainment Data from 1983-1987 3-3
Figure 3.2 Illustration of Measurement Locations for Notochordal Length and Head Depth (Height) and Width of a Preflexion Stage Larval Fish (from Tenera 2013) 3-4
Figure 3.3 Mean Larval Fish Density (#/100 m^3 sampled) by Week (all Life Stages Pooled) for Entrainment Samples Collected at Schiller Station for the Period of August 31, 2006 to September 27, 2007 3-9
Figure 3.4 Mean Macrocrustacean Larval Density (#/100 m^3 Sampled) by Week (all Life Stages Pooled) for Entrainment Samples Collected at Schiller Station for the Period of August 31, 2006 to September 27, 2007 3-10
Figure 3.5 Mean Fish Density (#/million gallons) by Week for Impingement Samples Collected at Schiller (Units 4, 5, and 6 combined) for the period August 31, 2006 to September 27, 2007 3-11

Figure 4.1 Locations of the Temperature Monitoring Stations 4-9
Figure 4.2 Hourly Average Temperature at Station-3 and Rainbow Smelt Thermal Criteria 4-13
Figure 4.3 Hourly Average Temperature at Station-7 and Atlantic Herring Thermal Criteria 4-13

1.0 INTRODUCTION AND OBJECTIVES

Petrudev was tasked by the Sierra Club to provide cooling water intake and discharge evaluations for Schiller Station. Schiller is a 150 MW electrical generating facility located in Portsmouth, New Hampshire, on the southwestern bank of the Piscataqua River, forming the boundary between coastal New Hampshire and Maine. Schiller is owned by the Public Service Company of New Hampshire (PSNH) and is seeking renewal of its existing National Pollutant Discharge Elimination System (NPDES) permit (no. NH0001473).

Schiller withdraws and discharges once-through cooling water into the Piscataqua River. The Piscataqua River is a 12 mile (19 km) long tidal estuary formed at the confluence of Cocheco River and Salmon Falls River that runs southeastwards and empties into the Atlantic Ocean. Mixing of freshwater and saltwater occur in estuaries. Estuarine environments are sensitive and ecologically important as they are highly productive and provide habitat (e.g., breeding grounds, nurseries), nutrients, and food for a diverse range of aquatic species (e.g., marine fish, macrocrustaceans). The Piscataqua River is important for diadromous fish species that utilize both fresh and saltwater during their lifetime. The Great Bay and Little Bay estuaries flow into the Piscataqua River. The Piscataqua River provides a variety of social, recreational and economic benefits including fishing, business, boating, and whale watching.

Three of Schiller's four generating units are in operation and each have a rated capacity of 50 MW. There are two cooling water intake structures (CWISs). Unit 4 withdraws once-through cooling water from a submerged offshore (32 ft out) intake while Units 5 and 6 withdraw once-through cooling water from a nearshore intake. Some features are employed to reduce the impingement and entrainment of fish and macrocrustaceans. These include: coarse mesh (3/8 in) travelling screens that operate intermittently, fish return troughs, and intakes located 2 ft above the river bed (maintained by dredging) to provide a vertical barrier to the movement of shellfish and benthic fish. Additionally, the submerged offshore intake (Unit 4) consists of a bar rack screening structure (1.5 in mesh) and a lobster diversion pipe.

Schiller has three discharge outfalls, one for each of Units 4, 5, and 6, and all discharge directly into the Piscataqua River. For all units, the separation between the intake and discharge has been designed to minimize recirculation of the warm discharge water back into the CWIS. Schiller does not use any discharge technologies to decrease thermal effluent temperatures discharged into to the Piscataqua River.

This report focuses on the cooling water intake and discharge structures at Schiller and their potential effects on biota and include the following:

- Describing the aquatic biota communities in the vicinity of Schiller Station and their vulnerability to impingement and entrainment (I&E) and discharge effects.
- Evaluating the impact of Schiller’s present intake structures on I&E and the effectiveness of existing controls in limiting I&E.
- Identifying issues of concern in the I&E sampling and Best Technology Available (BTA) assessment and other related studies.
- Evaluating the impact of Schiller’s existing thermal discharges on fish passage and fish populations, including an assessment of the effect of elevated temperature on aquatic organisms and whether Schiller’s thermal discharges allow for the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in the waterbody.
- Discussing the feasibility of alternative technologies and their relative efficiency for reducing I&E and thermal discharges (including cooling towers).
- Evaluating whether studies have properly considered the effects of climate change.

The report has been organized into the following sections:

- Impingement and Entrainment Impacts;
- Shortcomings in Monitoring Studies;
- Thermal Discharge Impacts;
- Climate Change and Thermal Effects; and
- Technologies for Reducing Impingement, Entrainment, and Discharges.

2.0 IMPINGEMENT AND ENTRAINMENT IMPACTS

This section addresses the task from the scope of work on describing the aquatic biota communities in the vicinity of Schiller Station and their vulnerability to I&E.

A large variety of fish and macrocrustaceans of all life stages are present in the Piscataqua River in the vicinity of Schiller Station. All of these organisms have the potential to be negatively impacted by I&E.

Fish

At least 46 fish species have been recorded in the vicinity of Schiller Station based on entrainment and impingement monitoring in 2006-2007 (Normandeau 2008) (Table 2.1). Annually, it is estimated that over 145 million fish are entrained and 5,365 fish are impinged at Schiller. Fish species comprise resident and seasonal fish, as well as migratory (e.g., anadromous, catadromous) fish. Detailed results related to entrainment and impingement studies are presented in Sections 2.1 to 2.3 and concerns are presented in Section 3.0.

Table 2.1 Fish Species in the Vicinity of Schiller Station

Fish Species		**Life History Stage**			
Common Name	**Scientific Name**	**Egg**	**Larvae**	**YOY***	**Juvenile/Adult**
Alewife	*Alosa pseudoharengus*				X
Alligatorfish	*Aspidophoroides monopterygius*		X		
American eel	*Anguilla rostrate*		X		
American plaice	*Hippoglossoides platessoides*	X	X		
American sand lance	*Ammodytes americanus*		X		
Atlantic cod	*Gadus morhua*	X	X		X
Atlantic cod/haddock	*Gadus/Melanogrammus*	X			
Atlantic cod/ haddock/ witch flounder	*Gadidae/Glyptocephalus*	X			
Atlantic herring	*Clupea harengus*		X		X
Atlantic mackerel	*Scomber scombrus*	X	X		
Atlantic menhaden	*Brevoortia tyrannus*	X			X
Atlantic seasnail	*Liparis atlanticus*		X		
Atlantic silverside	*Menidia menidia*				X
Atlantic tomcod	*Microgadus tomcod*			X	X
Blueback herring	*Alosa aestivalus*				X
Bluegill	*Lepomis macrochirus*				X
Cunner	*Tautogolabrus adspersus*	X	X	X	X
Cunner/Yellowtail flounder	*Labridae/Limanda*	X			
Emerald shiner	*Notropis atherinoides*				X

Table 2.1 Fish Species in the Vicinity of Schiller Station (Cont'd)

Fish Species		Life History Stage			
Common Name	**Scientific Name**	**Egg**	**Larvae**	**YOY***	**Juvenile/Adult**
Fourbeard rockling	*Enchelyopus cimbrius*	X	X		
Fourbeard rockling/hake	*Enchelyopus/Urophycis*	X			
Goosefish	*Lophius americanus*	X			
Grubby	*Myoxocephalus aenaeus*		X		X
Gulf snailfish	*Liparis coheni*		X		
Haddock	*Melanogrammus aeglefinus*	X			
Herring family	*Clupeidae* sp.				X
Inland silverside	*Menidia beryllina*				X
Longhorn sculpin	*Myoxocephalus octodecemspinosus*		X		
Lumpfish	*Cyclopterus lumpus*				X
Ninespine stickleback	*Pungitius pungitius*				X
Northern pipefish	*Syngnathus fuscus*		X		X
Pollock	*Pollachius virens*	X	X		X
Prionotus species	*Prionotus* sp.	X			
Pumpkinseed	*Lepomis gibbosus*				X
Radiated shanny	*Ulvara subbifurcata*		X		
Rainbow smelt	*Osmerus mordax*		X		X
Red hake	*Urophycis chuss*				X
Rock gunnel	*Pholis gunnellus*		X		X
Sculpin family	*Cottidae*	X	X		
Sea raven	*Hemitripterus americanus*		X		X
Shorthorn sculpin	*Myoxocephalus scorpius*		X		X
Silver hake	*Merluccius bilinearis*	X	X		X
Skate family	*Raja* sp.				
Striped bass	*Morone saxatilis*				X
Striped killifish	*Fundulus majalis*				X
Summer flounder	*Paralichthys dentatus*	X			
Tautog	*Tautoga onitis*	X			X
Threespine stickleback	*Gasterosteus aculeatus*				X
Urophycis species	*Urophycis* sp.	X			
White hake	*Urophycis tenuis*				X
White perch	*Morone Americana*				X
Windowpane	*Scophthalmus aquosus*	X	X		X
Winter flounder	*Pseudopleuronectes americanus*	X	X		X
Witch flounder	*Glyptocephalus cynoglossus*		X		
Wrymouth	*Cryptacanthodes maculatus*		X		

*YOY = young-of-the-year.
Adapted from: Normandeau (2008).

In addition to the fish species recorded near Schiller through I&E monitoring (Normandeau 2008), the following fish species are also present in the Piscataqua River according to the New Hampshire Fish and Game Department (Smith n.d.), the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) (NMFS 2013) and NatureServe[1]:

- American shad (*Alosa sapidissima*);
- Sea lamprey (*Petromyzon marinus*);
- Brown trout (*Salmo trutta*);
- Brook trout (*Salvelinus fontinalis*);
- Rainbow trout (*Oncorhynchus mykiss*);
- Atlantic salmon (*Salmo salar*) – Gulf of Maine Distinct Population Segment is endangered under the federal *Endangered Species Act (ESA)*;
- Atlantic sturgeon (*Acipenser oxyrinchus oxyrichnus*) – Gulf of Maine Distinct Population Segment is listed as threatened under the federal *ESA*; and,
- Shortnose sturgeon (*Acipenser brevirostrum*) – listed as endangered under the federal *ESA.*

Macrocrustacea

Several crab species and a lobster species exist in the vicinity of Schiller and have been entrained or impinged (Table 2.2). Annually, it is estimated that over 1.3 billion macrocrustaceans are entrained and 12,649 macrocrustaceans are impinged (Normandeau 2008). The most commonly impinged species at Schiller comprising 99.0% of impinged individuals are green crab, Atlantic rock crab and American lobster. Detailed results related to entrainment and impingement studies are presented in Sections 2.1 to 2.3 and concerns are presented in Section 3.0.

Table 2.2 Macrocrustaceans in the Vicinity of Schiller

Species		Life History Stage		
Common Name	**Scientific Name**	**Larvae**	**Juvenile**	**Adult**
American lobster	*Homarus americanus*	X		X
Arctic lyre crab	*Hyas coarctatus*	X		
Atlantic lyre crab	*Hyas araneus*	X		
Atlantic rock crab	*Cancer irroratus*	X	X	X
Atlantic rock/Jonah crab	*Cancer* sp.	X		
Green crab	*Carcinus maenus*	X	X	X
Horseshoe crab*	*Limulus polyphemus*			X
Japanese shore crab	*Hemigrapsus sanguineus*	X		
Jonah crab	*Cancer borealis*	X	X	X

*Not a crustacean but has significance to the Great Bay estuary community.

[1] http://www.natureserve.org/explorer/servlet/NatureServe?init=Species

2.1 ENTRAINMENT OF FISH AND MACROCRUSTACEANS

At the Schiller Plant, entrainment sampling was carried out in 2006-07. Normandeau reported that a total of 145 million ichthyoplankton (fish eggs and larvae) from 35 taxa were entrained annually at Schiller with an estimated 35% surviving entrainment. Approximately 1.3 billion macrocrustaceans comprising 7 taxa were entrained annually at Schiller with about 77% surviving entrainment.

Entrainment sampling was carried out from August 31, 2006 to September 27, 2007 at Screen House #2 (Units 5 and 6). Screen House #1 (Unit 4) was not sampled due to access issues. The sampling protocol was a seasonally-stratified fixed date design that was consistent with procedures used at other CWISs in estuaries in the U.S. (Normandeau 2008). Sampling occurred weekly during periods of expected higher entrainment (13 weeks in June-August 2007 and 13 weeks in January-March 2007). During other periods, sampling was conducted on a biweekly basis including May (which seemed to be a high entrainment period). A total of 41 entrainment events took place. During each sampling event, four separate 100 m^3 samples were taken at 6-hour intervals to represent one consecutive 24-hour period. It took approximately 148 minutes to filter 100 m^3 of water for each sample. Entrainment estimates for Unit 4 were based on sampling of Units 5 and 6. A total of 162 entrainment samples were collected.

Entrained Fish

A total of 15,671 ichthyoplankton from 35 taxa were collected from entrainment sampling. In addition, there were organisms that were badly damaged and unidentifiable as well as some that could not be differentiated because their life stage or size could be of two or more locally occurring species. Annualized estimates were based on 149 samples collected from October 2, 2006 to September 30, 2007 (Normandeau 2008). It was estimated that 145,554,178 ichthyoplankton are entrained annually with approximately equal numbers entrained at Units 4 (48,570,744 individuals), 5 (49,772,182 individuals), and 6 (47,211,253 individuals) (Normandeau 2008). More than half of the entrained ichthyoplankton were eggs (58%) and the remainder comprised of larvae of various stages. The dominant species entrained was cunner (Table 2.3), which comprised 21% or over 30 million of all ichthyoplankton entrained. Another 68 million eggs (47%) either belonging to cunner or yellowtail flounder were entrained. Normandeau (2008) assumed these to be cunner based on the absence of other life stages of yellowtail flounder. Thus, approximately 68% or over 98 million cunner are entrained annually. Other species entrained in higher numbers relative to other species include American sand lance (8.8% or 12.7 million), rock gunnel (5% or 7.1 million), fourbeard rockling / hake eggs (4.1% or 6 million), and Atlantic mackerel (3.7% or 5.4 million). Despite the few fish species comprising a majority of the over 145 million entrained, all other fish were entrained in high numbers from thousands to even over a million (e.g., grubby, Atlantic herring and rainbow smelt) (Table 2.3). Large quantities of fish were entrained during all months of the year, ranging from 203,862

(October 2006) to 47,275,132 (June 2007) (Table 2.4). It should be noted that considerable entrainment occurred in May (19.3M shown in red, Table 2.4) yet sampling was only biweekly. This likely underestimated entrainment during this period and is discussed in more detail in Section 3.0.

Table 2.3 Fish Species and Numbers Entrained Annually (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007

Common Name	Total (no.)	% of Total	Common Name	Total (no.)	% of Total
Alligatorfish	13,332	0.0%	Longhorn sculpin	395,848	0.3%
American eel	7,847	0.0%	Northern pipefish	668,067	0.5%
American plaice	989,624	0.7%	Pollock	616,284	0.4%
American sand lance	12,746,667	8.8%	Prionotus species	66,630	0.0%
Atlantic cod	307,445	0.2%	Radiated shanny	187,576	0.1%
Atlantic cod /haddock	150,212	0.1%	Rainbow smelt	1,633,509	1.1%
Atlantic cod/ haddock / witch flounder	321,061	0.2%	Rock gunnel	7,114,946	4.9%
Atlantic herring	1,790,893	1.2%	Sculpin family	55,116	0.0%
Atlantic mackerel	5,448,638	3.7%	Sea raven	12,422	0.0%
Atlantic menhaden	590,147	0.4%	Shorthorn sculpin	86,778	0.1%
Atlantic seasnail	363,166	0.2%	Silver hake	257,220	0.2%
Atlantic tomcod	49,434	0.0%	Striped killifish	7,847	0.0%
Cunner	30,325,771	20.8%	Summer flounder	11,094	0.0%
Cunner/ yellowtail flounder*	67,992,369	46.7%	Tautog	52,464	0.0%
Fourbeard rockling	1,605,954	1.1%	Unidentified	229,491	0.2%
Fourbeard rockling / hake	5,959,232	4.1%	Urophyscis species	1,302,112	0.9%
Goosefish	126,435	0.1%	Windowpane	509,994	0.4%
Grubby	3,162,379	2.2%	Winter flounder	347,480	0.2%
Gulf snailfish	20,289	0.0%	Witch flounder	16,418	0.0%
Haddock	6,591	0.0%	Wrymouth	5,396	0.0%

*All eggs. Assume cunner based on absence of other stages of yellowtail flounder.
Modified from Normandeau (2008).

Table 2.4 Numbers of Ichthyoplankton Entrained Annually by Month (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007

Year	Month	Total (no.)	% of Total
2006	October	203,862	0.1%
	November	1,031,355	0.7%
	December	508,165	0.3%
2007	January	5,630,527	3.9%
	February	10,796,680	7.4%
	March	5,976,711	4.1%
	April	3,620,361	2.5%
	May	19,309,488	13.3%
	June	47,275,132	32.5%
	July	27,703,843	19.0%
	August	22,675,538	15.6%
	September	822,516	0.6%
Total Fish Entrained		**145,554,178**	**100.0%**

Modified from Normandeau (2008).

Note: The red font shows a period of high entrainment that was not sampled on a weekly basis.

Equivalent adult (i.e., at the adult age of first reaching sexual maturity) losses were calculated for 16 fish taxa where at least 50 individuals were collected from sampling, as well as winter flounder, a commercial species of interest. These 17 taxa comprised 99.0% of entrained species based on raw data. Normandeau (2008) estimated that over 673,000 adult equivalents would have been produced had the fish not been entrained by Schiller, with rock gunnel comprising more than half of the adult equivalents (56%) (Normandeau 2008) (Table 2.5). Adult equivalent losses occurred every month and peaked in the months of January through March (Table 2.6).

Table 2.5 Annual Total Adult Equivalent Entrainment Abundance for 17 Fish Taxa Representing 99% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007

Common Name	Total (no.)	% of Total	Common Name	Total (no.)	% of Total
American plaice	14	0.0%	*Urophycis* (Hake) species	3	0.0%
American sand lance	10,341	1.5%	Longhorn sculpin	1,359	0.2%
Atlantic cod	54	0.0%	Northern pipefish	105,641	15.7%
Atlantic herring	2,261	0.3%	Pollock	14	0.0%
Atlantic mackerel	14	0.0%	Rainbow smelt	21,238	3.2%
Atlantic menhaden	8	0.0%	Rock gunnel	377,296	56.0%
Cunner	82,005	12.2%	Windowpane	6	0.0%
Fourbeard rockling	17,551	2.6%	Winter flounder	3	0.0%
Grubby	55,918	8.3%			

Modified from Normandeau (2008).

Table 2.6 Annual Total Adult Equivalent Entrainment Abundance by Month for 17 Fish Taxa Representing 99% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007

Year	Month	Total (no.)	% of Total
2006	October	42	0.0%
	November	30,167	4.5%
	December	4,591	0.7%
2007	January	104,816	15.6%
	February	132,054	19.6%
	March	140,456	20.8%
	April	76,319	11.3%
	May	25,006	3.7%
	June	9,482	1.4%
	July	64,482	9.6%
	August	67,705	10.0%
	September	18,607	2.8%
Total Adult Fish Equivalents Entrained		**673,727**	**100.0%**

Modified from Normandeau (2008).

Note: The red font shows a period of high entrainment that was not sampled on weekly basis

Entrained Invertebrates

A total of 149,976 crabs from six taxa and seven lobsters from one taxon were collected during entrainment sampling. Similar to ichthyoplankton, annualized estimates of macrocrustaceans entrained were based on 149 samples collected from October 2, 2006 to September 30, 2007. In total, it was estimated that over 1.3 billion macrocrustaceans are entrained annually and are approximately equal by Unit (Unit 4 – 429,816,877, Unit 5 – 438,537,416, and Unit 6 – 441,118,274) (Normandeau 2008). Green crab and *Cancer* crab species comprised over 99% of the total numbers entrained. However, the remaining <1% of species entrained comprised over 7 million individuals (Table 2.7).

Table 2.7 Macrocrustaceans and Numbers Entrained Annually (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007

Common Name	Total (no.)	% of Total
American lobster	56,471	0.0%
Arctic lyre crab	288,460	0.0%
Atlantic lyre crab	48,205	0.0%
Atlantic rock crab	1,575,392	0.1%
Cancer sp.	573,253,054	43.8%
Green crab	729,075,232	55.7%
Japanese shore crab	4,913,147	0.4%
Jonah crab	262,604	0.0%

Modified from Normandeau (2008).

Entrainment of macrocrustaceans occurred every month except for March (Table 2.8). During the other months, entrainment ranged from 31,827 individuals (February 2007) to 574,863,686 individuals (July 2007). The highest period of entrainment occurred in October 2006 and from May through September 2007. It should be noted that considerable entrainment occurred in May (141.9 M) and September (24.9 M) yet sampling was only biweekly (shown in red in Table 2.8). This likely underestimated entrainment during this period and is discussed in more detail in Section 3.0.

Table 2.8 Numbers of Macrocrustaceans Entrained Annually by Month (Units 4, 5, and 6 combined), October 2, 2006 to September 30, 2007

Year	Month	Total (no.)	% of Total
2006	October	9,095,902	0.7%
	November	307,935	0.0%
	December	188,935	0.0%
2007	January	48,580	0.0%
	February	31,827	0.0%
	March	0	0.0%
	April	170,951	0.0%
	May	141,888,188	10.8%
	June	386,096,800	29.5%
	July	574,863,686	43.9%
	August	171,863,453	13.1%
	September	24,916,312	1.9%
Total Macrocrustaceans Entrained		**1,309,472,569**	**100.0%**

Modified from Normandeau (2008).

Note: The red font shows a period of high entrainment that was not sampled on weekly basis

Equivalent adult losses were calculated for three macrocrustacean that comprised over 99% of raw entrainment counts. Normandeau (2008) estimated that over 145,000 adult macrocrustacean equivalents were lost to entrainment, with most being adult green crab (Table 2.9). In terms of months when these adults were lost, most losses occurred from spring through fall (May through October) (Table 2.10).

Table 2.9 Annual Total Adult Equivalent Entrainment Abundance for 3 Macrocrustacean Taxa Representing 99.6% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007

Common Name	Total (no.)	% of Total
American lobster	67	0.0%
Cancer sp.	15,488	10.6%
Green crab	130,130	89.3%

Modified from Normandeau (2008).

Table 2.10 Annual Total Adult Equivalent Entrainment Abundance by Month for 3 Macrocrustacean Taxa Representing 99.6% of Raw Entrainment Numbers, October 2, 2006 to September 30, 2007

Year	Month	Total (no.)	% of Total
2006	October	7,854	5.4%
	November	1,351	0.9%
	December	57	0.0%
2007	January	3	0.0%
	February	399	0.3%
	March	0	0.0%
	April	1	0.0%
	May	6,274	4.3%
	June	26,760	18.4%
	July	60,077	41.2%
	August	31,007	21.3%
	September	11,901	8.2%
Total Adult Equivalent Macrocrustaceans Entrained		**145,684**	**100.0%**

Modified from Normandeau (2008).

Note: The red font shows a period of high entrainment that was not sampled on weekly basis

Entrainment Survival

Entrainment survival was also estimated at Schiller (Normandeau 2008). Control-adjusted latent survival rates (24 hr) were calculated by Normadeau for the following larval species which had sufficient sample size: American sand lance, Atlantic herring, cunner, grubby, longhorn sculpin, and rock gunnel. For all other species, the latent survival rate of similar species was used (Table 2.11). For the egg, YOY, and juvenile life stages, a conservative latent survival rate of zero was used while for yolk sac larvae and post yolk sac larvae, latent survival rates ranged from zero survival to 100% survival. Overall, it was estimated that 35% of all entrained fish survive annually (Table 2.11) (Normandeau 2008). In terms of adult equivalents calculated for the 17 taxa indicated above, it was estimated that 297,848 of the 673,726 (44%) adult equivalents survived entrainment. Concerns with these survival results are discussed in Section 3.0.

Table 2.11 Annual Estimates of Entrained Fish and their Survival, Schiller, October 2, 2006 to September 30, 2007

Common Name	Total (no.)	Estimated survived (no.)	% Survived
Alligatorfish[e]	13,332	7,226	54.2%
American eel[c]	7,847	7,847	100.0%
American plaice[a]	989,624	20,488	2.1%
American sand lance[a]	12,746,667	10,579,734	83.0%
Atlantic cod[a]	307,445	26,973	8.8%
Atlantic cod /haddock[a]	150,212	0	0.0%
Atlantic cod/ haddock / witch flounder[a]	321,061	0	0.0%
Atlantic herring[b]	1,790,893	0	0.0%
Atlantic mackerel[e]	5,448,638	4,462	0.1%
Atlantic menhaden[b]	590,147	0	0.0%
Atlantic seasnail[d]	363,166	254,579	70.1%
Atlantic tomcod[d]	49,434	0	0.0%
Cunner[c]	30,325,771	30,297,223	99.9%
Cunner/ yellowtail flounder[c]*	67,992,369	0	0.0%
Fourbeard rockling[d]	1,605,954	664,512	41.4%
Fourbeard rockling / hake[d]	5,959,232	0	0.0%
Goosefish[d]	126,435	0	0.0%
Grubby[d]	3,162,379	2,216,828	70.1%
Gulf snailfish[d]	20,289	14,223	70.1%
Haddock[a]	6,591	0	0.0%
Longhorn sculpin[d]	395,848	277,490	70.1%
Northern pipefish[e]	668,067	326,570	48.9%
Pollock[a]	616,284	397,234	64.5%
Prionotus species[e]	66,630	0	0.0%
Radiated shanny[e]	187,576	101,666	54.2%
Rainbow smelt[a]	1,633,509	1,355,813	83.0%
Rock gunnel[e]	7,114,946	3,856,301	54.2%
Sculpin family[d]	55,116	31,057	56.3%
Sea raven[d]	12,422	8,708	70.1%
Shorthorn sculpin[d]	86,778	60,831	70.1%
Silver hake[d]	257,220	15,189	5.9%
Striped killifish[d]	7,847	0	0.0%
Summer flounder[c]	11,094	0	0.0%
Tautog[c]	52,464	0	0.0%
Unidentified[b]	229,491	0	0.0%
Urophyscis species[d]	1,302,112	0	0.0%
Windowpane[c]	509,994	44,954	8.8%
Winter flounder[c]	347,480	212,661	61.2%
Witch flounder[a]	16,418	13,627	83.0%
Wrymouth[e]	5,396	2,925	54.2%
Total	**145,554,178**	**50,799,121**	**34.9%**

[a] Assigned Latent survival rate calculated for American sand lance based on similar hardiness and morphological similarities.
[b] Assigned Latent survival rate calculated for Atlantic herring based on similar hardiness and morphological similarities.
[c] Assigned Latent survival rate calculated for cunner based on similar hardiness and morphological similarities.
[d] Assigned Latent survival rate calculated for grubby/longhorn sculpin based on similar hardiness and morphological similarities.
[e] Assigned Latent survival rate calculated for rock gunner based on similar hardiness and morphological similarities.
Modified from Normandeau (2008).

Control-adjusted latent survival rates were calculated for the following macrocrustaceans since sample size was sufficient: green crab and *Cancer* sp. Based on the data, Normandeau estimated that 1 billion of the 1.3 billion (77%) macrocrustaceans "survived entrainment through the Schiller Station CWIS" (Table 2.12). Of the estimated 145,685 adult equivalents that would have resulted from the entrained macrocrustaceans, Normandeau (2008) estimated that 114,860 survived entrainment (78.8%). Concerns with these survival estimates are discussed in Section 3.0.

Table 2.12 Annual Estimates of Entrained Macrocrustaceans and their Survival, Schiller, October 2, 2006 to September 30, 2007

Common Name	Total (no.)	Estimated survived (no.)	% Survived
American lobster	56,471	42,354	75.0%
Arctic lyre crab	288,460	216,345	75.0%
Atlantic lyre crab	48,205	36,154	75.0%
Atlantic rock crab	1,575,392	1,181,544	75.0%
Cancer sp.	573,253,054	429,939,790	75.0%
Green crab	729,075,232	578,156,659	79.3%
Japanese shore crab	4,913,147	3,684,861	75.0%
Jonah crab	262,604	196,953	75.0%
Total	**1,309,472,565**	**1,013,454,660**	**77.4%**

Modified from Normandeau (2008).

All of the results summarized above from Normandeau (2008) were based on CWIS operating flows when entrainment sampling occurred. Entrainment estimates were also provided based on historical operating flow and produced similar results (i.e. within expected variability of data). For example, based on historical operating flow, an annual estimate of 142 million fish and 1.28 billion macrocrustaceans were entrained (Normandeau 2008).

Summary

In one year, over 145 million ichthyoplankton from 35 taxa and 1.3 billion macrocrustaceans from 7 taxa were entrained at Schiller. Normandeau estimated that 35% of all entrained fish survived while 77% of all macrocrustaceans entrained survived. However, these are concerns with the term "survival" which can be misleading and is discussed in more detail in Section 3.0.

2.2 IMPINGEMENT OF FISH AND MACROCRUSTACEANS

At the Schiller Plant, impingement sampling was carried out in 2006-07. The Normandeau (2008) report indicated that a total of 5,365 fish from 33 taxa were impinged annually at Schiller with an estimated 18% surviving impingement. A total of 12,649 macrocrustaceans comprising 5 taxa were impinged at Schiller annually with about 68% surviving impingement.

Impingement sampling was conducted at Schiller Units 4, 5, and 6 from August 31, 2006 to September 27, 2007. The sampling protocol consisted of a fixed-date design with sampling occurring once per week throughout the year. The design was consistent with those used at other CWIS's located on estuaries in the U.S. (Normandeau 2008). Separate samples were collected from the travelling screens of each of Units 4, 5, and 6. For each sampling day, four consecutive 6-hr samples were collected to represent one 24-hour period. Impingement samples were only collected when the CWIS for the Unit was operating. A total of 205, 217, and 205 valid 6-hr impingement samples for Units 4, 5, and 6, respectively were collected, which were then combined into 24-hr samples by unit. A cumulative total of 6.4 billion gallons of operating flow was sampled corresponding to 14.2% of the total Schiller operating flow.

A total of 33 fish taxa were impinged, with most being seasonally resident fish. The annualized impingement estimate adjusted for collection efficiency was 5,365 for Units 4, 5, and 6 combined. Over 60% of the fish (3,357 individuals) were impinged at Unit 4 (submerged intake). Of the total 5,365 impinged, the dominant species were white hake (12.8% or 686 individuals), cunner (11.6% or 623 individuals), rainbow smelt (10.8% or 580 fish), northern pipefish (10.8% or 579 individuals), and winter flounder (10.0% or 534 individuals) (Table 2.13). Impingement occurred throughout the year, peaking in April. Using the latent survival rates obtained from this study, only 978 fish (18%) survived impingement (Table 2.14) (Normandeau 2008). However, it should be noted that latent survival was typically over a 12-hr period and not 24-hr or 48-hr estimates.

Table 2.13 Estimated Annual Fish Impingement (adjusted for collection efficiency) by Species, All Units Combined, October 2, 2006 to September 30, 2007

Common Name	Total no.	% of total	Fish Species	Total no.	% of total
Alewife	23	0.4	Pollock	23	0.4
American sand lance	8	0.1	Pumpkinseed	8	0.1
Atlantic cod	36	0.7	Rainbow smelt	580	10.8
Atlantic herring	277	5.2	Red hake	8	0.1
Atlantic menhaden	306	5.7	Rock gunner	24	0.4
Atlantic silverside	114	2.1	Sea raven	15	0.3
Atlantic tomcod	47	0.9	Shorthorn sculpin	7	0.1
Blueback herring	63	1.2	Silver hake	8	0.1
Bluegill	60	1.1	Skate family	16	0.3
Cunner	623	11.6	Striped bass	23	0.4
Emerald shiner	31	0.6	Tautog	8	0.1
Grubby	458	8.5	Threespine stickleback	49	0.9
Herring family	8	0.1	Unidentifiable	0	0.0
Inland silverside	15	0.3	White hake	686	12.8
Lumpfish	333	6.2	White perch	186	3.5
Ninespine stickleback	139	2.6	Windowpane	70	1.3
Northern pipefish	579	10.8	Winter flounder	534	10.0

Modified from Normandeau (2008).

Table 2.14 Estimated Annual Fish Impingement (adjusted for collection efficiency) and Survival by Month, October 2, 2006 to September 30, 2007

Year	Month	No. of Fish Impinged	% of Fish Impinged	Latent survival rate	No. Fish Survived
2006	October	288	5.4%	14.9%	43
	November	676	12.6%	14.8%	100
	December	525	9.8%	29.5%	155
2007	January	777	14.5%	29.6%	230
	February	216	4.0%	29.6%	64
	March	151	2.8%	17.9%	27
	April	1,773	33.0%	17.6%	312
	May	122	2.3%	17.2%	21
	June	285	5.3%	0.0%	0
	July	141	2.6%	0.0%	0
	August	234	4.4%	0.0%	0
	September	177	3.3%	14.7%	26
Total		**5,365**	**100.0%**	**18.2%**	**978**

Modified from Normandeau (2008).

Adult equivalent calculations were performed on 14 fish taxa that comprised almost 90% of raw impingement numbers. In total, Normandeau estimated that 1,756 adult equivalents were impinged and after applying latent survival rates, it was estimated that only 313 of these adult equivalents, or 17.8%, survived impingement (Table 2.15) (Normandeau 2008).

Table 2.15 Estimated Annual Adult Equivalent Impingement for the 14 Fish Taxa Comprising 89.6% of Raw Impingement Numbers, October 2, 2006 to September 30, 2007

Common Name	No. Impinged	No. Adult Equivalents Impinged	No. Adult Equivalents Survived	% Survival AE
Atlantic cod	36	29	4	13.8%
Atlantic herring	277	9	2	22.2%
Atlantic menhaden	306	2	0	0.0%
Cunner	623	370	23	6.2%
Grubby	460	457	109	23.9%
Lumpfish	332	60	10	16.7%
Northern pipefish	579	572	110	19.2%
Pollock	23	0	0	0.0%
Rainbow smelt	574	156	38	24.4%
Silver hake	8	0	0	0.0%
White hake	687	17	4	23.5%
White perch	185	73	12	16.4%
Windowpane	70	3	1	33.3%
Winter flounder	534	8	0	0.0%
Total	**4,694**	**1,756**	**313**	**17.8%**

Modified from Normandeau (2008).

A total of five macrocrustacean taxa were impinged. Horseshoe crabs, although not macrocrustaceans, were also enumerated for impingement sampling, and are referred to as 'macrocrustaceans'. Annualized estimates indicated that 12,649 macrocrustaceans were impinged at Schiller (all units combined) and green crab and Atlantic rock crab comprised over 96% of the total impinged (Table 2.16). Of the 12,649 individuals impinged, over three-quarters (9,746 individuals) were impinged at Unit 4 (submerged intake). Impingement of macrocrustaceans occurred monthly, peaking in April and of the 12,649 impinged, an estimated 68% (or 8,549 individuals) survived impingement (Table 2.17). However, it should be noted that latent survival was typically over a 12-hr period and not 24-hr or 48-hr estimates. Estimated adult equivalents impinged were not calculated for macrocrustaceans due to the difficulty in obtaining accurate age estimates necessary for calculations.

Table 2.16 Estimated Annual Impingement of Macrocrustaceans by Species, All Units Combined, October 2, 2006 to September 30, 2007

Common Name	No. Impinged	% of Total
American lobster	302	2.4
Atlantic rock crab	3,324	26.3
Cancer sp.	0	0.0
Green crab	8,924	70.6
Horseshoe crab	70	0.6
Jonah crab	29	0.2
Total	**12,649**	**100**

Modified from Normandeau (2008).

Table 2.17 Estimated Annual Impingement and Survival of Macrocrustaceans by Month, All Units Combined, October 2, 2006 to September 30, 2007

Year	Month	No. Impinged	Latent Survival Rate	No. Survived
2006	October	576	71.7%	413
	November	1,641	71.7%	1,177
	December	1,712	89.6%	1,534
2007	January	920	89.6%	824
	February	191	89.6%	171
	March	140	60.0%	84
	April	2,203	60.0%	1,322
	May	1,564	60.0%	938
	June	1,538	53.8%	827
	July	923	53.8%	497
	August	714	53.8%	384
	September	527	71.7%	378
Total		**12,649**	**67.6%**	**8,549**

Modified from Normandeau (2008).

All of the results summarized above from Normandeau (2008) were based on CWIS operating flows when impingement sampling occurred. Impingement estimates were also provided based on historical operating flow and produced similar results. For example, based on historical operating flow, an annual estimate of 4,753 fish and 11,611 macrocrustaceans were impinged. Total adult equivalents impinged annually were 1,633 fish (Normandeau 2008).

Summary

In one year, 5,365 fish from 33 taxa and 12,649 macrocrustaceans from 5 taxa were impinged at Schiller. Approximately 18% of all fish survived impingement while 68% of all macrocrustaceans survived impingement.

2.3 IMPACTS FROM ENTRAINMENT AND IMPINGEMENT LOSSES

2.3.1 General Impacts

Losses resulting from I&E can disrupt the natural food chain through the removal of organisms. Additionally, I&E losses can be cumulative if there are multiple facilities located in a single area such as a river.

Food Chain Ecology Impacts

Entrainment losses are critical since i) entrainable organisms (i.e., small size) form the base of an aquatic food web that supports a variety of higher trophic levels (Figure 2.1) and ii) some fish species have early life stages that are vulnerable to entrainment and feed upon entrained organisms. Over 145 million ichthyoplankton from 35 taxa and 1.3 billion macrocrustaceans from 7 taxa were entrained at Schiller.

Impingement losses are also important but impingement at Schiller is not excessive (5,365 fish from 33 taxa and 12,649 macrocrustaceans from 5 taxa). Still, large predators near the top of the food chain, when impinged, are removed from the natural waterbody and not available to consume organisms in the lower trophic levels and keep their numbers in check. When fish near the mid-trophic levels are impinged (e.g., omnivorous fish, forage fish), they are removed from the waterbody and not available as food for other trophic levels.

Figure 2.1 depicts a simplified aquatic food web for an estuarine environment. At the base of the chain are primary producers (e.g., phytoplankton). The next level of the chain includes small zooplankton such as copepods that feed on phytoplankton. The third level comprises macroinvertebrates (e.g., mussels) and other small fish that feed on zooplankton (e.g., herrings) and phytoplankton. The fourth level consists of larger fish (e.g., cunner) that feed on the levels of the food chain below them, including smaller fish. In general, juveniles of medium- or large-sized fish feed mostly on plankton and macroinvertebrates until they are large enough to consume small fish. Small fish are an essential food source for larger fish. Entrainment impacts the first three levels of this chain. Impingement impacts different levels of this chain through losses of both juvenile and adult fish and macrocrustacea.

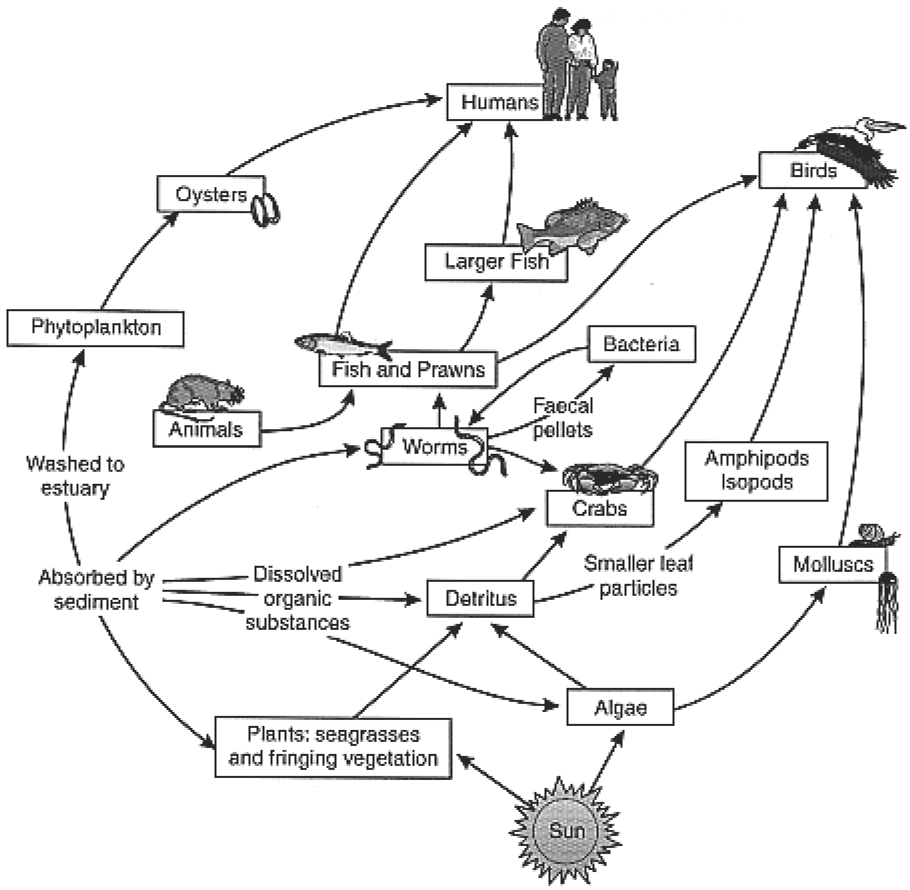
An example specific to the Piscataqua River, although not comprehensive or complete by any means, is provided below. Atlantic herring, a pelagic species found in the Piscataqua River, is considered one of the most important pelagic species in the Gulf of Maine and in the North Atlantic. They are considered to form a vital link between the base of the food web (e.g., plankton) and other aquatic organisms. Atlantic herring consume zooplankton such as copepods. These herring, in turn, are consumed by an array of predators including larger fish, birds, and other mammals (e.g., seals, whales). For example, cod, sculpins, hake, pollock, and striped bass – all present in entrainment or impingement sampling at Schiller – feed on at least one (and in some cases all) of the life stages of Atlantic herring (Gulf of Maine Research Institute 2013). Almost 1.8 million Atlantic herring larvae were entrained in one year at Schiller and an additional 277 individuals impinged (Normandeau 2008). Thus, approximately 1.8 million Atlantic herring individuals were removed from this food web.

Another example, also not comprehensive or complete by any means, is provided. American lobster larvae are omnivorous and consume zooplankton and phytoplankton while the diet of post-larvae lobster includes crab larvae and small shellfish (SLGO n.d.). Cunner and tautog, both resident species in the Piscataqua River, consume young American lobster (Auster 1989). In turn, cunner, tautog, and American lobster may be consumed by striped bass (Nelson *et al.* 2003). American lobster, cunner, and tautog were entrained and impinged at Schiller with cunner being a major species entrained and impinged. Striped bass were also impinged at Schiller (Normandeau 2008).

In a one-year period, over 145 million ichthyoplankton and over 1.3 billion macrocrustaceans (Normandeau 2008) were removed from the food chain and may not be available for higher trophic levels to consume and to sustain the ecosystem. Similarly, although no data was available for our review, it is expected that a similar or even larger number of other invertebrates (e.g., zooplankton) were entrained and removed from the food web. This entrainment and ultimate removal of invertebrates from the food chain can potentially have impacts on organisms higher in the food chain including species that are endangered, threatened or of special concern.

Furthermore, the numbers of organisms reaching adulthood can be reduced through entrainment and impingement (e.g., as seen by the calculated losses of adult equivalents of over 673,000 fish and 145,000 macrocrustacean adult equivalents entrained, see Section 2.1), as well as food sources for other species in the food chain.

Figure 2.1 Example of an Estuarine Food Web



Source: http://www.rivercare.southcoastwa.org.au/resources/awrb/c2.3.html.

Cumulative Impacts

Cumulative impacts must be considered if there are other industrial water users in the area; significant impacts resulting from I&E losses could occur when there are multiple facilities, even though the impact from individual facilities may be low. Furthermore, I&E impacts from one waterbody may impact populations in a connecting waterbody. As previously mentioned in Section 1.0, the Piscataqua River connects the Great Bay and Little Bay estuaries to the Atlantic Ocean. Injury and mortality through I&E at Schiller in the Piscataqua River may impact fish populations that also use the Great Bay or Little Bay estuaries. For example, winter flounder (Gulf of Maine stock) migrate to the Great Bay in late winter and prepare to spawn in the spring (April and May).

Summary

I&E losses from power plants can potentially disrupt the ecological food web at all levels through the removal of organisms. I&E losses that impact populations in one waterbody could also potentially affect populations in a connecting waterbody. I&E losses can be cumulative resulting in significant impacts if there are multiple facilities located in a single area such as a river.

2.3.2 Species-Specific Impacts at Schiller

Impingement and entrainment at Schiller result in the removal of fish, macrocrustaceans, and other organisms from the food web. Some species of interest impinged and/or entrained at Schiller include dominant species (e.g., cunner); those of commercial and/or recreational importance (e.g., winter flounder, Atlantic herring, tautog, Atlantic menhaden, American lobster); those whose populations are in decline (e.g., American eel); and those that are listed as species of concern by NMFS (e.g., rainbow smelt, alewife and blueback herring). Threatened and endangered species under the *ESA* (e.g., shortnose sturgeon, Atlantic sturgeon, Atlantic salmon), although not recorded as impinged or entrained at Schiller, are found in the Piscataqua River and thus risk being impinged or entrained. Cumulative impacts from I&E at other facilities must also be considered as the Public Service of New Hampshire's (PSNH) Newington Station is located on the same road as Schiller and Essential Power's (EP) Newington Energy Facility is just miles upstream of Schiller.

Schiller withdraws and discharges once-through cooling water into the Piscataqua River which can be classified as an estuary. Estuarine environments are sensitive and ecologically important as they are highly productive and provide habitat (e.g., breeding grounds, nurseries), nutrients and food for a diverse range of aquatic species (e.g., marine fish, macrocrustaceans). The Piscataqua River is important for diadromous fish species that utilize both fresh and saltwater during their lifetime. The Great Bay and Little Bay estuaries flow into the Piscataqua River. The Piscataqua River provides a variety of social, recreational and economic benefits including fishing, business, boating, and whale watching.

Entrainment losses at Schiller are very high and were estimated by Normandeau (2008) to be over 145 million ichthyoplankton and over 1.3 billion macrocrustaceans annually. Mortality typically occurs when organisms pass through the condenser cooling water screens and are subjected to physical, thermal, chemical and mechanical stressors in the plant. Impingement occurs when aquatic biota enter the condenser cooling water system and are collected on travelling screens (typically 3/8 in mesh) in the pumphouse. An estimated 5,365 fish and 12,649 macrocrustaceans were impinged annually at Schiller. Entrainment losses, unlike impingement, are generally proportional to the water sampled since planktonic organisms are less motile in the water body. Some of these impacts are discussed in more detail below.

The magnitude in which entrainment and impingement losses can seriously impact local populations depends on the species, existing population estimates in the river, life history stages present, their interactions with other species, and variability in year-class strength. Listed below are examples of selected species of interest where entrainment and/or impingement at Schiller can potentially have a significant impact.

Winter Flounder

An estimated 347,480 winter flounder eggs and larvae are entrained annually at Schiller. An additional 534 winter flounder are impinged annually. Winter flounder are an anadromous species that are important recreationally and commercially. Spawning generally occurs from winter to spring and egg hatching occurs in 2-3 weeks, depending on temperature. Since timing of hatch is temperature-dependent, activities such as thermal discharges could change ambient temperatures and thus may impact hatch times and affect survival (NMFS 1999a). Some winter flounder migrate from the Piscataqua River to the Great Bay estuary in the late winter and spawn in the spring (April and May) (Vachon and Sullivan 2007). Juveniles use estuaries for nursery habitat. Since 2002, winter flounder abundance has been decreasing in New Hampshire. In a 2011 study conducted under a New Hampshire Marine Fisheries Investigations grant (No author 2011), abundance of juvenile winter flounder was the second lowest ever recorded and according to the Atlantic States Marines Fisheries Commission's Plan (ASMFC) Reviews for winter flounder (2007), an anthropogenic factor contributing to low abundance is power plant I&E.

Atlantic Herring

Almost 1.8 million Atlantic herring larvae are entrained annually at Schiller. An additional 277 individuals are impinged annually. Atlantic herring are an anadromous species and use estuaries for nursery habitat. They are considered valuable commercial fish. Atlantic herring are a very important species in the Gulf of Maine and in the North Atlantic; they are forage fish and thus form an essential link between the bottom of the food web (i.e., plankton) and other organisms (Gulf of Maine Research Institute 2013).

Rainbow Smelt

At Schiller, over 1.6 million rainbow smelt larvae are estimated entrained annually. An additional 580 smelt are impinged annually. Rainbow smelt, an anadromous species, utilizes estuaries for nursery habitat. In 2004, rainbow smelt were designated as a species of concern by NMFS. Population declines in the last few decades are partly because of pollution and habitat loss, among other factors. In a 2011 survey, rainbow smelt abundance was the fifth lowest on record in New Hampshire (No author 2011).

American Eel

Almost 8,000 American eel larvae are entrained annually. The American eel is a catadromous species. A 2012 stock assessment stated that in the U.S., the eel population is depleted and declines are caused by a variety of factors including habitat loss, environmental changes, contaminants and turbine mortality (hydroelectric power plants). A hearing held by the New Hampshire Fish and Game Department recently took place in New Hampshire (April 15, 2013) on the American Eel Draft Addendum III which responds to the 2012 findings. The draft Addendum proposes a variety of management options to reduce eel mortality and increase the conservation of eel stocks (NHFG 2013).

Atlantic Tomcod

An estimated 49,434 Atlantic tomcod young-of-the-year are entrained annually at Schiller. An additional 47 individuals are impinged. Atlantic tomcod are found in estuarine habitats and subject to disturbances including thermal discharge pollution. Spawning occurs from November through February and hatching occurs after approximately 3-4 weeks.

Shortnose Sturgeon

Shortnose sturgeon are an anadromous species that prefer nearshore riverine, estuarine and marine habitat of large river systems and that feed on benthic organisms (e.g., crustaceans, insects, mollusks) (NMFS 2013). They are listed as endangered under the federal *ESA* and NMFS (2013) indicates that they are found in the Piscataqua River. Shortnose sturgeon were not recorded during entrainment and impingement monitoring at Schiller (Normandeau 2008). However, as discussed in Section 3.0, it is possible that the sampling methods and approach were not robust enough to adequately sample this species given their expected low abundance. In addition, sampling was only biweekly in May for entrainment sampling a period of time when larvae would be susceptible to entrainment.

The NMFS (NMFS 1998) Recovery Plan stated that shortnose sturgeon are susceptible to impingement and entrainment from cooling water intakes and power plants. In a National Pollutant Discharge Elimination System (NPDES) permit for EP’s Newington Energy Facility in New Hampshire (no. NH0023361) (USEPA 2012) also located on the Piscataqua River and only a few miles upstream of Schiller, it was indicated that the USEPA reviewed federal endangered and threatened species and indicated that shortnose sturgeon have the potential to be present near the Newington Energy Facility; Attachment E of this permit indicated that two shortnose sturgeon were documented in the Piscataqua River by the New Hampshire Fish and Game in 1989; in a more up-to-date assessment of the occurrence of shortnose sturgeon in the Piscataqua River, NMFS in 2011 has reported that shortnose sturgeon are not known to use the portion of the Piscataqua River in the area near the Dover Wastewater Treatment Facility (WWTF), which is about 4.3 miles upstream of Newington Energy Facility and within 10 miles upstream of Schiller (see Attachment E of USEPA 2012).

Atlantic Salmon

Atlantic salmon are an anadromous species and were not recorded in entrainment or impingement monitoring at Schiller (Normandeau 2008). However, the Gulf of Maine Distinct Population Segment (DPS) is listed as endangered under the federal *ESA*. The endangered Atlantic salmon has been extirpated as a breeding population in much of its historic range, including the Piscataqua River and Great Bay estuary (NMFS and USFWS 2005). Historically, the Cocheco and Lamprey rivers were home to major runs of the Atlantic salmon. Both of these rivers can only be accessed by fish that first pass Schiller on the Piscataqua River. Efforts to restore spawning populations of Atlantic salmon in New Hampshire and Connecticut have been underway for nearly 40 years (NMFS and USFWS 2005). NMFS has designated the Piscataqua River, the Great Bay estuary, and its tributary rivers such as the Cocheco and the Lamprey Rivers essential fish habitat for Atlantic salmon (Fay et al. 2006).

Atlantic Sturgeon

Atlantic sturgeon are an anadromous species that are dependent on estuaries. This species was not collected in entrainment or impingement sampling at Schiller (Normandeau 2008). However, the Atlantic sturgeon Gulf of Maine DPS is listed as threatened under the federal *ESA*. Under the final listing rule for the Gulf of Maine DPS[2], Atlantic sturgeon are present in the Piscataqua River. Additionally, in the NPDES permit (USEPA 2012) for the Newington Energy Facility, just miles upstream from Schiller, the USEPA reviewed federal endangered and threatened species and identified Atlantic sturgeon as having potential to be present near the facility. Attachment E of the NPDES permit indicated that the Atlantic States Marine Fisheries Commission's 1998 *Atlantic Sturgeon Stock Assessment, Peer Review Report* stated that "An occasionally Atlantic sturgeon (Hoff 1980) has been captured in the Piscataqua River…" In 2007, the NMFS published a status review of Atlantic sturgeon which noted that catch in the Piscataqua River/ Great Bay Estuary System included "a large gravid female Atlantic sturgeon (228 cm TL) weighing 98 kg (of which 15.9 kg were eggs) [who] was captured by a commercial fisherman in a small mesh gill net at the head-of-tide in the Salmon Falls River in South Berwick, ME on June 18, 1990" (Atlantic Sturgeon Status Review Team 2007). But the review went on to note that since 1990 there had been no further reported catches and concluded that, as a breeding population, the Atlantic sturgeon is likely extirpated in the Great Bay. However, Attachment E of Newington Energy Facility's NPDES permit (USEPA 2012) states that NMFS,

[2] Federal Register Vol. 77, No. 24 (Feb. 6, 2012). Endangered and Threatened Wildlife and Plants; Threatened and Endangered Status for Distinct Population Segments of Atlantic Sturgeon in the Northeast Region. Final Rule. http://www.nmfs.noaa.gov/pr/pdfs/fr/fr77-5880.pdf.

in 2011, indicated that Atlantic sturgeon use the portion of the Piscataqua River near the Dover WWTF, which is 4.3 miles upstream of Newington Energy and within 10 miles upstream of Schiller.

American Shad

American shad are an anadromous species and were not recorded at Schiller during entrainment and impingement sampling (Normandeau 2008). Juveniles have not been captured in New Hampshire estuaries since 2002 (No author 2011). However, impingement and entrainment at power plants are likely contributing factors to their low abundance, according to the 2011 ASMFC Plan Review for American shad (No author 2011).

Tautog

An estimated 52,464 tautog eggs are entrained annually at Schiller. An additional 8 individuals were impinged annually. The tautog supports coastal commercial and recreational fisheries (Auster 1989). Since this species does not migrate long distances, it may be a key indicator of local stresses in the coastal areas along its range. Tautog eggs are pelagic; elevated surface water temperatures mostly associated with low-slack and maximum ebb tides could potentially directly impact tautog eggs. Thermal discharges may impact different life stages of tautog. For example, there is a preferred temperature for spawning (16.1°C), for egg incubation (21.1°C) and for larvae (23.4°C) (See Section 4.0); thus an increase in temperatures may result in less preferred temperatures or stress. The spawning period for tautog is generally mid-May to mid-August. The egg incubation period is 42-45 hours at 20-22°C and about 10-12 hours longer in colder water (Auster 1989). Thermal impacts to developing eggs may include direct mortality; however, since the egg incubation period is short (generally 2-3 days), advanced hatch would be less of a concern and exposure time would need to be several days (see Section 4.0).

Cunner

Cunners are a dominant species entrained at Schiller, with approximately 98 million (30 million + 68 million assumed cunners) ichthyoplankton entrained annually, corresponding to 67% of all fish entrained (Section 2.2). Cunners do not migrate long distances and thus they may be a key indicator of local stresses in the coastal areas along their range (Auster 1989). Cunner eggs are buoyant and generally hatch after 42-45 hours of incubation in 20-22°C water (similar to tautog eggs). Juvenile and adult cunners generally live together and depend on cover and thus are locally abundant in their preferred habitats (Auster 1989). More detailed temperature discharge information from the field on a seasonal basis is required to better define potential thermal effects to cunner eggs and larvae.

Atlantic menhaden

An estimated 590,147 Atlantic menhaden eggs are entrained at Schiller annually and annual total adult equivalent entrainment abundance is estimated at 8 individuals. In addition to entrainment, an estimated 306 individuals are impinged yearly at Schiller. Atlantic menhaden are an important commercial fish species. As forage fish, they play an important role in the ecosystem. Elevated surface water temperatures mostly associated with low-slack and maximum ebb tides directly impact pelagic eggs and larvae of Atlantic menhaden. The seasonal occurrence for eggs is April to August (Carpenter 2012). Thermal impacts to developing eggs may include mortality; however, since the egg incubation period is short (generally 2-3 days; Rogers and Van Den Avyle 1989), advanced hatch would be less of a concern and several days exposure would be required (Section 4.0). More detailed temperature discharge information from the field on a seasonal basis is required to better define potential thermal effects.

American lobster

An estimated 56,471 American lobster larvae are entrained annually at Schiller and the total adult equivalent entrainment abundance is estimated at 67 lobsters. Additionally, 302 lobsters are impinged yearly. The American lobster is an important and valuable commercial fishery in the Northeast region of the U.S. with revenues of $400 million annually (Bradt 2012). American lobsters can be found both inshore and offshore. According to NMFS (1994), temperature has the greatest effect on American lobster growth, survival, and reproduction compared to any other environmental parameter.

Alewife and Blueback Herring (River Herring)

An estimated 23 alewife and 63 blueback herring are impinged annually at Schiller (Section 2.3). Alewife and blueback herring (collectively termed river herring) are anadromous species and use estuaries for nursery habitat. Due to their declining numbers, alewife and blueback herring are considered species of concern by NMFS (NMFS 2009). A study conducted in 2011 under a New Hampshire Marine Fisheries Investigations grant stated that juvenile alewife abundance was the third lowest ever recorded and juvenile blueback herring abundance was the lowest ever recorded (No author 2011). Furthermore, in 2011, a petition to list alewife and blueback herring as threatened was found to be warranted and workshops to address identified data gaps (including climate change) were held to provide information that will help to develop a listing determination (NMFS 2012). However, in August 2013, NMFS announced that following a comprehensive status review of alewife and blueback herring, their listing as either threatened or endangered under the federal *ESA* was not warranted at this time (NOAA 2013).

Horseshoe crab

Horseshoe crabs which belong to a class of arthropods called Merostomata, are of significance to the Great Bay estuary community comprising a large population. An estimated 70 horseshoe crabs are impinged annually at Schiller (Section 2.3). Horseshoe crabs are linked to the successful migration of birds along the eastern U.S. coast and significantly impact bottom sediments and communities in estuaries (Schaller *et al*. 2010).

Cumulative Impacts

Cumulative impacts must be considered given other industrial water users in the area near Schiller; significant impacts resulting from I&E losses could occur when there are multiple facilities, even though the impact from individual facilities may be low.

There are several power plants within 20 miles of Schiller. For example, beside Schiller (< 1 mile) on Gosling Road is PSNH's Newington Station. PSNH Newington Station is a 420 MW gas and oil fueled power plant; the NPDES permit (no. NH0001601; USEPA 1993) authorizes Newington Station to operate a once-through cooling water intake system that withdraws up to 324.6 MGD of cooling water from the Piscataqua River and discharges a similar volume of heated water back into the river. Another facility on the Piscataqua River is a few miles upstream of Schiller; EP's Newington Energy Facility is a 525 MW station that uses natural gas and #2 fuel oil fired, combined cycle electrical generating facility; this facility employs a cooling tower. According to Newington Energy's NPDES permit (USEPA 2012), the maximum design flow intake is 10.8 MGD of water from the Piscataqua River for cooling tower makeup and the maximum allowable discharge of heated cooling tower blowdown is 4.0 MGD.

We did not find I&E data from PSNH's Newington Station readily available. Since EP's Newington Energy Facility utilizes a mechanical draft cooling tower to remove heat from water discharged from the condenser, the volume of river water withdrawn is reduced by about 95% compared to facilities with once-through cooling systems (USEPA 2012) (See Section 6.0 on technologies) and thus I&E numbers would be greatly reduced compared to facilities operating once through cooling facilities such as Schiller and PSNH's Newington Station. Overall, I&E estimates have been low at EP's Newington Energy Facility [e.g., annual impingement of 324 fish per year (2002-2004 data), entrainment losses between 0.008% and 0.1% relative to the locally available source pool (2001-2003 data)], consistent with closed-cycle cooling (USEPA 2012).

I&E losses from multiple facilities, despite the low numbers resulting from EP's Newington Energy Facility, as well as other structures such as dams, could result in significant impacts to fish in the Piscataqua River and Great Bay estuary. In this case, the impacts from Schiller can be significant given annual entrainment of 145 million fish eggs and larvae and 1.3 billion invertebrates.

Summary

Fish, macrocrustaceans and other organisms are removed from the ecological food web when they are impinged and /or entrained at Schiller. Some species of note that are impinged and/or entrained by Schiller include: dominant species (e.g., cunner); those of commercial and/or recreational importance (e.g., winter flounder, Atlantic herring, tautog, Atlantic menhaden, American lobster); those whose populations are in decline (e.g., American eel); and those that are listed as species of concern by NMFS (e.g., rainbow smelt, alewife and blueback herring). Threatened and endangered species listed under the *ESA* (e.g., shortnose sturgeon, Atlantic sturgeon, Atlantic salmon) were not recorded as impinged or entrained at Schiller but they are found in the Piscataqua River and are thus at risk for I&E. Several generating stations, including the PSNH Newington Station and the EP Newington Energy Facility are in the near vicinity of Schiller and thus cumulative impacts caused by I&E must be considered (even though I&E impacts at EP's Newington Energy Facility are generally low since it operates cooling towers).

2.4 CONCLUSIONS

Impingement and entrainment impact aquatic life the degree of which is important. There are over 45 fish species and at least 7 taxa of macrocrustaceans that occur near Schiller Station, with some organisms such as shortnose sturgeon, Atlantic sturgeon and Atlantic salmon listed as endangered or threatened under the *ESA*. Over 145 million fish (eggs and larvae) from 35 taxa and 1.3 billion macrocrustaceans from 7 taxa were entrained at Schiller. Additionally, 5,365 fish from 33 taxa and 12,649 macrocrustaceans from 5 taxa were impinged at Schiller. These impinged and entrained species included those that are of commercial and/or recreational interest, those whose populations are in decline, and those who are listed by NMFS as species of concern. No species listed as endangered or threatened under the *ESA* were impinged or entrained; however, since these species occur in the Piscataqua River, they may still be at risk of I&E. Cumulative impacts from I&E are possible from other facilities and dams including the PSNH Newington Station (< 1 mile of Schiller) and EP Newington Energy Facility (just miles upstream of Schiller).

3.0 SHORTCOMINGS IN MONITORING STUDIES

This section addresses shortcomings in both entrainment and impingement monitoring. Overall, the Normandeau (2008) I&E study was a well-designed study; however, there are some shortcomings identified in the study. These include issues with the entrainment sampling design related to robustness and entrainment survival studies; comparison of entrainment and source water body densities; impingement survival determination; lack of data on larval head capsule measurement to assist in technology assessments such as wedgewire screens, and characterization of seasonal year-to-year variation in both entrainment and impingement densities. These shortcomings systematically underestimate the extent of impacts from operations at Schiller.

3.1 ISSUES WITH ENTRAINMENT SAMPLING DESIGN

3.1.1 Sampling Design Not Robust and Not Designed to Detect Species of Low Abundance

The entrainment sampling design for Schiller was not robust enough for periods of high entrainment such as the months of May and September. Additionally, the sampling was not designed to detect species of very low abundance such as *ESA* listed species found in the Piscataqua River.

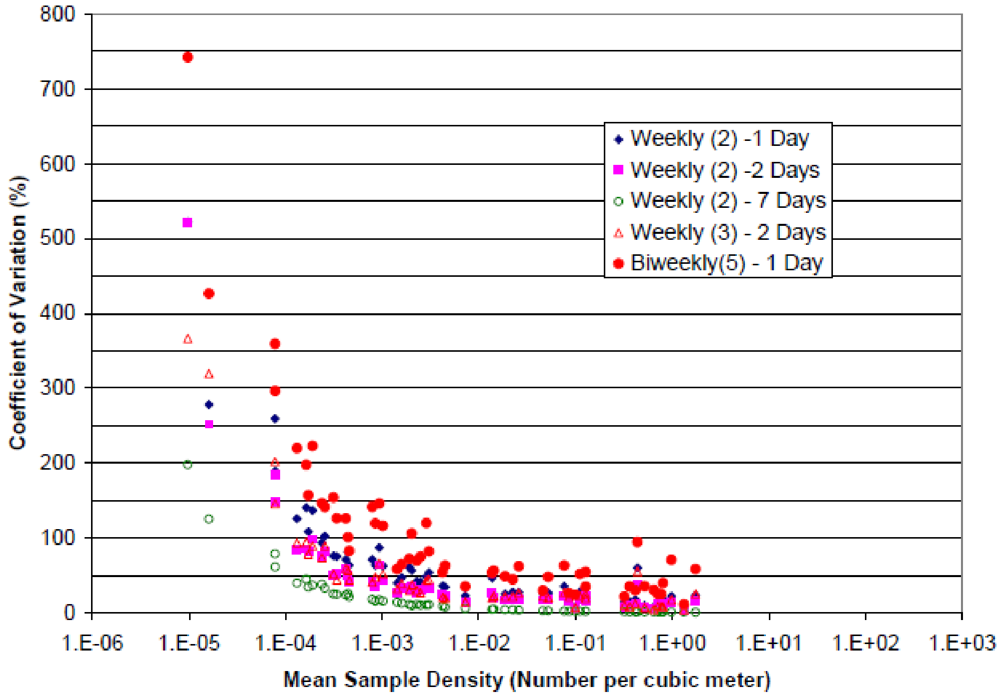
At the Schiller Plant, entrainment sampling was carried out from August 31, 2006 to September 27, 2007 at Screen House #2 (Units 5 and 6). Screen House #1 (Unit 4) was not sampled due to access issues. The sampling protocol was a seasonally-stratified fixed date design that was consistent with procedures used at other CWISs in estuaries in the U.S. (Normandeau 2008). Sampling occurred weekly during periods of expected higher entrainment (13 weeks in June-August 2007 and 13 weeks in January-March 2007). During other periods, sampling was conducted on a biweekly basis. It is noteworthy that May and September were also key entrainment periods for ichthyoplankton (Table 2.4) and macrocrustaceans (Table 2.6) but were only sampled biweekly. A total of 41 entrainment events took place. During each sampling event, four separate 100 m^3 samples were taken at 6-hour intervals to represent one consecutive 24-hour period. It took approximately 148 minutes to filter 100 m^3 of water for each sample. Entrainment estimates for Unit 4 were based on sampling of Units 5 and 6. A total of 162 entrainment samples were collected.

A total of 162 entrainment samples were collected over the one year study which at first glance appears adequate. However, as mentioned above, sampling was not robust enough for both ichthyoplankton and macrocrustaceans in May or macrocrustaceans in September (e.g., biweekly sampling) and the sampling was not designed to detect species of expected low abundance such as the shortnose sturgeon which are found in the Piscataqua River (NMFS 2013). Sampling could have been improved by increasing sampling frequency for the months May and September to 1-2 times per week (as opposed to biweekly, see following subsection on Number of Samples). If after making a BTA determination and requiring Schiller to install such BTA measures, the USEPA wants to require subsequent monitoring to verify the reduced levels of I&E, future sampling could incorporate increased sampling frequency.

Number of Samples

Variability in entrainment rates increases when entrainment rates are high compared to when they are low. Thus, it would make sense to sample at a higher frequency during periods of high entrainment to reduce the uncertainty when estimating annual entrainment. In theory, this was partly addressed at Schiller except for the months of May and September which were periods when significant entrainment of ichthyoplankton and crustaceans occurred (Tables 2.4 and 2.6). As mentioned above, sampling occurred one day per week at the CWIS during periods of expected higher entrainment and during times of expected lower entrainment, sampling occurred on a biweekly basis. However, as shown below in Figure 3.1,entrainment sampling frequency strongly affects the precision of annual entrainment estimates. For biweekly sampling, the coefficient of variation (CV) of annual entrainment estimates ranged from about 50% at the highest densities to 750% at the lowest densities. For sampling one day per week (Scenario 2), CV ranged from over 250% at the lowest densities to less than 50% at the highest densities. Sampling twice per week on random days (Scenario 2) decreased the CV and sampling 7 days a week (Scenario 2) decreased the CV even further (although sampling every day is cost prohibitive). In Scenario 3 where sampling was also conducted twice per week but on consecutive days, the CV was higher than when weekly sampling was conducted on random days (EPRI 2005a). In all cases presented in Figure 3.1, there were four events per day with 100 m^3 of water per sample which is similar to that which was used at Schiller (Normandeau 2008). A more robust sampling design of one or more samples/week especially during periods of high entrainment is recommended for verification monitoring following BTA selection.

Figure 3.1 Mean Coefficient of Variation of Annual Entrainment Estimates for all Taxa Combined and for 10 Individual Taxa, Based on 100 Iterations of Weekly Sampling Scenarios 2 (1, 2, and 7 Days per Week), 3 (2 Days per Week), and 5 (1 day per Biweek), with 4 Events per Day, 100 m^3 per Sample, applied to Indian Point Entrainment Data from 1983-1987



Source: EPRI (2005a)

Conclusions

The entrainment sampling design for Schiller was not robust enough for periods of high entrainment, especially during the months of May and September. Variability in entrainment rates increases when entrainment rates are high compared to when they are low. Thus, it would make sense to sample at a higher frequency during periods of high entrainment to reduce the uncertainty when estimating annual entrainment. Additionally, the sampling was not designed to detect species of low abundance such as *ESA* listed species found in the Piscataqua River, and sampling frequency should have been increased (2 times/week).

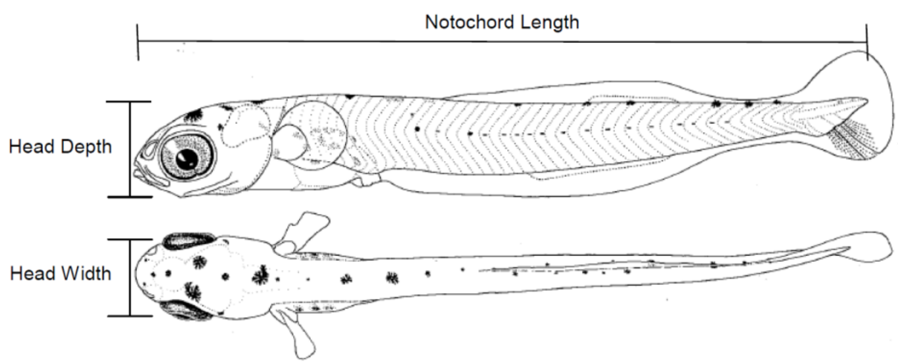
3.1.2 Lack of Data on Larvae Head Capsule Measurements and Its Importance

In the Normandeau report, ichthyoplankton (except winter flounder) was enumerated into five life history stages which included eggs, yolk-sac larvae, post-yolk-sac larvae, and juveniles. Winter flounder were classified into five life stages (1-5). Although the total length (to 0.1 mm) was done for subsamples of each ichthyoplankton life stage per stage there do not appear to be any measurements of head capsule depth and width which is critical information in order to assess entrainment reduction technologies such as wedgewire screens.

Cylindrical wedgewire screens are being considered as one option to reduce to entrainment mortality at Schiller. Still, it is unclear what mesh size would be optimal in reducing entrainment mortality. PSNH has used literature values to determine body depth in their assessment of various mesh sizes in excluding larvae which EPA has based their technology recommendations on (EPA Draft NPDES Permit NH0001473). However, technology determination involving screen mesh size selection can be very site specific and will vary with site location, water body, intake configuration, intake velocities, and the species, number and sizes (head capsule and total length) of larvae entrained. Literature values are of interest and are used conservatively in the PSNH report, but may not be applicable at the Schiller Plant.

If wedgewire screens performs primarily as filters to limit entrainment, then entrainment would be directional proportional to the dimensions of the eggs and/or larval which are susceptible. For this reason, larval head capsule size (both width and depth) are measured as a means of determining size of larval exposed to entrainment (Tenera 2013, Figure 3.2). At the early stages of development, most parts of the fish larval are easily compressible and soft; however, the head capsule consists of harder cartilage and bone that is not compressible. Thus, head capsule width or depth can be used to determine whether or not a larva would be excluded from a given mesh size. This information is very valuable for assessing technologies such as wedgewire screens. The use of literature values is not site specific.

Figure 3.2 Illustration of Measurement Locations for Notochordal Length and Head Depth (Height) and Width of a Preflexion Stage Larval Fish (from Tenera 2013)



Conclusions

Head capsule width and depth should have been measured which would accurately define the sizes of larvae being entrained at Schiller. These measurements are extremely important especially considering different mesh sizes being considered as an entrainment mortality reduction technology. Nevertheless, this data can still be obtained since entrainment samples were preserved in 10% buffered formalin. Larvae are therefore still available for head capsule measurement and updating screen mesh assessments.

3.1.3 Issues with Entrainment Survival Studies

There is concern related to determination of entrainment survival that may result in the underestimation of the extent of the impacts.

The entrainment survival determination did not appear to address all aspects related to passage through the CWIS, likely resulting in an overestimate of survival. As part of entrainment sampling procedures at Schiller, entrainment survival studies were carried out on a monthly basis at Screenhouse #2 and consisted of collecting one hour samples using a barrel-type reverse flow entrainment sampler. Control adjusted latent entrainment survival rates were applied to entrainment abundance estimates to identify the fraction and number of entrained organisms surviving mechanical damage due to passage through the cooling water intake pumps (page 16 of Normandeau 2008). Survival estimates focused only on losses due to mechanical mortality at the CWIS. The problem is that these survival estimates do not seem to consider passage through the condenser system which also focus on additional stressors including the following:

- Thermal Stressor: Rapid temperature rise through and beyond the condenser boxes;
- Pressure Stressor: Changes in hydrostatic and hydrodynamic pressure caused by differences in level and pumping;
- Chemical: Potential exposure to biocides such as chlorine (sodium hypochlorite) throughout the system;
- Mechanical: Hydraulic shear stress, turbulence and abrasion associated with passage through filters, condenser tubes and other pipework.

These additional stressors can cause considerable damage on entrained organisms. Given the number of stressors on entrained organisms, researchers in the UK have focused on developing a simulator which is able to mimic the level and ranges of stressors found at power plants (Turnpenny *et al*. 2010). These stressors could be varied individually and applied alone or in combination. A summary of results suggest high variability among major animal groups and species with some groups showing high survival whereas others do not.

Thus, statements made in Normandeau (2008) that indicate that different species of either ichthyoplankton or macrocrustaceans survived entrainment "through the Schiller Station CWIS's" are misleading since only survival from mechanical damage through the intake pumps was measured.

In conclusion, the estimates of overall average of 34.9% of ichthyoplankton (all life stages) and 77.4% of the macrocrustacean larvae surviving entrainment at Schiller Station is overestimated since other stressors such as temperature and pressure effects do not seem to have been considered.

3.1.4 Conclusions

The entrainment sampling design for Schiller may not have robust enough for periods of high entrainment, especially during the months of May and September. Additionally, the sampling was not designed to detect species of low abundance such as *ESA* listed species found in the Piscataqua River. Entrainment survival determinations may not have addressed all aspects of entrainment through a CWIS likely resulting in an overestimation of survival.

3.2 ENTRAINMENT ESTIMATES RELATIVE TO SOURCE WATER BODY DENSITIES

EPA in their 308 letter requested an estimate of the percentage of eggs and larvae lost to entrainment compared to the density of eggs and larvae in the Piscataqua River for each week of sampling. Section 6.1 of Normandeau (2008) provides a discussion on this comparison. Unfortunately, PSNH proposed no water source sampling for ichthyoplankton and macrocrustacean larvae that was concurrent with the entrainment sampling completed from August 2006 to September 2007. Instead, the percentage of eggs and larvae withdrawn into Schiller Plant in the CWIS was estimated volumetrically based on the assumption that entrainment is directly proportional to flow. Normandeau (2008) compared the design intake flow for Schiller Station for all six circulating water pumps associated with Units 4, 5 and 6 with the tidal flow and source water body flow. This comparison is subject to error because of a number of assumptions which are difficult to satisfy and requires field work to validate. Listed below are some criticisms:

- The relationship between entrainment and CWIS flow is well established for some sites but not between both CWIS flow and flow of river and entrainment. This latter relationship is not believed to be well developed especially for an estuarine environment. Entrainment densities would be assumed to be homogeneous throughout the Piscataqua River, and densities are assumed to be almost identical in both nearshore and offshore locations. This assumption has not been satisfied in the absence of field work but is critical since there are two CWISs at the Schiller Plant. Unit 4 withdraws once-through cooling water from a submerged offshore (32 ft out) intake while Units 5 and 6 withdraw once-through cooling water from a nearshore intake.

- Comparisons were not done for each week of sampling (as per EPA request). Entrainment varies seasonally and the calculations in Section 6.1 of Normandeau (2008) are based on an annual period rather than when most entrainment typically occurs (May to August).
- Adult distributions of spawning fish are also assumed to be homogeneous for both migratory and non-migratory species in the vicinity of the Schiller Plant. This has not been verified based on field data.
- EPRI (2003) has summarized findings on the relationship between entrainment and impingement and CWIS volumetric flow. It was concluded that site-specific analyses remain essential for predicting or monitoring fish population effects of water intakes. "Site-specific details of the environment and specific fish populations appear to predominate over a simple dose-response model in determining whether populations are affected by specific water withdrawal rates". Field "in-situ" river work would thus be necessary at the Schiller Plant.
- Although focused on impingement, King *et al*. (2010) explored environmental, power plant design and operational factors that may influence impingement rates over a two year period. Environmental factors included water temperature and hydrological data (e.g., river flow, stage, change in flow and stage during sampling events) while plant design and operational factors included: volume of cooling water pumped during sampling events, design flow, design approach velocities at intakes, intake configurations (i.e., submerged or surface), intake locations along the river, and position of the intakes on the riverbank (shoreline or recessed canals). The results, along with the episodic impingement events suggested that the abundance and distribution of age-0 fish in this riverine system were major factors contributing to the variability of impingement rates at the power plants investigated. The only factor investigated under direct control of the power plants, actual cooling water pumping rate during sampling events, was one of the least important variables affecting impingement rates. Statistical analyses did not identify volume of cooling water used or design pumping capacity as a major factor influencing impingement rates (King *et al*. 2010).
- The estimates of entrainment survival based on tidal flow and source water flow in Section 6.1 of Normandeau (2008) are also misleading given concerns expressed earlier (Section 3.0) since other stressors do not appear to be have been addressed for entrainment survival estimates.

3.3 Issue with Characterization of Seasonal Year-to-Year Variation in Entrainment Densities

EPA in their 308 letter requested a justification that collection of one year of entrainment data reflects an appropriate characterization of overall entrainment at Schiller Station CWIS, including seasonal and year-to-year variation. Section 6.2 of Normandeau (2008) provides arguments justifying the collection and analysis of one year of entrainment data during the 52 week sampling period from 2 October 2006 through 30 September 2007 that it reflects an approximate characterization of overall ichthyoplankton and macrocrustacean entrainment at Schiller Station. These arguments are not appropriate for the following reasons:

- No Seasonal Data: Data only presented over a five (5) week period and no seasonal component.
- Limited Data: The year-to-year comparisons are based only on five-(5) data points for each over the 5 week period from August 31-September 28, 2006 and August 30-September 27, 2007. This period (5 weeks) represents less than 15% of the entire year sampled. It is important to note that these samples were also based on biweekly samples, not weekly, which was done during the key entrainment periods. Entrainment sampling occurred weekly during periods of expected higher entrainment (13 weeks in June-August 2007 and 13 weeks in January-Mach 2007). EPRI (2005a) reviewed entrainment data at Indian Point which shows that sampling frequency strongly affects the precision of annual entrainment estimates. For biweekly sampling, the coefficient of variation (CV) of annual entrainment estimates ranged from about 50% at the highest densities to 750% at the lowest densities. Comparisons used at Schiller were at the lower densities of ichthyoplankton abundance (see Figures 3.3 and 3.4). For this reason, it is believed that these comparisons are not considered statistically valid for an entire year of entrainment.

Figure 3.3 Mean Larval Fish Density (#/100 m^3 sampled) by Week (all Life Stages Pooled) for Entrainment Samples Collected at Schiller Station for the Period of August 31, 2006 to September 27, 2007

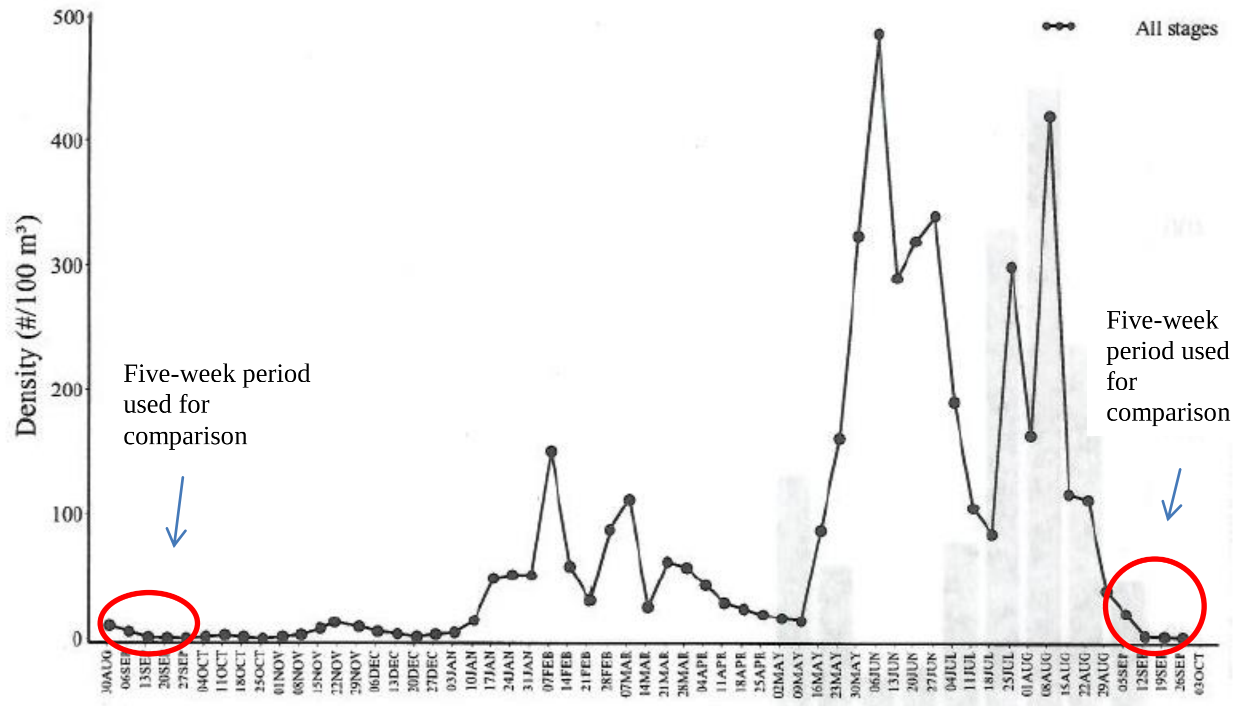
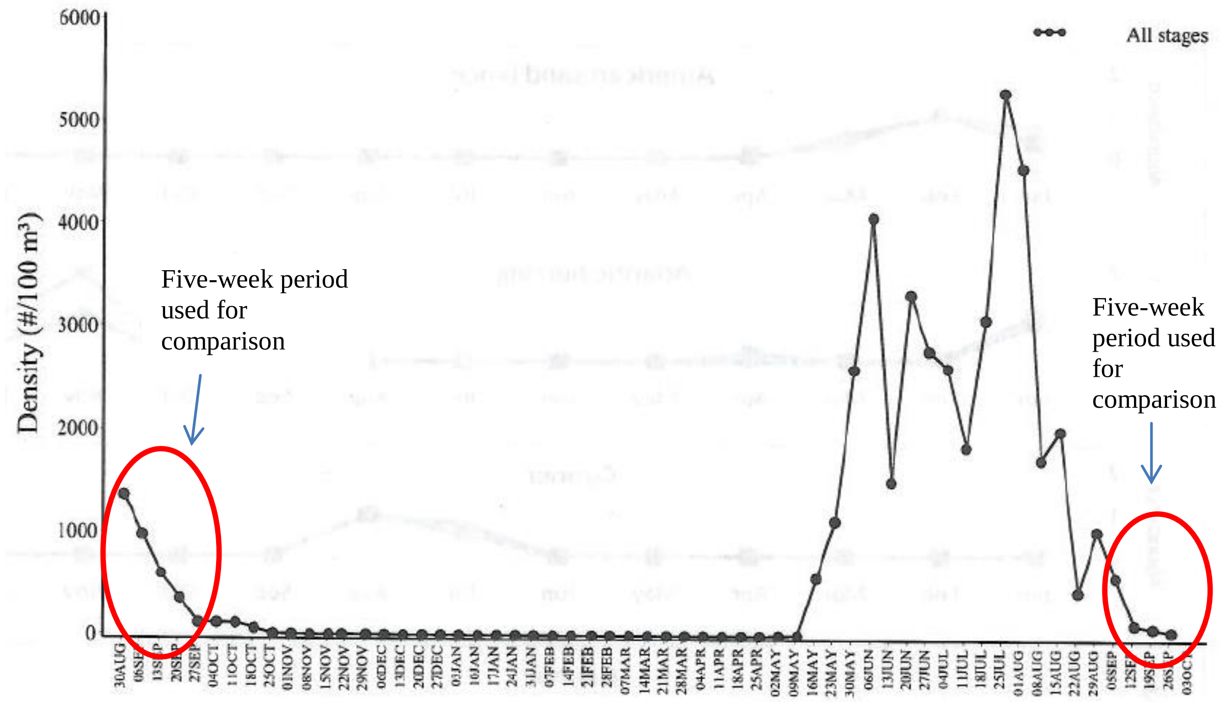


Figure 3.4 Mean Macrocrustacean Larval Density (#/100 m^3 Sampled) by Week (all Life Stages Pooled) for Entrainment Samples Collected at Schiller Station for the Period of August 31, 2006 to September 27, 2007



3.4 Issue with Impingement Survival Determination

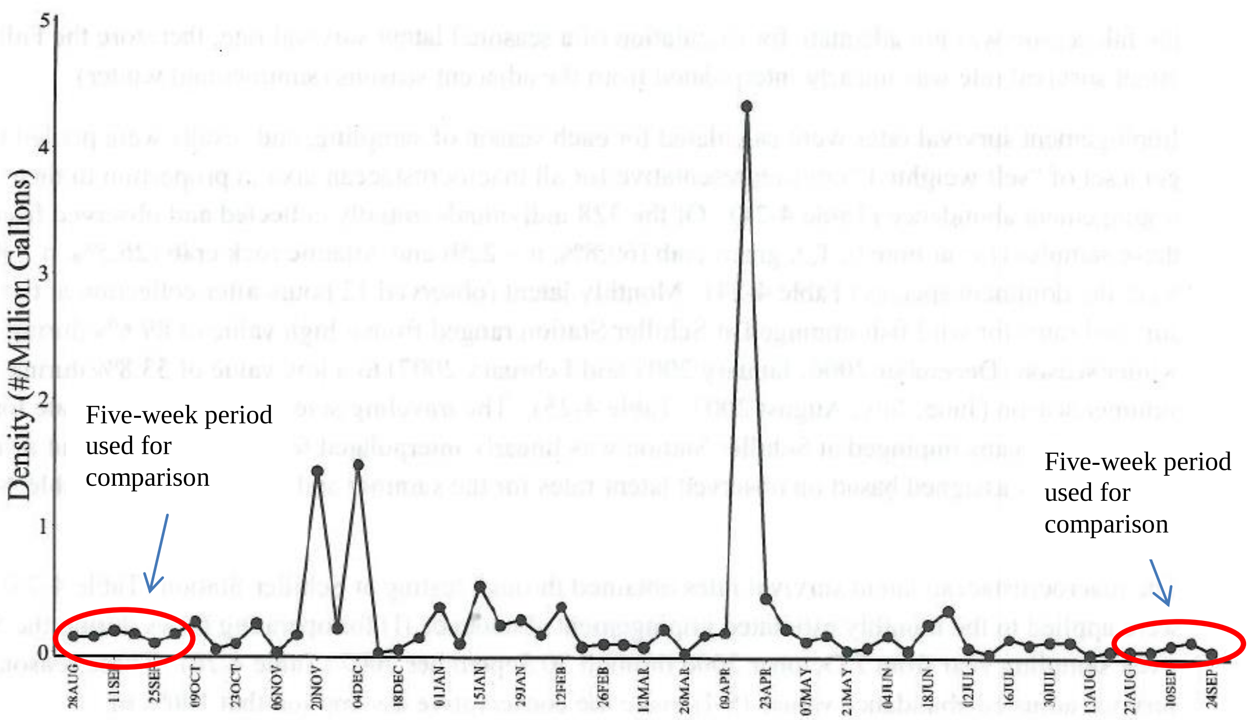
Impingement survival was determined by the collection of 19 taxa of wild fish at the discharge end of the return sluice after they were subjected to the travelling screen collection and wash (Normandeau 2008). All survival test fish and macrocrustacea collected were separated from the debris, gently removed, and placed into holding tanks. Their initial (time-0) survival was determined as alive, stunned or dead. All alive and stunned fish and macrocrustaceans were held to determine a 12-hr latent survival rate. A 12-hr latent survival period is not long enough and not the industry norm which is usually 24-hr or in some cases, 48-hr following the initial survival observations. Therefore, these survival estimates for both fish and macrocrustacea are not long enough in duration, and therefore may be subject to error.

3.5 Issue with Characterization of Seasonal Year-to-Year Variation in Impingement Densities

EPA in their 308 letter requested a justification that collection of one year of impingement data reflects an appropriate characterization of overall impingement at Schiller Station CWIS, including seasonal and year-to-year variation. Similar to entrainment, Section 6.2 of Normandeau (2008) provides arguments justifying the collection and analysis of one year of entrainment data during the 52 week sampling period from 2 October 2006 through 30 September 2007 that it reflects an approximate characterization of overall fish and macrocrustacean impingement at Schiller Station. Similar to entrainment, these arguments are not appropriate for the following reasons:

- No Seasonal Data: Data only presented over a five (5) week period for 2006 (August 31 to September 28) and 2007 (August 30 to September 27) and no seasonal component.
- Key Impingement Periods. The key impingement period for fish impingement is clearly not during end of August to end of September. The adjusted fish densities impinged (see Table 2.13) represent less than 4% of total annual impingement for September 2007. Figure 4.1 of Normandeau (2008) shows the relatively low densities for comparison for the sampling month comparison for which are clearly not representative of higher periods of impingement (see Figure 3.5). The same occurs for macrocrustacea.
- Comparisons cannot be extrapolated for an entire year since there is no seasonal component and at a period when densities are naturally low.

Figure 3.5 Mean Fish Density (#/million gallons) by Week for Impingement Samples Collected at Schiller (Units 4, 5, and 6 combined) for the period August 31, 2006 to September 27, 2007



Modified from Normandeau (2008)

3.6 CONCLUSIONS

Although overall being a well-designed study, there were some shortcomings identified in the Normandeau (2008) I&E study which systematically may have underestimated the extent of impacts from operations at Schiller. These include: a sampling design not sufficiently robust especially for periods of high entrainment and the detection of species in low abundance such as listed species; an entrainment survival determination that does not seem to address all stressors associated with entrainment through the CWIS; using a comparison of entrainment densities with source water body densities which requires a number of assumptions that are difficult to satisfy and requires field work to validate; impingement survival estimates based on 12-hrs (i.e., not long enough); and characterization of seasonal year-to-year variation in both I&E densities that are not based on seasonal data and only based on limited data.

4.0 THERMAL DISCHARGE IMPACTS

This section addresses the following task in the scope of work: evaluating the impact of Schiller's existing thermal discharges on fish passage and fish populations, including an assessment of the effects of elevated temperature on aquatic organisms and whether Schiller's thermal discharges allow for the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the waterbody.

This section first presents general effects that warmer discharge waters have on aquatic life, followed by the preliminary risk assessment findings for Schiller which includes a summary of risk assessment calculations carried out for species in the thermal plume of Schiller, based on available information. This section concludes with a discussion on cumulative thermal impacts.

4.1 DISCHARGE EFFECTS

Warmer temperatures at the discharge of power plants may impact aquatic biota. For example, advanced hatch of fish species may occur, which could indirectly lead to mortality since food sources may not be readily available. Changes to a variety of life history variables such as reproductive capacity and fecundity may also occur in fish species. Additionally, thermal pollution may alter or affect habitat (e.g., for spawning) and fish community structure. Heated effluent may impair or even kill organisms (USEPA 2012).

A power plant's thermal pollution or discharge into a waterbody may alter or affect habitat and fish community structure. For example, a study was conducted in Brazil to investigate the effects of a nuclear plant's discharge into the Ilha Grande Bay (Teixeira *et al*. 2009). The thermal impact location (32 ± 0.4°C) was compared to two control locations (25.9 ± 0.3°C and 24.6 ± 0.2°C). Compared to the control locations, the impact location had a significant decrease in the richness and diversity of fish species (13 species vs. 33 and 44 species at control locations), as well as a reduction in benthic cover. Additionally, statistical analysis revealed that the fish communities of the impact location and control locations were significantly different. The authors concluded that thermal pollution – in this case, 6-7°C above ambient – alters benthic cover and impacts fish assemblages by decreasing richness and altering composition. The same may be occurring in the vicinity of Schiller.

One potential effect of thermal discharge is advanced hatch. Advanced hatch of embryos may indirectly lead to mortality but more studies are needed. NMFS (1999a) summarized several studies on winter flounder and hatch advancement. For example, in a study conducted by Williams (1975) cited in NMFS (1999a), eggs incubated at 0°C took an average of 38.6 days to hatch. At an incubation temperature of 3.5°C, average hatch time was 21.5 days. For eggs incubated at even higher temperatures (12-17°C), average hatch time was 18 days but only about half of the eggs survived. Rogers (1976), cited in NMFS (1999a), found that incubation time was shorter with higher temperatures: winter flounder eggs took 19 to 31 days to hatch at 3°C but only 5 to 10 days at 14°C. Similarly, Frank and Leggert (1983) found that fish species such as capelin, seasnail, radiated shanny, and winter flounder, which lay demersal eggs time their hatching to coincide with favourable conditions. Onshore winds provide favourable conditions including warmer waters that are food-abundant, predator-poor and surface water over shallow spawning areas (NMFS 1999a).

Advanced hatch due to temperature increases may also result in larval mortality since food sources may not be readily available. Casselman (1995) noted that early hatch can be detrimental to lake trout eggs. Other researchers have shown that with a ΔT or temperature change of 3-5°C, advanced hatch can occur for cold water species such as round and lake whitefish (Patrick et al. 2013). For example, at a ΔT of 5°C, hatch may occur one month earlier than at ambient temperatures. The effects of temperature on hatch are likely a function of the duration of the incubation period of the species and exposure time of the thermal plume. Therefore, we would expect to see evidence of advanced hatch for species which incubate over a longer period [e.g., winter flounder (as noted above, NMFS 1999a) and Atlantic tomcod, (Carpenter 2012)] as opposed to species such as tautog and Atlantic menhaden (for example, egg incubation period of 2-3 days) which have much shorter incubation periods in the spring/summer. In other words, in species with long incubation periods, advanced hatch of eggs may be more of an issue than eggs which incubate over shorter periods of time in the summer. Still, this assumes long term exposure to the thermal plume which may not be the case at Schiller where the plume is localized, somewhat buoyant and well mixed with the tidal flows. The tidal induced high river velocities would reduce the exposure time. Still, potential thermal effects need to be more quantified with seasonal data which does not seem available.

Power plant discharges may adversely impact other aquatic habitat which can indirectly affect fish survival. For example, eelgrass underwater habitat forms the base of an estuarine food web; it supports a variety of commercially, recreationally and ecologically important species. Eelgrass provides food, nursery habitat and shelter for fish and shellfish. Other functions of eelgrass include the filtering of estuarine waters (improving water clarity), removing nutrients and suspended sediments from the water column, and holding sediments in place (via its roots and rhizomes) (Short 2013). Eelgrass habitat is utilized by a variety of species present near Schiller such as cunner, tautog (Auster 1989), and American lobster (Short *et al.* 2001). Eelgrass habitat has declined 90% from historic levels (i.e., 32.5 acres in 1948, 1962, 1980 and 1980 datasets to 3.9 acres in 2008-2010) in the portion of the Piscataqua River near Schiller and New Hampshire considers this to be an impairment of water quality (Trowbridge 2012). Impairments to the growth of eelgrass include: eutrophication, turbidity, and increased temperatures. The combination of increased temperatures (which decreases respiration) and increased turbidity (which decreases photosynthesis) can adversely impact eelgrass. In the 2013 State of our

Estuaries Report for the Great Bay Estuary, it was indicated that the connectivity of eelgrass between Great Bay and Portsmouth Harbor is disrupted with the loss of eelgrass in the Piscataqua River (PREP 2013). The relative contribution of thermal discharges from several power plants to eelgrass habitat loss should be considered.

Thermal effects also can affect spawning of species impinged at Schiller Station such as white perch. Sandström *et al.* (1995) studied a European perch population exposed to a thermal discharge and reported that spawning and hatching of perch occur very early in discharge waters compared to reference waters and that this early spawning may explain the maturation of males during the first summer while in reference waters, eggs have yet to hatch or the perch are still in the larval stages. It was concluded from this study that the life-time fecundity of the perch was reduced and there was a shift of reproductive performance to younger ages.

Luksiene *et al*. (2000) investigated the effect of thermal effluent exposure on the gametogenesis of female fish, including perch (*P. fluviatilis*) at the effluent of three power plants in Europe (Forsmark Nuclear, Ignalina Nuclear, and Oskarshamn Nuclear). At full production, the water temperature at all three plants are 10-12°C above ambient. The results revealed that thermal effluent had a negative influence on gametogenesis which suggested reduced reproductive capacity. Oocyte atresia or degeneration began during vitellogenesis in the fall season and was frequently followed by asynchronous egg cell development. Other anomalies included multi-nucleus oocytes and hermaphroditism. While these phenomena were also observed in natural (reference) populations, they were more common in the fish (including perch) collected near the effluent.

A physiological individual-based model for foraging and growth of larval Atlantic herring (*Clupea harengus)* was constructed and reported in Hufnagl and Peck (2011). The model was used to examine climate-driven limitations on life history scheduling. The results from modeling suggested that climate driven changes in bottom-up factors would impact both spring- and autumn-spawned larvae. Spring-spawned herring larvae would be tightly constrained by match-mismatch dynamics between zooplankton and larvae production while autumn-spawned larvae will likely not be able to avoid unfavourable conditions by delaying their spawning time or by using more northern spawning areas due to limitations in day length to larval growth and survival.

4.2 RISK ASSESSMENT

4.2.1 Thermal Effects Risk Assessment Methodology

Thermal discharges from a facility may cause increases in the temperature of the receiving waters, leading to possible detrimental impacts on the ecology of the aquatic environment.

A preliminary thermal risk assessment on aquatic biota was carried out as part of our thermal effects evaluation for Schiller Station. The risk assessment we used involved similar methodology to that used in ecological risk assessment involving exposure to chemicals.

The purpose of the risk assessment was to determine the potential impacts on species (fish and benthic invertebrates) that could inhabit the receiving water body, in this case the Piscataqua River, near the Schiller Plant. A risk assessment, such as the one applied for Schiller, uses available information to assess population-level impacts, covering all species and life stages, using the methodical approach described below.

Subject Matter	References with Similar Approach
Types and derivation of thermal effects benchmarks	USEPA (2001), CSA (2012)*, Wismer and Christie (1987), WDOE (2002)
Assessment of each life stage of fish	USEPA (2001), CSA (2012)*, Wismer and Christie (1987), WDOE (2002)
Use of hazard quotient to quantify risk	CSA (2012)*

Notes:
* CSA (2012) is the Canadian Standards Association standard for Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills (CSA 2012).

Hazard Quotients

The hazard quotient (HQ) is an index that can be used to indicate whether there may potentially be an effect on fish species due to thermal effects. This is essentially a screening tool. A HQ value greater than 1 indicates that there may be potential effects from the thermal plume.

In general, the HQ is calculated by comparing measured or modeled temperatures to the thermal effects benchmarks (these two components are explained further below):

$$HQ = \frac{Exposure\ Temperature}{Thermal\ Effects\ Benchmark} \quad (Equation\ 1)$$

- **If HQ < 1**, adverse effects on biota are not expected, based on the available information.
- **If HQ > 1**, an adverse effect is possible.

Different types of HQ calculations reflect potential effects to fish at different life stages and different exposure periods or time frames. The types of HQs calculated are as follows:

i) HQ for Avoidance (sub-lethal effects)

$$HQ = \frac{T - T_{pref}}{T_{upper} - T_{pref}}, \text{ for } T > T_{pref}$$

where T temperature of water at the location of interest. Maximum 7-day rolling average temperature (MWAT) value, as described below; this statistic is representative of long-term or chronic exposure.

T_{pref} typical temperature within the range of temperatures that the fish species prefers.

T_{upper} temperature that the fish will tend to avoid, or where other effects become apparent.

ii) HQ for Maximum Weekly Average Temperature (MWAT, sub-lethal effects)

$$HQ = \frac{T}{T_{MWAT}}$$

where T temperature of water at the location of interest. Maximum 7-day rolling average temperature value, as described below; this statistic is representative of long-term or chronic exposure.

T_{MWAT} temperature benchmark specific to the MWAT statistic; derived in literature.

iii) HQ for Short-Term Maximum (lethal effects)

$$HQ = \frac{T}{T_{STmax}}$$

where T temperature of water at the location of interest. Maximum 24-hour (i.e., daily) average temperature value, as described below; this statistics representative of short-term or acute exposure.

T_{STmax} temperature above which lethal, critical or similar effects occur, regardless of acclimatization time.

Exposure Temperatures

Temperature data from the site are used to determine the exposure temperature, which is representative of the conditions to which fish would be exposed.

Temperatures could be measured or modeled. Ideally, temperature data would be available for:

- locations within the thermal plume (i.e., expected to be influenced by thermal discharges from the facility), and for locations at a reference point (i.e., where temperatures are not likely to be influenced by thermal discharges);

- both nearshore and offshore locations;
- both shallow and deep positions in the water column; and
- time periods throughout the year, but particularly during seasons of interest (e.g., for spring spawning species, the spring and summer would be of interest, as the eggs and larvae are considered sensitive life stages).

Statistical summaries of the data are typically conducted, depending on the type of effects being studied. For example, short-term (acute) effects are assessed using the maximum hourly average temperature over a 24-hour period. Long-term (chronic) effects are assessed using the maximum weekly average temperature (MWAT), which is the highest 7-day rolling daily average. These temperature statistics are inserted into the HQ calculation (Equation 1), along with the corresponding acute or chronic thermal effects benchmark (discussed below).

Thermal Effects Benchmarks

Thermal effects benchmarks, or criteria, are inserted into the HQ calculation (Equation 1), along with the corresponding temperature statistic. These benchmarks represent the temperature levels at which meaningful effects on growth, survival and reproduction are unlikely. They are typically derived from the results of laboratory studies and field investigations, and summarized in literature.

For fish species, thermal effects benchmarks are specific to species and life stage. For example, the benchmark for yellow perch spawning is different from the benchmark for gizzard shad spawning, and the benchmark for yellow perch juveniles.

Five age categories were established for classification of thermal effects criteria, including:

1. Spawning;
2. Egg/Incubation;
3. Larvae;
4. Growth, YOY, Fry and Juveniles; and
5. Adults.

Values obtained from a literature review were categorized into one of four types of thermal effects as follows:

1. Preferred Temperature;
2. Upper Temperature Limits (those associated with sub-lethal effects);
3. Maximum Weekly Average Temperature (MWAT) Criteria, calculated to represent sub-lethal effects/ growth effects; and
4. Short Term (Acute) Maximum Temperature Limits (those associated with lethal effects).

There is uncertainty in the selection of benchmarks, due to inconsistencies in the interpretation of study results. For example:

- Literature documents often interpret the same study data in different ways; for example, if a study presents an optimal temperature range, different documents select different values from within that range.
- Documents do not categorize criteria into the same life stages.
- The studies reviewed do not always compare the same types of temperature values to the criteria. The most commonly referred-to statistic is the MWAT, but the method of calculating MWATs is defined differently in different documents.

Several assumptions were made in order to address these inconsistencies when compiling and selecting thermal effects benchmarks for this study. These include (but are not limited to):

- When obtaining values from literature, only measured criteria were recorded, i.e. where documents make use of professional judgment to derive a value (e.g., deriving a value for one age group by assuming it is equal to another's) such values were not included. The exception to this is when MWAT values are derived in literature, based on the formulas presented (and used) in Wismer and Christie (1987) and USEPA (1977).
- When obtaining values from literature, where multiple documents make reference to the same values from the same underlying study, a single reference was included; subsequent instances were not recorded in order to avoid over-representation (double-counting) of criteria.
- When obtaining values from literature, instances occurred where benchmarks were found with no corresponding age, weight or size information. Where this information could not be assumed based on context, the values were excluded.
- Criteria for the "hatching" life stage were categorized into the "larval" age group.
- Criteria for the "embryo" life stage were categorized into the "egg/incubation" age group.
- Criteria for the "migration" life stage were categorized into the "adult" age group.
- "T Preferred" criteria include values for "optimum temperature(s)", "final preferendum temperatures", and other similar values (e.g., "Ideal temperature for spawning").
- "T Upper" criteria are based on "Upper Avoidance" values. They do not include Upper Incipient Lethal values.
- "ST Max" criteria include "short term maximum temperatures", "short term mortality temperatures", and similar values (e.g., lethal upper limit values, or, critical thermal temperatures).
- Where reasonable, field-based values were selected over lab-based (or non-specified) benchmarks.

For non-fish species, a limited number of thermal effects benchmarks are also available.

Non-HQ Assessment

Some potential thermal effects cannot be assessed using the HQ methodology. These include:

- Advanced hatch, i.e., the potential for hatching to be successful but noticeably early (discussed in further detail in this report); and

- Physical impacts, such as the habitat created by the facility and the physical displacement caused by the thermal plume.

4.2.2 Selection of Indicator Species

Risk assessment calculations were carried out for selected species in the thermal plume of Schiller, based on available information.

Based on early assessment on the site, we selected representative species for risk calculations:

- Atlantic herring;
- Atlantic menhaden;
- Rainbow smelt;
- Winter flounder.

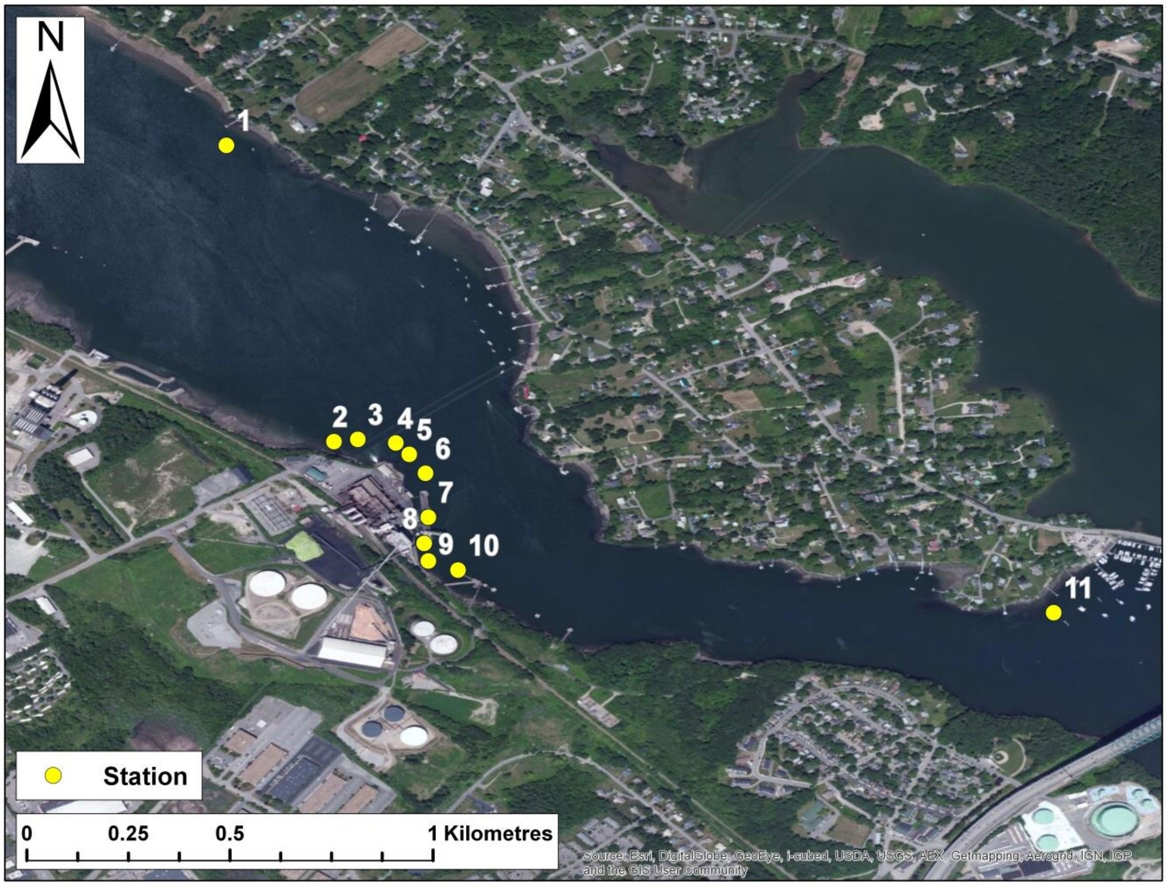
Other species were considered such as Atlantic tomcod, tautog and American lobster but no data were readily available for calculations.

Only the egg/incubation and larval life stages were assessed for rainbow smelt.

4.2.3 Temperature Data

Temperature data were available for the Schiller site for the period Aug 15 to November 15, 2010 at 5-min interval at 11 stations. Temperature data was available at the surface, mid-depth and near-bottom at all the stations, except at station-2, where only surface and near-bottom temperature data was available. Figure 4.1 shows the locations of the temperature monitoring stations. Stations-2,3,4,5,6,7,8,9 and 10 are located in the vicinity of the Schiller generating station. Stations 1 and 11 are located north-east and south west of the generating station and are considered as reference stations (where the effect of the thermal discharge is expected to be minimal).

Figure 4.1 Locations of the Temperature Monitoring Stations



Typically in a thermal effects risk assessment, two types of temperature statistics are calculated:

- 24-hour Max (maximum of hourly average data over a 24-hour period); and
- Maximum Weekly Average Temperature (MWAT, highest calculated 7-day rolling average).

The above statistics were calculated from the available data at the 11 stations.

4.2.4 Thermal Effects Criteria

Thermal effects criteria were compiled from readily-available sources. Criteria were characterized according to the species and the type of thermal effects they represent, such as preferred temperature, upper temperature limits (i.e., fish observed to avoid areas at this temperature) and short-term (acute) maximum temperature limits (i.e., lethal temperatures). The availability of this information varied for each species. Some of the available criteria were developed in the lab environment, while others were determined from field study. In general, field-derived values were considered preferable to laboratory-derived values.

4.2.5 Results

4.2.5.1 Hazard Quotient Calculations and Results

Illustrative HQ calculations were carried out, based on the limited data available (Table 4.1). Only the locations and life stages for which HQs were calculated are shown in Table 4.1.

Table 4.1 Summary of HQ Values

Species	Location	Depth	Life Stage	Corresponding Season/ Months	HQ (HQ Type shown in parentheses)
Rainbow Smelt	Station-1	Mid-depth	Egg/ Incubation	April-August	**1.04 (ST Max)**
			Larvae	April-August	0.86 (ST Max)
	Station-3	Mid-depth	Egg/ Incubation	April-August	**1.07 (ST Max)**
			Larvae	April-August	0.88 (ST Max)
	Station-4	Mid-depth	Egg/ Incubation	April-August	**1.06 (ST Max)**
			Larvae	April-August	0.87 (ST Max)
	Station-5	Mid-depth	Egg/ Incubation	April-August	**1.04 (ST Max)**
			Larvae	April-August	0.86 (ST Max)
	Station-6	Mid-depth	Egg/ Incubation	April-August	**1.04 (ST Max)**
			Larvae	April-August	0.86 (ST Max)
	Station-7	Mid-depth	Egg/ Incubation	April-August	**1.05 (ST Max)**
			Larvae	April-August	0.87 (ST Max)
	Station-8	Mid-depth	Egg/ Incubation	April-August	**1.04 (ST Max)**
			Larvae	April-August	0.86 (ST Max)
	Station-9	Mid-depth	Egg/ Incubation	April-August	**1.04 (ST Max)**
			Larvae	April-August	0.86 (ST Max)
	Station-10	Mid-depth	Egg/ Incubation	April-August	**1.03 (ST Max)**
			Larvae	April-August	0.85 (ST Max)
	Station-11	Mid-depth	Egg/ Incubation	April-August	**1.01 (ST Max)**
			Larvae	April-August	0.84 (ST Max)
Atlantic Herring	Station-1	Surface	Growth/YOY/Juvenile	April-October	**1.0 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	**1.0 (ST Max)**
		Bottom	Egg/ Incubation	August-November	0.76 (A&HL)
	Station-2	Surface	Growth/YOY/Juvenile	April-October	**1.04 (ST Max)**
		Bottom	Egg/ Incubation	April-October	0.82 (A&HL)
	Station-3	Surface	Growth/YOY/Juvenile	April-October	**1.05 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	**1.02 (ST Max)**
		Bottom	Egg/ Incubation	August-November	0.81 (A&HL)

Table 4.1 Summary of HQ Values (Cont'd)

Species	Location	Depth	Life Stage	Corresponding Season/ Months	HQ (HQ Type shown in parentheses)
Atlantic Herring	Station-4	Surface	Growth/YOY/Juvenile	April-October	**1.05 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	**1.01 (ST Max)**
		Bottom	Egg/ Incubation	August-November	0.78 (A&HL)
	Station-5	Surface	Growth/YOY/Juvenile	April-October	**1.00 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	0.99 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-6	Surface	Growth/YOY/Juvenile	April-October	**1.01 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	0.99 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-7	Surface	Growth/YOY/Juvenile	April-October	**1.11 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	**1.0 (ST Max)**
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-8	Surface	Growth/YOY/Juvenile	April-October	**1.04 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	0.99 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-9	Surface	Growth/YOY/Juvenile	April-October	**1.03 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	0.99 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-10	Surface	Growth/YOY/Juvenile	April-October	**1.0 (ST Max)**
		Mid-depth	Growth/YOY/Juvenile	April-October	0.98 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.75 (A&HL)
	Station-11	Surface	Growth/YOY/Juvenile	April-October	0.97 (ST Max)
		Mid-depth	Growth/YOY/Juvenile	April-October	0.96 (ST Max)
		Bottom	Egg/ Incubation	August-November	0.72 (A&HL)
Atlantic Menhaden	Station-1	Surface	Larvae	May-August	0.67 (ST Max)
		Mid-depth	Larvae	May-August	0.67 (ST Max)
	Station-2	Surface	Larvae	May-August	0.70 (ST Max)
	Station-3	Surface	Larvae	May-August	0.71 (ST Max)
		Mid-depth	Larvae	May-August	0.68 (ST Max)
	Station-4	Surface	Larvae	May-August	0.70 (ST Max)
		Mid-depth	Larvae	May-August	0.68 (ST Max)
	Station-5	Surface	Larvae	May-August	0.67 (ST Max)
		Mid-depth	Larvae	May-August	0.66 (ST Max)
	Station-6	Surface	Larvae	May-August	0.68 (ST Max)
		Mid-depth	Larvae	May-August	0.66 (ST Max)
	Station-7	Surface	Larvae	May-August	0.73 (ST Max)
		Mid-depth	Larvae	May-August	0.67 (ST Max)

Table 4.1 Summary of HQ Values (Cont'd)

Species	Location	Depth	Life Stage	Corresponding Season/ Months	HQ (HQ Type shown in parentheses)
	Station-8	Surface	Larvae	May-August	0.69 (ST Max)
		Mid-depth	Larvae	May-August	0.66 (ST Max)
	Station-9	Surface	Larvae	May-August	0.68 (ST Max)
		Mid-depth	Larvae	May-August	0.66 (ST Max)
	Station-10	Surface	Larvae	May-August	0.67 (ST Max)
		Mid-depth	Larvae	May-August	0.66 (ST Max)
	Station-11	Surface	Larvae	May-August	0.65 (ST Max)
		Mid-depth	Larvae	May-August	0.65 (ST Max)
Winter Flounder	Station-1	Mid-depth	Growth/YOY/Juvenile	May-December	0.68 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.68 (ST Max)
	Station-2	Bottom	Growth/YOY/Juvenile	May-December	0.70 (ST Max)
	Station-3	Mid-depth	Growth/YOY/Juvenile	May-December	0.69 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-4	Mid-depth	Growth/YOY/Juvenile	May-December	0.69 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-5	Mid-depth	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-6	Mid-depth	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.66 (ST Max)
	Station-7	Mid-depth	Growth/YOY/Juvenile	May-December	0.68(ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-8	Mid-depth	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-9	Mid-depth	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-10	Mid-depth	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.67 (ST Max)
	Station-11	Mid-depth	Growth/YOY/Juvenile	May-December	0.65 (ST Max)
		Bottom	Growth/YOY/Juvenile	May-December	0.65 (ST Max)

Notes:
Only temperature data from August to November was used for assessment.
Bold indicates HQ values ≥1.

The results for rainbow smelt (Station-3) and Atlantic herring (Station-7) are summarized in Figures 4.2 and 4.3, respectively, as examples.

Figure 4.2 Hourly Average Temperature at Station-3 and Rainbow Smelt Thermal Criteria

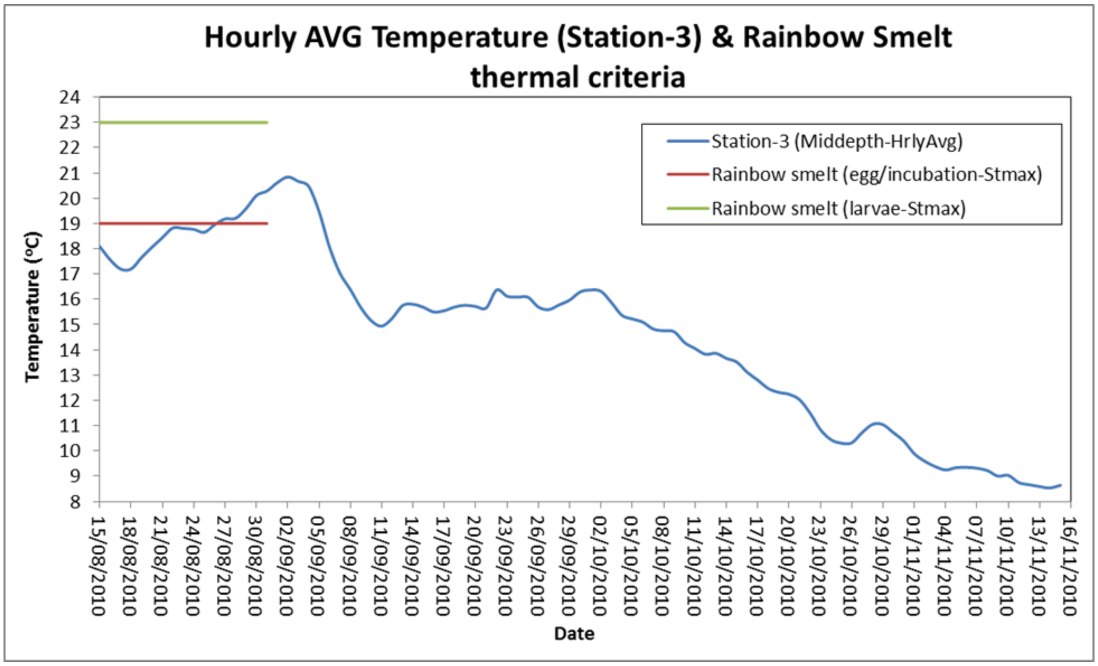
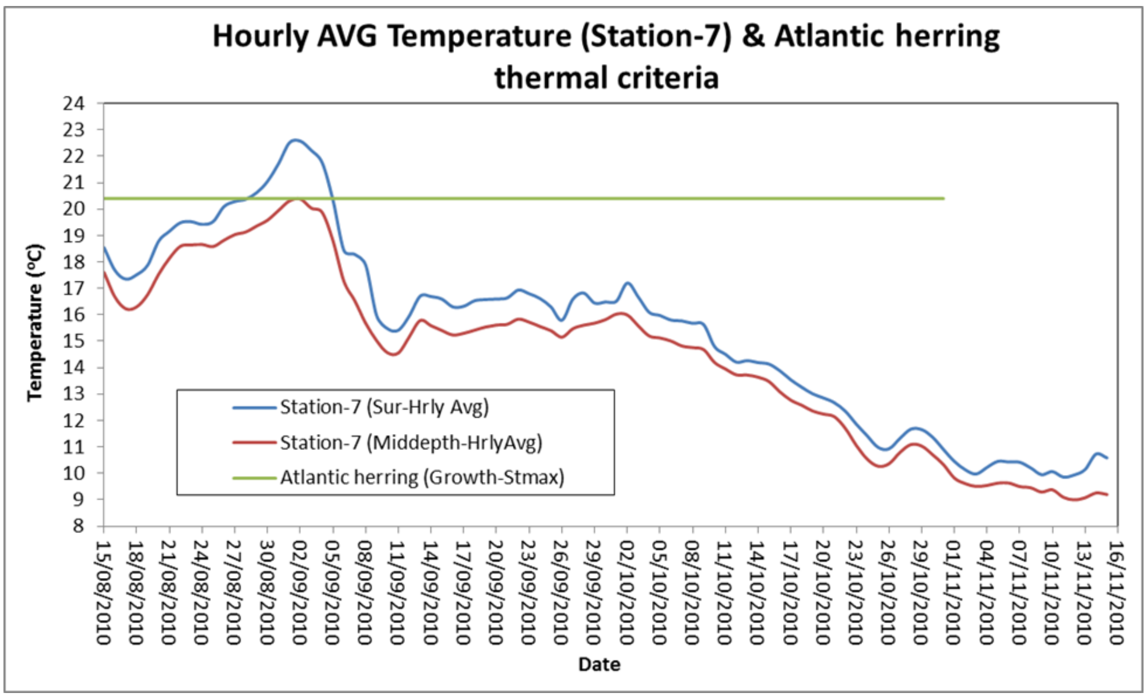


Figure 4.3 Hourly Average Temperature at Station-7 and Atlantic Herring Thermal Criteria



4.2.5.2 Overall Findings

Based on the available information, which was limited, potential exceedances were identified for:

- Rainbow smelt at mid-depth (egg/incubation), at all the 11 stations including reference sites;
- Atlantic herring at surface (juveniles), at all stations except at station 11 (reference): and
- Atlantic herring at mid-depth (juveniles), at stations 1, 3, 4 and 7.

Based on the limited available information, potential effects were not identified for:

- Atlantic menhaden, and
- Winter flounder.

The temporal and spatial extent of the exceedances could be better-defined if more data were available.

Rainbow smelt in the North Atlantic generally spawn in late March to late May (Buckley 1989, Scott and Crossman 1998) at temperatures of 4.0 – 9.0 °C. In some instances, however, there have been reports of spawning occurring at higher temperatures (e.g., up to 15°C in Miramichi Estuary, New Brunswick). Fertilized eggs are negatively buoyant and adhesive and attach to substrates such as gravel or submerged vegetation. The egg incubation period generally lasts 2-3 weeks. Normandeau (2008) collected rainbow smelt larvae during entrainment sampling at Schiller Station in the months of May and June. Since the available thermal data for Schiller was limited, it is assumed that bottom depth temperatures would be similar to mid-depth temperatures if some vertical mixing occurs. he summary of HQ values (Table 4.2) included data for June-August for rainbow smelt eggs when eggs have likely already hatched and therefore results may be somewhat misleading. Exceedances also occurred at both reference sites 1 and 11 suggesting that effects due to thermal plumes (sites 2 to 10) may not occur. Still, it is unclear whether sites 1 and 11 are adequate reference locations. For example, the PSNH Newington NPDES permit authorizes Newington Station which is next door to Schiller to operate a once-through cooling water intake system that withdraws up to 324.6 MGD of cooling water from the Piscataqua River and discharges a similar volume of heated water back into the river. More information is needed to better define the potential for thermal effects on rainbow smelt eggs and larvae in the Piscataqua River.

Atlantic herring in the Gulf of Maine metamorphose into juveniles (40-50 mm total length) in the early spring (April-May) and mature to adults between 25 and 27 cm, which may take a few years (NMFS 1999b). The limited data available suggested that there were potential exceedances to juveniles at mid-depth and surface at Schiller Station. However, it is likely that these juvenile herring would exhibit an avoidance response to the area if temperature exceedances occurred. Still, this would prevent fish access to potential habitat although likely localized. Overall, the thermal data collected at Schiller is limited as data were only available for the months of mid-August through mid-November 2010 for analysis. It is recommended that a more detailed thermal study is conducted at Schiller to better determine potential thermal effects.

4.2.6 Conclusions

- Overall, exceedances were found at both the reference and plume locations for rainbow smelt (egg/incubation) at mid-depth at all locations including the two reference sites. For Atlantic herring (juveniles), the exceedances were seen at the plume stations and the north-east reference location (Station 1). The significance of these exceedances needs to be determined.
- The assessment would be more complete if more temperature measurements were available during April-July. **Additional data could be used to identify additional potential detrimental effects and would not change the conclusions presented in the previous paragraphs.** In particular, spring data would be useful, as that is when spawning and egg/ incubation occur for many fish species.
- Numerical modeling studies can help in determining the spatial extent of the plume and considering the effects of climate change on ambient and plume temperature.

4.3 CUMULATIVE THERMAL IMPACTS

Cumulative impacts must be considered given other industrial water users in the area near Schiller; similar to potential cumulative I&E impacts described in Section 2.3.2, significant impacts resulting from thermal discharges (e.g., mortality, impairment, advanced hatch, alteration of habitat, changes to community structure, etc.) could occur when there are multiple facilities, even though the thermal impacts from individual facilities may be low. If there are overlapping thermal plumes of multiple facilities, then changes in water temperature from ambient may be even greater. As discussed in Section 2.3.2, the PSNH Newington Station (420 MW) is located on the same road as Schiller (<1 mile). The PSNH Newington NPDES permit authorizes Newington Station to operate a once-through cooling water intake system that withdraws up to 324.6 MGD of cooling water from the Piscataqua River and discharges a similar volume of heated water back into the river. The Newington Station discharge canal is approximately 1400 feet upriver from the nearest of Schiller's three thermal discharge outfalls (and less than 2000 feet from the farthest of Schiller's outfalls). The Newington Station NPDES permit establishes a thermal discharge mixing zone that allows for a thermal plume occupying up to 25 acres of the river at an increased temperature (ΔT) of 4 ºF (2.2 ºC); and a 60 acre area with a ΔT of 1.5 ºF (0.83 ºC).

EP's Newington Energy Facility (525 MW) is also in close proximity (i.e., a few miles upstream) to Schiller (see Section 2.3.2). According to Newington Energy's NPDES permit (USEPA 2012), the maximum design flow intake is 10.8 MGD of water from the Piscataqua River for cooling tower makeup and the maximum allowable discharge of heated cooling tower blowdown is 4.0 MGD. Given that this facility employs a cooling tower, the cumulative impacts in combination with Schiller are not expected to be significant although the heated waste, although minimal, would still add to the cumulative total of heated discharge to the Piscataqua River. .

5.0 CLIMATE CHANGE AND THERMAL EFFECTS

This section addresses the following task from the scope of work: evaluating whether studies for Schiller have properly considered the effects of climate change.

The effects of climate change on aquatic life at Schiller are not discussed in the documents reviewed.

The climate of the Piscataqua/Great Bay region has changed over the past century (CSNE 2011). Overall, the region has been getting warmer and wetter over the last century, and the rate of change has increased over the last four decades. Since 1970, mean annual temperatures have warmed 1 to 2^{o}C, with the greatest warming occurring in winter (3 to 5^{o}C). Average minimum and maximum temperatures have also increased over the same time period, with minimum temperatures warming faster than mean temperatures.

Emissions from fossil fuel consumption are predicted to increase the seasonal and annual temperatures in the Piscataqua/Great Bay region. Mid-century temperatures are predicted to increase by 3 to 5^{o}C, and end-of-century temperatures to increase as much as 4 to 6^{o}C.

Climate model results predict warmer summer temperatures that can have damaging effects on the ecosystem health. For example, a predicted increase of 3-6^{o}C in the ambient temperature is expected to have potential exceedances (HQ>1; Table 4.1) in the larvae of rainbow smelt and juveniles of Atlantic herring. It is expected that climate change will have similar effects on other fish species and macrocrustaceans such as American lobster.

For example, temperature, more than any other environmental factor, affects American lobster growth, development, survival and reproduction (NMFS 1994, Tlusty *et al*. 2008). Tlusty *et al*. (2008) indicated that winter temperatures in the North Atlantic are up to 3°C above average and that this climate change can have microecological impacts on the release of larvae from American lobster females. Temperature increases would increase the period over which larvae are released by the female which may increase predation. More females may also release eggs early if cold water is not accessible to delay the rate of egg development. Additionally, lobster larvae production is likely a major contributor to overall productivity of the Gulf of Maine ecosystem. Thus, changes in the distribution of abundance of these larvae would impact other species in the food web. The preferred temperature for growth, young-of-the-year, fry and juvenile American lobster is 22°C. The preferred temperature for larvae is 15.8°C and the upper avoidance temperature being 24.1°C. The short-term maximum temperature for larvae is 30.0°C (NMFS 1994). Thus, an increase of 3-6°C in ambient temperature either by climate change or thermal discharge at Schiller would have an impact on American lobster in the Piscataqua River.

Some examples of potential fish species impacts at Schiller include:

- Tautog – preferred temperature for spawning is 16.1°C, temperature for egg/incubation is 21.1°C and temperature for larvae is 23.4°C[3]. A predicted 3-6°C rise in ambient temperature in the Piscataqua River either by climate change or thermal discharge effects may impact tautog.
- Atlantic tomcod – Upper avoidance temperature values are 5°C for larvae and 15.6°C for the growth of young-of-the-year, fry and juveniles[4]. A predicted 3-6°C rise in ambient temperature in the Piscataqua River either by climate change or thermal discharge effects may impact Atlantic tomcod.

In July 2012, a workshop was held in Massachusetts on possible climate change impacts to river herring (i.e., blueback herring and alewife). Goals of the workshop included: i) review climate science and river herring research applicable to climate change assessments from Atlantic Canada through Florida; ii) review ongoing qualitative and quantitative approaches to assessing impacts of climate change on habitat and population dynamics of river herring; iii) examine possible impacts of climate change on river herring; and, iv) identify research gaps so that assessment of climate impacts can be improved (NMFS 2012). Participants and presentations included those from state and federal fisheries management agencies and academia.

Some of the points, including findings on observed climate or environmental impacts on river herring included:

- Water temperature is an important spawning and migration cue for river herring. For example, the movement of adult river herring up coastal rivers in the spring is in response to water temperature. Additionally, the energetic costs for river herring increases with increased water temperatures.

- In spring 2012 in the northern states, many spawning runs began 2-3 weeks earlier than usual and were correlated with unseasonably warm spring temperatures. This change in the timing of spawning may influence "match-mismatch" between predator and prey.

- 2002 to 2005 data on blueback herring in Florida indicate that they spawn January-April (coldest time of the year) with the peak occurring at the coldest temperatures (16-19°C). The window in which these temperatures are occurring is decreasing.

[3] References: i) www.gma.org/fogm/tautog, ii) Carpenter Environmental Associates, Inc. 2012. Review and Analysis of the 316(b) Best Technology Available (BTA) Report for the Bridgeport Harbor Energy Generating Station & the 316(a) Hydrothermal Model Study (HMS) for the Bridgeport Harbor and Bridgeport Energy Generating Stations in Bridgeport, Connecticut.

[4] Reference: Carpenter Environmental Associates, Inc. 2012. Review and Analysis of the 316(b) Best Technology Available (BTA) Report for the Bridgeport Harbor Energy Generating Station & the 316(a) Hydrothermal Model Study (HMS) for the Bridgeport Harbor and Bridgeport Energy Generating Stations in Bridgeport, Connecticut.

As described in Section 4.3, there are potential cumulative impacts from thermal discharges when multiple facilities are in close proximity to each other (e.g., PSNH Newington Station) or are in the same waterbody. Thus, the cumulative thermal effects coupled with the effects of climate change may result in further adverse effects (e.g., possible increased mortality, alteration of habitat) on aquatic life. However, the plume appears localized and somewhat buoyant, and the exposure time to elevated temperatures may be of short duration for organisms due to the high tidal influence.

The effects of climate change on aquatic life at Schiller are not discussed in the documents reviewed. However, waters in the Piscataqua/Great Bay region are warming and the thermal discharges from Schiller in combination with the higher ambient temperatures is likely to adversely affect fish and macrocrustaceans such as rainbow smelt, Atlantic herring, tautog, Atlantic tomcod, river herring, and American lobster in ways or to an extent not addressed in the Schiller documents reviewed.

6.0 TECHNOLOGIES FOR REDUCING IMPINGEMENT, ENTRAINMENT AND DISCHARGES

This section addresses two tasks: discussing the feasibility of alternative technologies for reducing impingement, entrainment and thermal discharges (including cooling towers); and evaluating, from a biological perspective, the relative efficacy of these alternatives to the existing suite of controls.

A variety of I&E reduction technologies were reviewed with the most effective (i.e., biological efficacy) being cooling towers and fine mesh cylindrical wedge wire screens (0.5 mm mesh and through- slot velocity of 0.5 fps; and modified 0.5-0.8 mm mesh with reduced through slot velocity of 0.2 fps). Fine mesh cylindrical wedge wire screens with through-slot velocity of 0.5 fps may reduce entrainment up to 75%, while a through screen velocity of 0.2 fps may reduce entrainment by up to 85%-90%. This is consistent with EPA's recommendation for fine mesh screens in the Draft NPDES Permit (NH0001473) with a noticeable exception of the lower through-slot velocity (0.2 fps). The small mesh size and low through-slot velocity (0.2 fps) would address both physical exclusion as well as larval avoidance behavior (by larger size organisms), and also reduce larval contact and impingement mortality against the screens. Still, more data regarding post-screen contact survival rates of excluded organisms is necessary to characterize the relationship between entrainment reductions and entrainment <u>mortality</u> reductions for the species most frequently entrained at Schiller.

Thermal reduction technologies could include cooling towers, helper cooling towers and thermal tempering. Our assessment indicates that an integrated system of modified fine mesh cylindrical wedge wire screens (0.5 mm mesh with a through-slot velocity of 0.2 fps) with a helper cooling tower or thermal tempering may offer significant I&E reductions and reduce thermal load but this still requires field evaluations. However, cooling towers will likely still provide the greatest reduction in I&E and thermal load. Reducing the potential for I&E (especially entrainment) and potential thermal impacts through technology at Schiller is especially important to minimize potential impacts to threatened and endangered species present in the Piscataqua River (i.e., shortnose sturgeon, Atlantic sturgeon, Atlantic salmon).

6.1 TECHNOLOGIES FOR REDUCING I&E AT THE INTAKE

Schiller Intake Description

As discussed in Section 1.0, Schiller possesses two once-through CWISs situated on the lower Piscataqua River in Portsmouth, NH. Screenhouse #1 contains a submerged offshore intake for Unit 3 (now retired) and Unit 4; the intake is approximately 32 ft out into the Piscataqua River. Screenhouse #2 contains a nearshore intake for Units 5 and 6.

<u>Unit 4</u>

A fixed screen (1.5 inch fibreglass mesh) on the offshore intake in front of the intake pipe prevents lobsters from entering the intake. This screen extends 4 ft up from the bottom of the offshore intake. Additionally, to divert lobsters from crawling into the intake pipe, an 8-inch pipe is attached to the bottom of the fibreglass screen. The floor of the offshore intake is 2-ft above the river bottom grade, thus providing a vertical barrier to bottom-oriented fish and shellfish movement into the CWIS. Unit 4 has a travelling water screen (3/8 in mesh) that operates intermittently to handle fish and debris. A fish return trough returns the fish/debris back into the Piscataqua River. The travelling water screen services two circulating water (CW) pumps located in the power plant building.

<u>Units 5 and 6</u>

Cooling water is withdrawn through a forebay for each of Units 5 and 6. Each unit has two CW pumps and two travelling water screens each. The travelling water screens operate intermittently to handle fish and debris. A fish return trough returns the fish/debris back into the Piscataqua River. The floor of Screenhouse #2 is 2 ft above the river bottom grade, providing a vertical barrier to bottom-oriented fish and shellfish movement into the CWIS.

In addition to the above-mentioned features to minimize fish and macrocrustacean I&E, Schiller also employs a lobster separation procedure to reduce impingement (Enercon 2008).

Technology Assessment

The USEPA had requested information from PSNH regarding Schiller's compliance with CWA Section 316b. Specifically, technology information was requested to support EPA's development of Schiller's new permit. Thus, Enercon (2008), in consultation with Normandeau Associates, prepared a report to provide PSNH's response.

A variety of fish protection options were assessed including cooling towers, upgrades to the existing system (i.e., fish return system and travelling screens), flow reduction, Unit 3 intake renovations, fine mesh cylindrical wedge wire screens, barrier nets (coarse mesh and aquatic filter barrier), Geiger MultiDisc screens, and Water Intake Protection (WIP) screens. Biological assessments were conducted for the technologies in terms of impingement and entrainment reduction (Enercon 2008).

There were some concerns regarding the biological assessments (I&E reduction) for the technologies described in Enercon (2008). These concerns included: i) using the full-flow instead of actual flow to determine I&E reductions, ii) using equivalent adults as the basis for biological assessment, and iii) impingement reduction assessments assuming that impingement is proportional to flow.

1) Full-flow vs. actual flow

For Schiller, Enercon (2008) used a calculation baseline that was based on its design intake or full-flow capacity. Enercon (2008) also used the assumption that there is a direct relationship between flow reduction and the number of fish entrained or impinged (more on impingement to follow). Since in actual fact, the station did not operate year-round at full-flow, credit was taken for reduced flows which correspond to a reduction of organisms impinged and entrained. These “flow reductions” are factored into the biological assessments of BTA for Schiller.

A calculation baseline is typically required where i) a starting point is needed from which I&E reductions are measured (i.e., performance standards), and ii) comparing two different fish protection technologies. A calculation baseline is often used to compare cooling towers (closed-cycle cooling) to other fish protection technologies.

Calculation baselines have been a challenging aspect mentioned by the USEPA. In the Phase II rule (being revised), the calculation baseline is the impingement mortality and entrainment estimate that would occur at a site with the assumption that baseline conditions are those that the facility would maintain without operational controls (e.g., flow or velocity reductions) implemented either in part of fully for reducing impingement mortality and entrainment.

If operational controls have not been implemented for fish protection, then the operational baseline would just reflect the actual intake flow and seasonality of that actual flow. However, some power companies indicate that the operational component of the calculation baseline should be a full-flow baseline whereby it is assumed that the power plant runs 24 hours a day year-round. This scenario does not occur at any power plant.

Using a full-flow baseline, a power plant may take credit for ‘saving’ fish since it is operating below full capacity even though it has not made any real reductions. Additionally, using a full-flow calculation baseline would result in less protection of aquatic resources. For example, a plant is estimated to entrain 200 million fish at full-flow but at actual flow, entrainment is 140 million. Using the full-flow baseline, reducing entrainment from 200 million to 10 million organisms a year would equate to a 95% reduction (i.e., equivalent to closed-cycle cooling). Similarly, using an actual flow baseline, reducing entrainment by 95% would require a reduction in entrainment from 140 million to 7 million organisms a year. In this situation, the plant would indicate that reducing its entrainment to 10 million organisms annually will result in a 95% reduction in entrainment (calculation based on full-flow). However, in reality, this would only equate to a 93% reduction since the actual annual entrainment is 140 million (i.e., reduction in entrainment from 140 million to 10 million).

Thus, the biological assessments for BTA may be slightly overestimated.

2) Using equivalent adults (EA) for biological assessment

Throughout the Enercon (2008) document, assessments of the technologies in terms of biological efficacy were calculated in terms of equivalent adults (EA). Estimates of EA losses can vary greatly depending on the survival curves used. Thus, the mortality curves used may not be a true representation of survival for these species in the vicinity of Schiller depending on which one was used (and from what water body).

3) Impingement assessments

For calculations of estimated impingement at Schiller for assessment of BTA, it was assumed that the number of fish impinged is proportional to flow. While this is generally true with entrainment where egg or early life stages are less motile, it is not necessarily the case with impingement as seen in a study conducted from June 2005 to June 2007 as part of the Ohio River Ecological Research Program (ORERP) (King *et al*. 2010). The factors potentially influencing impingement at 15 power plants subject to the USEPA 316b Phase II rule on the Ohio River were assessed. The 15 power plants and some design characteristics are displayed in Table 6.1.

Table 6.1 Selected Characteristics of 15 Ohio River Power Plants Studied during the ORERP Impingement Study, 2005-2007

Plant name	rkm	Design flow (m^3/min)	Generating capacity (MW)	Design approach velocity (m/s)	Number of generating units	Intake location	Intake configuration	River bank position
Cardinal	124	3,077	1,830	0.4	3	Canal	Submerged	Outside bank
Kammer	179	1,817	630	0.2	3	Canal	Submerged	Inside bank
Willow Island	257	606	243	0.4	3	Shoreline	Submerged	Straight channel
Gorsuch	283	963	213		3	Shoreline	Surface	Straight channel
Philip Sporn	389	2,729	1,050	0.5	5	Shoreline	Submerged	Straight channel
Kyger Creek	418	3,142	1,085	0.5	5	Canal	Submerged	Straight channel
J. M. Stuart	653	2,503	1,830	0.3	4	Shoreline	Surface	Straight channel
W. C. Beckjord	729	1,938	1,186	1.0	6	Shoreline	Surface	Straight channel
Tanners Creek	795	2,801	995	0.3	4	Shoreline	Submerged	Straight channel
Clifty Creek	901	3,770	1,306	0.8	6	Canal	Submerged	Outside bend
Gallagher	982	1,167	637	0.5	4	Shoreline	Surface	Straight channel
Cane Run	993	1,379	550	1.2	3	Shoreline	Submerged	Straight channel
Coleman	1,165	938	455		1	Shoreline	Submerged	Straight channel
Elmer Smith	1,215	803	445	1.5	2	Shoreline		Outside bend
Shawnee	1,522	3,962	1,750	0.2	10	Canal	Submerged	Straight channel

rkm = river kilometer
Source: King *et al.* (2010).

The two-year evaluation explored environmental, power plant design and operational factors that may influence impingement rates. Environmental factors included water temperature and hydrological data (e.g., river flow, stage, change in flow and stage during sampling events) while plant design and operational factors included: volume of cooling water pumped during sampling events, design flow, design approach velocities at intakes, intake configurations (i.e., submerged or surface), intake locations along the river, and position of the intakes on the riverbank (shoreline or recessed canals). All data were collected under consistent and controlled protocols.

The factors potentially influencing impingement were grouped into two categories: within plant variables and among plant variables. The ‘within’ plant variables were the physical variables that varied over time within a given power plant and included water temperature, volume of cooling water used during sampling events, river flow and stage, and change in river flow and stage during each sampling event. The ‘among’ plant variables were the intake characteristics that varied among plants and included river kilometres, plant capacity, intake location, intake configuration and intake position.

Multiple regression analyses revealed that water temperature was the most important physical variable, with impingement more likely increasing during the winter. The results of the study indicated that most of the physical variables investigated had little or no effect on impingement rates. **The only factor investigated under direct control of the power plants, actual cooling water pumping rate during sampling events, was one of the least important variables affecting impingement rates. Statistical analyses did not identify volume of cooling water used or design pumping capacity as a major factor influencing impingement rates (King *et al*. 2010).** This is in contrast to what had been found by Kelso and Milburn (1979) on the relationship between flow volume and impingement and entrainment for power plants located on the Great Lakes but these results suggested an exponential relationship not linear as assumed for Schiller Station. The King *et al.* (2010) results, along with the episodic impingement events suggested that the abundance and distribution of age-0 fish in this riverine system were major factors contributing to the variability of impingement rates at the power plants investigated.

These results suggest that the assumption of a linear increase with impingement and CCW flow is not realistic based on recent literature findings.

Technology Reviews

Based on our experience and judgement, and a review of both scientific literature and industrial literature, we reviewed the technologies assessed by Enercon (2008) in terms of biological efficacy (direct counts and not adult equivalents) and have provided additional comments (Table 6.2). Expected numbers of fish impinged or entrained were provided for each technology in relation to current I&E numbers as well as the corresponding expected efficacy relative to the current existing technology at Schiller. These estimates reflect percent reductions based on total organisms, and are not adjusted for additional mortality that may occur such as damage to organisms impinged against the screens. Furthermore, other technologies not assessed in the Enercon (2008) report were included with their expected biological efficacy at Schiller (Table 6.3). Some of these technologies included are integrated technologies which address both I&E reduction as well as some reduction in thermal loading.

There are several impingement technologies which can effectively reduce fish impingement losses such as modified fish return systems and barrier nets (Table 6.2). It should be noted that entrainment losses (i.e., 145.5 million fish and 1.3 billion macrocrustaceans) are much more of an issue than impingement (5,365 fish and 12,649 macrocrustaceans) given the large numbers of entrained organisms lost. Some of the more effective technologies which focus on entrainment reduction are described in detail below.

A mechanical draft cooling tower (Table 6.2) is a closed cycle cooling system that uses fans to remove heat from water discharged from a condenser. The cooled water is then discharged back into the water body or recirculated and reused. Cooling towers thus reduce intake flow. Cooling towers would significantly reduce I&E at Schiller and would also reduce thermal loading into the Piscataqua River. Entrainment reductions of 95% are expected (i.e., 7.3 million ichthyoplankton and 65.5 million macrocrustaceans entrained compared to existing technology which results in 145 million ichthyoplankton and 1.3 billion macrocrustaceans entrained). Efficacy is expected to be slightly lower (<95% reduction) for impingement compared to entrainment since impingement is not likely proportional to flow (King *et al*. 2010).

Aquatic microfiltration barrier technology is an option for reducing I&E at Schiller (Table 6.2). These barriers are full depth water curtains that are made of filter fabric allowing water to filter through into a CWIS while excluding organisms. Velocities at the face of the permeable curtain are very low and the systems have a large surface area. Any organisms or sediments trapped on the fabric can be removed with an airburst system. An aquatic microfiltration barrier is expected to eliminate impingement only when operating under optimal conditions (e.g., net is 100% operational with no tears or sagging and minimal biofouling). Entrainment reductions of 80% are expected for short periods under optimal operating conditions. Issues such as clogging and biofouling are associated with aquatic filter barriers (Seaby *et al*. 2002) and literature suggests that these nets are problematic and not effective if in place for extended periods (Henderson *et al*. 2003).

Fine mesh cylindrical wedge wire screens (0.5 mm) with a through slot velocity of 0.5 fps are an effective alternative technology to reduce impingement and entrainment at Schiller (Table 6.2). Cylindrical wedge wire screens physically exclude aquatic organisms and are available in a range of slot widths (e.g., fine or coarse mesh). The shape of these screens makes it easier for fish to swim away and avoid being impinged. The effectiveness of cylindrical wedge wire screens depends on site specific conditions such as flow. Since these screens reduce intake velocity, larger design flows require more screens. Impingement reduction of juvenile and adult fish and macrocrustaceans at Schiller is expected to be close to 100% (i.e., no fish impinged) while entrainment reduction is expected to be lower (up to 75% or no more than 36.4 million fish and 327.4 million macrocrustaceans entrained). Enercon (2008) estimated entrainment exclusion for equivalent adult fish which was 73.3% for 1.0mm mesh, 89.6% for 0.8 mm mesh, 92.4% for 0.69 mesh and 98.9% for 0.6 mm. These estimates assume a 0.5 fps through-slot velocity and seem to be theoretical based on literature values (e.g. larval body size). Our entrainment reduction estimates are lower than those predicted by Enercon (2008) since we considered results from recent field studies (EPRI 2005b, 2006) which seem more realistic than theoretical predictions. In addition to entrainment reduction, there is also an issue with retention of larvae on the screens. Larval mortality on the screens would also have to be considered on fine-mesh screens which is discussed later in this section.

A potentially effective alternative are fine mesh (0.5 mm) cylindrical wedge wire screens with reduced through-slot velocities of 0.20 fps (6.0 cm/s). The concepts of this alternative are the same as those described for fine mesh cylindrical wedge wire screens in the previous paragraph but modified with a reduced through-slot velocity of 0.20 fps from 0.5 fps. The lower through-slot velocity is expected to further reduce larval entrainment but not egg entrainment. Our assessment is based on Miller *et al*.'s (1988) recognition that larval fish characteristics can differ among species but that swimming ability is often correlated with larval body size. This is why it is critical to have both larvae head capsule data as well as total length data to better assess performance of a wedgewire screen (identified in Section 3.2). The analysis by Enercon (2008) assumes that effectiveness of a specific mesh or slot size is based solely on physical exclusion which is not always the case, as it has been demonstrated that larval avoidance of screens can occur based on swim speed performance.

The swimming capability of a fish is important in determining whether or not it may be entrained. Those whose swimming abilities exceed the intake velocity of a facility may be able to react and swim away, avoiding potential entrainment. Swimming can be classified as sustained, prolonged, or burst. Sustained swimming can be maintained indefinitely or does not fatigue. Prolonged or critical swimming is the speed that can be maintained for a period of time before fatiguing. Burst swimming describes swimming that results in rapid fatigue such as fast starts, sprints, acceleration, and turns lasting a short time generally for behavioral responses. A review and analysis of data from 17 studies covering 9 species (n=76 individuals) showed a positive relationship exists between burst speed and larval fish size (Miller *et al.* 1988). In general, larval fish as small as 3.8 mm can attain burst speeds of 6 cm/s (0.2 fps) and likely would not be able to avoid an approach velocity of 0.5 fps. In contrast, a 15-20 mm larval fish will be able to overcome approach velocity speeds of 0.5 fps or higher but only for short periods of time. Miller *et al.* (1988) recognized that larval fish characteristics (e.g., size at hatch, swim speeds, etc.) may vastly differ among species but concluded that swimming ability is correlated with larval body size. However, it should be noted that temperature is also an important variable.

For Alewife, Klumb *et al.* (2003) reported that measured age-0 larvae are capable of prolonged swimming speeds ranging from 0.03-0.33 fps (1-10 cm/s). Thus, it is possible that smaller Alewife larvae collected from screen mesh testing do not have swimming capabilities exceeding an intake velocity of 15 cm/s (0.5 fps) through the screen and thus would be unable to display a behavioral response and avoid entrainment or impingement against the screens.

Kopf *et al.* (2014) investigated the critical and prolonged swimming performance of Golden Perch larval and Silver Perch larval, both Australian freshwater species. The standard larval length used in the study ranged from 4.5 - 11.9 mm for Golden Perch and 4.7 - 11.4 mm for Silver Perch. Different larval development stages (preflexion, flexion, postflexion, and metalarval) were also used for the study. Kopf *et al.* (2014) found that the critical swimming speed increased with the size of the larval, as well as other factors including age and larval developmental stage. For example, for Silver Perch, the critical swim speed ranged from approximately 0 -1 0 cm/s (0 – 0.33 fps) while the prolonged swim speed ranged from 0-1.1 cm/s (0 – 0.04 fps).

Thus, this modified technology is expected to virtually eliminate juvenile and adult impingement (i.e., 100% reduction) and significantly reduce entrainment by up to 85-90%. It should be noted that this reduction is based on only the percent reduction of total numbers and is not corrected for egg or larvae mortality due to contact and impingement against the screens. As noted above EPA has estimated survival of eggs to be 80% while larval survival was estimated to be only 12%.

Still, this modified technology (0.5-0.8mm, 0.2 fps slot-velocity) has not been evaluated in the field. A drawback of this modified technology is that more screens may be required to handle the reduced velocities resulting in considerably more habitat loss compared to conventional fine mesh cylindrical wedge wire screens operating at 0.5 fps. Still, there are other advantages. For example, with a lower slot- velocity, less larval retention would be expected on the fine mesh screens since larvae would have a greater ability to display avoidance behavior compared to a 0.5 fps slot-velocity.

Another potentially effective alternative to reduce I&E at Schiller is an integrated system which combines the modified fish mesh cylindrical wedge wire screen (i.e., 0.5 mm mesh with through slot velocity reduced to 0.20 fps) with a technology that reduces thermal loading such as a helper cooling tower or thermal tempering (Section 6.2). The impingement and entrainment reductions are expected to be the same as the modified fine mesh cylindrical wedge wire screen (i.e., 100% for impingement and up to 85-90% for entrainment) but there is the added benefit of reducing thermal load. This integrated technology would require field evaluation.

Survival of Eggs and Larvae Impinged Against Wedgewire Screens

EPA has estimated in their Draft NPDES Permit (NH0001473) that survival of eggs in contact with a wedgewire screen to be 80% while larval survival was estimated to be only 12% based on performance of fine mesh traveling screens. EPA based these estimates on reviewing scientific literature concerning the survival of eggs and larvae after being impinged against a fine-mesh traveling screen. Although EPA recognizes that this is not the same technology as wedge wire screens, it is important to note that estimates based on fine mesh traveling screen results are not applicable as estimates for wedgewire screens. Traveling screens are not wedgewire screens.

As a result there is considerable uncertainty in survival of organisms impinged against the screens. New data regarding post-screen contact survival rates of excluded organisms is necessary to characterize the relationship between entrainment reductions and entrainment mortality reductions for the species most frequently entrained at Schiller.

6.2 TECHNOLOGIES FOR REDUCING THERMAL DISCHARGES

Schiller Discharge Description

The three units at Schiller each have their own discharge. For each unit, a weir structure keeps the outlet pipes full of water, which causes a siphon flow in the CW system. The outfall from each of the Unit's weir discharges directly into the Piscataqua River. For all units, the separation between the intake and discharge has been designed to minimize recirculation of the warm discharge water. For Unit 4, the outfall is 185 ft northeast of Screenhouse #1. For Unit 5, the outfall is about 145 southwest of the Screenhouse #2 intake. For Unit 6, the outfall is about 150 ft southwest of the Screenhouse #2 intake.

Discharge Technology Assessment

Other than cooling towers, technologies to reduce thermal discharge effects were not directly discussed in Enercon (2008). It is reported that Schiller does not use any discharge technologies to decrease thermal effluent temperatures before the effluent is discharged into the Piscataqua River. However, some of the I&E reduction technologies presented in Enercon (2008) such as cooling towers and flow reduction may also help decrease thermal impacts. Alternative discharge technologies may help reduce thermal loading and discharge effects and include: helper cooling towers applied to the thermal discharge and thermal tempering (i.e., diverting water from the intake to the discharge (Table 6.3). Integrated systems that include fish protection technologies and discharge technologies would reduce I&E and thermal loading, and these are also discussed. An example that was described in Section 6.1 was the fine mesh (0.5 mm) cylindrical wedge wire screens with reduced through-slot velocity (0.20 fps or 6 cm/s)

+ helper cooling tower or thermal tempering. This combined system could significantly reduce I&E levels at the Schiller Plant (100% reduction in impingement and likely up to 85-90% reduction in entrainment) and potentially reduce thermal loading but would require field verification.

6.3 SPECIES AT RISK

As mentioned previously in Section 2.3.2, shortnose sturgeon and Atlantic salmon (Gulf of Maine DPS) are endangered under the federal *ESA* while Atlantic sturgeon are listed as threatened under the federal *ESA.* While these listed species have not been collected in impingement or entrainment sampling conducted by Normandeau (2008), they may potentially occur in the vicinity of Schiller.

6.4 CONCLUSIONS

A suite of technology alternatives were reviewed to reduce I&E and thermal impacts including expected biological efficacy. There are several impingement technologies which can effectively reduce fish impingement losses such as a modified fish return system but they are not effective in reducing entrainment. It should be noted that entrainment losses (i.e., 145.5 million fish and 1.3 billion macrocrustaceans) are considerably higher than impingement (5,365 fish and 12,649 macacrustaceans). For I&E reductions at the intake, the effective technologies include cooling towers, fine mesh cylindrical wedge wire screens (0.5 mm mesh with through-slot velocity of 0.5 fps), and also modified fine mesh cylindrical wedge wire screens (0.5 mm mesh with reduced through-slot velocity of 0.20 fps which will result in a higher entrainment reduction). Fine mesh cylindrical wedge wire screens with through-slot velocity of 0.5 fps may reduce entrainment up to 75%, while a through screen velocity of 0.2 fps may reduce entrainment by up to 85%-90%. This is consistent with EPA's recommendation for fine mesh screens in the Draft NPDES Permit (NH0001473) with a noticeable exception of the lower through-slot velocity (0.2 fps). For thermal load reductions at the discharge, technologies include cooling towers, helper cooling towers and thermal tempering. Integrated systems such as the modified fine mesh cylindrical wedge wire screen combined with either a helper cooling tower or thermal tempering have the potential to significantly reduce I&E losses and reduce thermal outputs. However, cooling towers will likely still provide the greatest reduction in I&E and thermal load. Implementing technologies to reduce the potential for I&E and thermal impacts at Schiller is especially important to minimize potential impacts to threatened or endangered species present in the Piscataqua River and potentially present in the vicinity of Schiller (i.e., shortnose sturgeon, Atlantic sturgeon, Atlantic salmon).

Table 6.2 Estimated I&E Reduction (Experience and Literature)

Technology	Description	Expected I&E of Various Technologies (efficacy in brackets based on percent reduction of total organisms not corrected for survival)*		Additional Comments
		Impingement	**Entrainment**	
Existing Technology Schiller	Unit 4 – Offshore intake with fixed screen in front of intake pipe to prevent lobsters from entering. There is also a lobster diversion pipe. A travelling water screen (3/8 in) operates intermittently to handle fish and debris. A fish return trough returns fish back into the Piscataqua River. Units 5 and 6 – Shoreline intake. Travelling water screens (3/8 in) operate intermittently to handle fish and debris. A fish return trough returns fish back into the Piscataqua River.	Fish: 5,365 Macrocrustaceans: 12,649	Eggs/Larvae (Fish): 145,554,178 Macrocrustacean Larvae: 1,309,472,569	Impingement is relatively low. Entrainment of fish eggs and larvae, and especially macrocrustaceans is extremely high and variable.
Cooling Tower (Mechanical Draft)	A closed cycle cooling system that removes heat from water discharged from a condenser. Fans are used to cool the water. The cooled water can then either be discharged into a water body or recirculated and reused. Cooling towers reduce intake flow.	Fish: > 268 (<95%) Macrocrustaceans: > 632 King *et al*. (2010)	Eggs/Larvae: 7,277,709 (95%) Macrocrustacean Larvae: 65,473,628 (95%)	In addition to significant I&E reduction, the use of cooling towers would also reduce thermal loading into the Piscataqua River. Efficacy will be slightly lower for impingement than entrainment since entrainment is likely not proportional to flow (e.g., King *et al*. 2010).
Unit 3 Intake Renovation	Refurbish or replace existing valves at Unit 3 and install two new travelling water screens (modified Ristroph) and a fish return system. This can be used by Unit 4 and would potentially reduce through screen velocity to 0.46 ft/s at Mean Low Water, satisfying proposed Phase II rule for impingement mortality.	Unit 4: Fish: 336-1343 (60-90%) Macrocrustaceans: 975-3898 (60-90%) Units 5 and 6: Fish: 2008 (0%) Macrocrustaceans 2903 (0%)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Affects impingement at Unit 4 only. Annual impingement at Unit 4 was 3,357 fish and 9,746 macrocrustaceans (Enercon 2008). Significant reduction for impingement but not entrainment. However, impingement is less of a concern compared to entrainment based on numbers lost o the ecosystem. Does not address thermal loading
Continuous operation of screens with upgraded fish return system	When travelling screens are operating continuously, fish impingement is reduced. This is because fish and debris are continuously removed and not accumulating on the screen, thus preventing head losses and increased velocities that occur when accumulation occurs and there is less surface area for water to pass.	Fish: 4,829 (10%) Macrocrustaceans: 11,384 (10%)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Minimal effort. Does not address thermal loading.
Upgraded fish return trough	A quality fish return system generally consists of: a trough designed to maintain a water velocity of 3-5 ft/s; minimum water depth of 4-6 in; no sharp radius turns; discharge slightly above the low water level; a removable cover to address predation; and return fish downstream of the intake to reduce re-impingement.	Fish: 3,219-4,292 (20-40%) Macrocrustaceans: 7,58910,119 (20-40%)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Some reduction for impingement but not entrainment. Does not address thermal loading.
Coarse mesh Ristroph screens + fish return system	Modified Ristroph screens with fish handling buckets are designed to operate continuously. Fish carried up to the screen face during screen rotation are immersed in water and washed with a gentle low pressure spray to a fish return trough. The design of the Ristroph travelling screen is such that fish injury is decreased.	Fish: 536-2,146 (60-90%) Macrocrustaceans: 1,265-5,060 (60-90%) Beak (2000), ASA (2008)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	The upgrading of the current travelling screens to Ristroph will reduce impingement mortality but since these upgraded screens are coarse mesh (e.g., 3/8 in), they will not reduce entrainment. Must be used with upgraded fish return system. Impingement survival is species-specific. For this reason, a range in efficacy is given. Higher mortality will occur for less robust species such as herring than for instance grubby or lumpfish. Does not address thermal loading.

Table 6.2 Estimated I&E Reduction (Experience and Literature) (Cont'd)

Technology	Description	Expected I&E of Various Technologies (efficacy in brackets based on percent reduction of total organisms not corrected for survival)*		Additional Comments
		Impingement	Entrainment	
Dual flow conversion travelling screens	Dual flow travelling screens have flows that come from the sides and have greater surface area, which results in reduced approach velocity (and higher fish survival). Another advantage of a dual flow design compared to a single through-flow design includes zero (or close to zero) carryover of all debris and fish which results in higher effectiveness of fish transport to return systems, and keeps water boxes and condensers clean.	Fish: 536-2,146 (60-90%) Macrocrustaceans: 1,265-5,060 (60-90%) Beak (2000), ASA (2008)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	The upgrading of the current travelling screens to dual flow screens will reduce impingement mortality but since these upgraded screens are coarse mesh (e.g., 3/8 in), they will not reduce entrainment. Must be used with upgraded fish return system. Impingement survival is species-specific. For this reason, a range in efficacy is given. Higher mortality will occur for less robust species such as herring than for instance grubby or lumpfish. Does not address thermal loading.
MultiDisc Screens + fish return system	Geiger MultiDiscTM rotary screens are comprised of sickle-shaped mesh panels rotating on a single plane which can be equipped with fish protection features. These screens may offer advantages in operation and maintenance by eliminating debris carryover. For fish protection, fish buckets can be attached to the screen panels. The fish buckets retain water during their upward travel, keeping fish alive. A low pressure spray header gently guides any fish trapped on the screen panels into the fish bucket directly below. The fish buckets are gently discharged and the fish are led into a trough.	Fish: 536-2,146 (60-90%) Macrocrustaceans: 1,265-5,060 (60-90%) Beak (2000), ASA (2008)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	The upgrading of the current travelling screens to Geiger Multidisc screens will reduce impingement mortality but since these upgraded screens are coarse mesh (e.g., 3/8 in), they will not reduce entrainment. Must be used with upgraded fish return system. Impingement survival is species-specific. For this reason, a range in efficacy is given. Higher mortality will occur for less robust species such as herring than for instance grubby or lumpfish. Does not address thermal loading.
Water Intake Protection (WIP) Screen	With the Beaudrey Water Intake Protection (WIP) screen, aquatic organisms are directed into radial compartments in front of patented No ClingTM fine mesh panels as intake water flows through the screening disk. A gentle current created by a fish friendly pump channels fish into a returning flume. Aquatic organisms do not leave the water and are returned downstream of the intake structure. The WIP eliminates the potential for debris carryover since all flow must pass through the screen before entering the screenwell and condenser.	Fish: 536-2,146 (60-90%) Macrocrustaceans: 1,265-5,060 (60-90%)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Little technical information on performance seems available at power plants. No effect on entrainment. Does not address thermal loading.
Fish Net Barriers	Coarse mesh (e.g., ≥ 3/8 in or 9.5 mm) barrier nets placed in front of an existing intake structure with physical exclusion depending on mesh size. The nets should have a large surface area so that the velocity through the net is small (< 0.5 ft/s) to ensure that organisms impinged on the net are not damaged.	Fish: 536-805 (85-90%) Under Optimal Conditions Macrocrustaceans: 1,265-1,897 (85-90%) Under Optimal Conditions Patrick et al. (2014)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	A coarse mesh barrier net will not exclude entrainable organisms. However, impingement reduction effectiveness can approach 90% especially for pelagic species but there can be issues with clogging and debris requiring continual maintenance. Effectiveness data from lacustrine environments not rivers. Does not address thermal loading.
Cylindrical wedgewire screens (fine mesh)	Cylindrical wedge wire (CWW) screens physically exclude aquatic organisms and are available in a range of slot widths (e.g., coarse mesh and fine mesh). The cylindrical screen shape also makes it easier for fish to swim away before becoming impinged. The effectiveness of CWW screens depends on site specific conditions (e.g., flow). Since CWW screens reduce intake velocity, larger design flows require more screens.	Fish: 0 (100%) Macrocrustaceans: 0 (100%)	Eggs/Larvae: 36,388,545 (75%) Macrocrustacean Larvae: ≤ 261,894,514-327,368,142 (75-80%) EPRI (2005b, 2006) Stantec (2007)	We understand that for technologies such as wedgewire screens, the estimated per cent reductions were based on sizes of eggs and larvae potentially entrained based on literature values. However, recent field studies by EPRI (2005b, 2006) suggest that performance for small slotted screens is not as high as predicted by Enercon (2008). We believe the through-flow velocity at 0.5 fps is still too high to significantly reduce larvae entrained and impinged using wedgewire screen technology. Will require construction and placement of screens in Piscataqua River. Loss of fish habitat. Average efficacy (75% is given for a 0.5-1.0 mm slot screen but effectiveness will vary with species based on lab and field trials.

Table 6.2 Estimated I&E Reduction (Experience and Literature) (Cont'd)

Technology	Description	Expected I&E of Various Technologies (efficacy in brackets based on percent reduction of total organisms not corrected for survival)*		Additional Comments
		Impingement	Entrainment	
				There is an issue with larval retention on the screens. Larval mortality on the screens would also have to be considered on fine-mesh screens, and is unknown. EPA has estimated egg survival to be 80% and larvae survival is 12% after contact with the wedgewire screens. Does not address thermal loading.
Fine mesh Ristroph screens	Fine mesh (e.g., 0.5-1.0 mm) modifications can be made to various travelling water screens (e.g., dual flow, through flow) to address entrainment. Fine mesh inserts may also be placed in fish baskets to safely return entrainable organisms.			Not feasible at Schiller because of space requirements (Enercon 2008).
Aquatic Microfiltration Barriers	Aquatic microfiltration barriers are full depth water curtains (e.g., Gunderboom) made of filter fabric that exclude organisms but allows water to filter through into a CWIS. Velocities at the face of the permeable curtain are very low and the systems have a large surface area. Organisms or sediments trapped on the fabric can be removed with an airburst system.	Fish: 0 (100%) Macrocrustaceans: 0 (100%) Assumes net is 100% operational with no tears or sagging and biofouling is minimal Seaby *et al*. (2002)	Eggs/Larvae: 29,110,836 (80%) for short periods Macrocrustacean Larvae: 261,894,514 (80%) for short periods Henderson *et al*. (2003), McCusker *et al*. (2004)	An aquatic filter barrier net would only be in place year-round. There are serious issues with clogging, and biofouling (Seaby *et al*. 2002) and debris with this technology requiring continual maintenance. Can be effective for very short periods if operated properly and minimal biofouling. Literature suggests the nets are problematic and not effective if in place for extended periods (Henderson *et al*. 2003). Does not address thermal loading.
Flow Reduction - Variable Speed Pumps	Reducing the flow would potentially reduce impingement and entrainment. One method is to install variable frequency drives (VFDs). The resulting variable speed pumps (VSPs) reduce flow (and thus impingement and entrainment) through the Unit's condenser. Condenser design limitations are not exceeded.	Fish: 4,292-4,829 (10-20%) Macrocrustaceans: 10,119-11,384 (10-20%)	Eggs/Larvae: 116,443,342-130,998,760 (10-20%) Macrocrustacean Larvae: 1,047,578,055-1,178,525,312 (10-20%)	May increase ΔT and possibly enhance thermal effects to biota in the river.

Table 6.3 Estimated I&E Reduction (Experience and Literature) of Additional Technologies

Technology	Description	Expected I&E of Various Technologies (efficacy in brackets based on percent reduction of total organisms not corrected for survival)*		Additional Comments
		Impingement	Entrainment	
Existing Technology at Schiller	Unit 4 – Offshore intake with fixed screen in front of intake pipe to prevent lobsters from entering. There is also a lobster diversion pipe. A travelling water screen (3/8 in) operates intermittently to handle fish and debris. A fish return trough returns fish back into the Piscataqua River. Units 5 and 6 – Shoreline intake. Travelling water screens (3/8 in) operate intermittently to handle fish and debris. A fish return trough returns fish back into the Piscataqua River.	Fish: 5,365 Macrocrustaceans: 12,649	Eggs/Larvae: 145,554,178 Macrocrustacean Larvae: 1,309,472,569	Impingement is relatively low. Entrainment of fish eggs and larvae, and especially macrocrustaceans is extremely high and variable.
Cylindrical Wedge Wire Screens (Fine mesh with through-slot velocity less than 0.20 ft/s or 6.0 cm/s)	Same as fine mesh cylindrical wedge wire screens discussed in Table 5.2 but with a through-slot velocity less than 0.2 ft/s or approximately 6 cm/s (compared to 0.5 ft/s or 15 cm/s) and slot size 0.5 mm. This will further reduce larval entrainment but not egg entrainment.	Fish: 0 (100%) Macrocrustaceans: 0 (100%)	Eggs/Larvae: minimum 14,555,418-21,833,127 (85-90% with the smallest slot size, i.e., 0.5 mm) Not field evaluated Macrocrustacean Larvae: minimum 130,947,257-196,420,885 (85-90% with the smallest slot size, i.e., 0.5 mm) Not field evaluated	An alternative with reduced through-slot velocity of 0.2fps and 0.5 mm openings. Some larval fish as small as 5.0-7.0 mm can attain burst speeds of 6 cm/s for short periods of time and possibly overcome entrainment. Larvae exceeding 10 mm in size have greater swimming capabilities. Miller *et al*. (1988) recognized that larval fish characteristics (e.g., size at hatch, swim speeds, etc.) may vastly differ among species but concluded that swimming ability is often correlated with larval body size. This modified technology has not been field evaluated so effectiveness is largely unknown but could approach 85-90% for entrainment reduction. There is an issue with larval retention on the screens. Larval mortality on the screens would also have to be considered on fine-mesh screens. Still, with a lower approach velocity, less larval retention would be expected on the fine mesh screens. EPA has estimated egg survival to be 80% and larvae survival is 12% after contact with the wedgewire screens (at 0.5fps). Considerably more habitat loss than conventional cylindrical wedge wire screens operating at 0.5 ft/s as described in Table 5.2 since many more screens required. Does not address thermal loading.
Helper cooling towers	A "helper" cooling tower may be used (e.g., Aggreko) with the once through cooling system or cooling towers to reduce thermal discharge effects.	Fish: 5,365 (0%) Macrocrustaceans: 12,649 (0%)	Eggs/Larvae: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Reduces thermal load.
Thermal tempering	Thermal tempering involves diverting flow from the intake channel to the discharge channel to reduce thermal discharge effects.	Fish: 5,365 (0%) Macrocrustaceans: 12,649 (0%)	Eggs/Larvaesh: 145,554,178 (0%) Macrocrustacean Larvae: 1,309,472,569 (0%)	Reduces thermal load.
Fine mesh (0.5 mm) cylindrical wedge wire screens with reduced through-slot velocity (6 cm/s) + helper cooling tower or thermal tempering	Integrated system. A combination of technologies would reduce I&E, as well as thermal discharge effects.	Fish: 0 (100%) Macrocrustaceans: 0 (100%)	Eggs/Larvae: minimum 14,555,418-21,833,127 (85-90% with the smallest slot size, i.e., 0.5 mm) Not field evaluated Macrocrustacean Larvae: minimum 130,947,257-196,420,885 (85-90% with the smallest slot size, i.e., 0.5 mm) Not field evaluated	An alternative with reduced through slot velocity (6 cm/s) and 0.5 mm openings. Some larval fish as small as 5.0-7.0 mm can attain burst speeds of 6 cm/s for short periods of time and possibly overcome entrainment. Larvae exceeding 10 mm in size have greater swimming capabilities. Miller *et al*. (1988) recognized that larval fish characteristics (e.g., size at hatch, swim speeds, etc.) may vastly differ among species but concluded that swimming ability is often correlated with larval body size. This modified technology has not been field evaluated so effectiveness is largely unknown but could approach 85-90% . Considerably more habitat loss than conventional cylindrical wedge wire screens operating at 0.5 ft/s as described in Table 6.2 since many more screens required. Thermal loading partly addressed with helper cooling tower or thermal tempering.

7.0 REFERENCES

ASA Analysis and Communication, Inc. (ASA) 2008. *Evaluation of Impingement Survival on the Hydrolox™ Traveling Water Screen at the E.F. Barrett Generating Station October 2007 – June 2008.* Final Report. Prepared for: National Grid Environmental Engineering Department and Intralox. November.

Atlantic Sturgeon Status Review Team. 2007. *Status Review of Atlantic Sturgeon (Acipenser oxyrinchus oxyrinchus).* Report to National Marine Fisheries Service, Northeast Regional Office. February 23, 2007. 174 pp.

Auster, P.J. 1989. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic and Mid-Atlantic) – Tautog and Cunner.* U.S. Fish and Wildlife Service Biol. Rep. 82(11.105). U.S. Army Corps of Engineers, TR EL-82-4. 13 pp.

Beak Consultants Incorporated (Beak) 2000. *Post Impingement Fish Survival Dunkirk Steam Station, Winter, Spring, Summer and Fall 1998-1999*. Report prepared for NRG Dunkirk Power L.L.C.

Bradt, G. 2012. *Seafood Watch: American Lobster Homarus americanus.* Monterey Bay Aquarium. Available at: http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_AmericanLobsterReport.pdf.

Buckley, J.L. 1989. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic) – Rainbow Smelt.* U.S. Fish Wildl. Serv. Biol. Rep. 82(11.106). U.S. Army Corps of Engineers, TR EL-82-4. 11 pp.

Canadian Standards Association (CSA) 2012. *CSA Standard N288.6: Environmental Risk Assessments at Class I Nuclear Facilities and Uranium Mines and Mills.* June.

Carpenter Environmental Associates, Inc. 2012. *Review and Analysis of the 316(b) Best Technology Available (BTA) Report for the Bridgeport Harbor Energy Generating Station & the 316(a) Hydrothermal Model Study (HMS) for the Bridgeport Harbor and Bridgeport Energy Generating Stations in Bridgeport, Connecticut.*

CSNE 2011. *Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future, University of New Hampshire.*

Electric Power Research Institute (EPRI) 2006. *Field Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intake Structures: Chesapeake Bay Studies.* EPRI Report 1012542.

Electric Power Research Institute (EPRI) 2005a. *Entrainment Abundance Monitoring Technical Support Document.* EPRI Report 1011280.

Electric Power Research Institute (EPRI) 2005b. *Field Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intake Structures.* EPRI Report 1010112.

Electric Power Research Institute (EPRI) 2003. *Impacts of Volumetric Flow Rate of Water Intakes on Fish Populations and Communities.* EPRI Report 1005178.

Enercon Services, Inc. (Enercon) 2008. *Response to United States Environmental Protection Agency CWA §308 Letter: PSNH Schiller Station, Portsmouth, New Hampshire.* Prepared in consultation with Normandeau Associates.

Fay, C., M. Bartron, S. Craig, A. Hecht, J. Pruden, R. Saunders, T. Sheehan, and J. Trial. 2006. *Status Review for Anadromous Atlantic Salmon (Salmo salar) in the United States.* Report to the National Marine Fisheries Service and U.S. Fish and Wildlife Service. 294 pages. Available at: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/atlanticsalmon.pdf.

Gulf of Maine Research Institute 2013. *Atlantic Herring.* Available at: http://www.gma.org/herring/default.asp.

Henderson, P.A., R.M.H. Seaby and J.R. Somes 2003. *A Comparison of Ecological Impacts of Power Plant Once-through, Evaporative and Dry Cooling Systems on Fish Impingement and Entrainment.* Pisces Conservation Ltd. May.

Johnston I.A., V.L.A. Viera and M. Abercrombie 1995. *Temperature and Myogenesis in Embryos of the Atlantic Herring Clupea Harengus.* Journal of Experimental Biology 198: 1389-1403.

Kelso, J.R.M. and G.S. Milburn 1979. *Entrainment and Impingement of Fish by Power Plants in the Great Lakes which use the Once-Through Cooling Process.* Journal of Great Lakes Research 5(2): 182-194.

King, R.G., G. Seegert, J. Vondruska, E.S. Perry and D.A. Dixon 2010. *Factors Influencing Impingement at 15 Ohio River Power Plants*. North American Journal of Fisheries Management 30: 1149-1175.

Klumb, R.A., L.G. Rudstam and E.L. Mills. 2003. *Comparison of Alewife Young-of-the-Year and Adult Respiration and Swimming Speed Bioenergetics Model Parameters: Implications of Extrapolation*. Transactions of the American Fisheries Society, 132:6, 1089-1103.

McCusker, A.M., H.B. Dreyer, M.A. Hamlin, S.B. Ravenna and J.C. Campbell 2004. *Full-Plant Deployment of an Aquatic Filter Barrier System at a Generating Station on the Hudson River in New York.* Power-Gen International. November 30-December 2, 2004. Available at: http://www.gunderboom.com/PDFfiles/Full-Plant%20Deployment%20of%20an%20MLES.pdf.

Miller, T.J., L.B. Crowder, J.A. Rice and E.A. Marschall 1988. *Larval Size and Recruitment Mechanisms in Fish: Towards a Conceptual Framework.* Can. J. Fish. Aquat. Sci. 45: 1657-1670.

National Marine Fisheries Service (NMFS) 2013. *Shortnose Sturgeon (Acipenser brevirostrum)*. Available at: http://www.nmfs.noaa.gov/pr/species/fish/shortnosesturgeon.htm.

National Marine Fisheries Service (NMFS) 2012. *River Herring Climate Change Workshop Report.* Report to the National Marine Fisheries Service, Northeast Regional Office. December 27, 2012, 60pp.

National Marine Fisheries Service (NMFS) 2009. *Species of Concern: River Herring (Alewife and Blueback Herring).* Available at: http://www.nmfs.noaa.gov/pr/pdfs/species/riverherring_detailed.pdf.

National Marine Fisheries Service (NMFS) 1999a. *Essential Fish Habitat Source Document: Winter Flounder, Pseudopleuronectes americanus, Life History and Habitat Characteristics.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Region, NOAA Technical Memorandum NMFS-NE-138.

National Marine Fisheries Service (NMFS) 1999b. *Essential Fish Habitat Source Document: Atlantic Herring, Clupea harengus, Life History and Habitat Characteristics.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Region, NOAA Technical Memorandum NMFS-NE-126.

National Marine Fisheries Service (NMFS) 1994. *Review of American Lobster (Homarus americanus) Habitat Requirements and Responses to Contaminant Exposure.* National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Region, NOAA Technical Memorandum NMFS-NE-105.

National Marine Fisheries Service and U.S. Fish and Wildlife Service (NMFS and USFWS). 2005. *Recovery Plan for the Gulf of Maine Distinct Population Segment of Atlantic Salmon (Salmo salar).* Available at: http://www.nmfs.noaa.gov/pr/pdfs/recovery/salmon_atlantic.pdf.

Nelson, G.A., B.C. Chase and J. Stockwell 2003. *Food Habits of Striped Bass (Morone saxatilis) in Coastal Waters of Massachusetts.* J. Northw. Atl. Fish. Sci. 32: 1-25.

New Hampshire Fish and Game Department (NHFG) 2013. *N.H. Hearing on American Eel Draft Addendum III.* Available at: http://www.wildlife.state.nh.us/Newsroom/2013/Q1/eel_hrg_032913.html.

No author 2011. *Anadromous Fish Investigations: Estuarine Survey of Juvenile Fish*. Progress Report. New Hampshire's Marine Fisheries Investigations Grant. Available at: http://www.wildlife.state.nh.us/marine/marine_PDFs/2011_project_reports/Juvenile_Finfish_2011.pdf.

Normandeau Associates (Normandeau) 2008. *Entrainment and Impingement Studies Performed at Schiller Generating Station from September 2006 through September 2007* Prepared for: Public Service of New Hampshire.

Patrick, P.H., E. Chen, J. Parks, J. Powell, J.S. Poulton and C. Fietsch. 2013. *Effects of Fixed and Fluctuating Temperature on Hatch of Round Whitefish and Lake Whitefish Eggs.* North American Journal of Fisheries Management 33: 1091-1099.

Patrick, P.H., E. Mason, J. Powell, S. Milne, and J.S. Poulton. 2014. *Evaluating the Effectiveness of the Pickering Nuclear Generating Station Fish Diversion System Barrier Net*. North American Journal of Fisheries Management 34: 287-300.

Piscataqua Region Estuaries Partnership (PREP). 2013. *State of our Estuaries 2013.* 48 pp. Available at: http://www.prep.unh.edu/resources/pdf/2013%20SOOE/SOOE_2013_FA2.pdf.

Schaller, S.Y., C.C. Chabot and W.H. Watson III. 2010. *Seasonal Movements of American Horseshoe Crabs Limulus polyphemus in the Great Bay Estuary, New Hampshire, (USA).* Current Zoology 56(5): 587-598.

Seaby, R.M.H., P.A. Henderson, C.R. Cailes and J.R. Somes 2002. *Gunderboom Fouling Studies.* Pisces Conservation Ltd. August.

Short, F.T. 2013. *Eelgrass Distribution in the Great Bay Estuary for 2012.* Final Report. Prepared for The Piscataqua Region Estuaries Partnership.

Short, F.T., K. Matso, H.M. Hoven, J. Whitten, D.M. Burdick, and C.A. Short. 2001. *Lobster Use of Eelgrass Habitat in the Piscataqua River on the New Hampshire/Maine Border, USA.* Estuaries 24(2): 277-284.

Smith, B. W. No date. *The Marine Living Resources of the Piscataqua River.* Presentation given by the New Hampshire Fish and Game Department. Available at: http://des.nh.gov/organization/divisions/water/wmb/coastal/ocean_policy/documents/te_workshop_piscataqua_marine.pdf.

Stantec Consulting Ltd (Stantec) 2007. *Fish Exclusion Technology – A Literature Review.* Prepared for SaskPower. December 2007.

St. Lawrence Global Observatory (SLGO) No date. *American Lobster – Predator and Prey.* Available at: http://slgo.ca/en/lobster/context/foodchain.html.

Tenera. 2013. *Length-specific Probabilities of Screen Entrainment of Larval Fishes based on Head Capsule Measurements*. Prepared for Bechtel Power Corporation. July 31.

Tlusty, M., A. Metzler, E. Malkin, J. Goldstein and M. Koneval 2008. *Microecological Impacts of Global Warming on Crustaceans – Temperature Induced Shifts in the Release of Larvae from American Lobster, Homarus americanus, Females.* Journal of Shellfish Research 27(2): 443-448.

Trowbridge, P. 2012. *New Hampshire's 2012 Section 305(b)/303(d) List. Technical Support Document. Assessments of Aquatic Life Use Support in the Great Bay Estuary for Chlorophyll-a, Dissolved Oxygen, Water Clarity, Eelgrass Habitat, and Nitrogen*. State of New Hampshire Department of Environmental Services. April. Available at: http://www.prep.unh.edu/resources/pdf/Eelgrass_Report_dated_20130823-unh-2012.pdf.

Turnpenny, A.W.H., J. Coughlan, B. Ng, B. Bamber and P. Rowles 2010. *Cooling Water Options for the New Generation of Nuclear Power Stations in the UK*. Environment Agency. SC070015/SR3. June 2010.

United States Environmental Protection Agency (USEPA) 2007. *Fact Sheet: Draft National Pollutant Discharge Elimination System (NPDES) Permit to Discharge to Waters of the United States Pursuant to the Clean Water Act.* NPDES permit no. NH0023361. Newington Energy Facility. Available at: http://www.epa.gov/region1/npdes/permits/2007/attachments/finalnh0023361fs.pdf.

United States Environmental Protection Agency (USEPA) 2012. *Authorization to Discharge under the National Pollutant Discharge Elimination System (NPDES).* EP Newington Energy Facility. Permit no. NH0023361. Available at: http://www.epa.gov/region1/npdes/permits/2012/finalnh0023361permit.pdf.

United States Environmental Protection Agency (USEPA) 2001. *Issue Paper 5: Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids.* Prepared as Part of EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005. May.

United States Environmental Protection Agency (USEPA) 1993. *Authorization to Discharge under the National Pollutant Discharge Elimination System.* PSNH Newington Station. Permit no. NH0001601. Available at: http://www.epa.gov/region1/npdes/permits/finalnh0001601permit.pdf.

United States Environmental Protection Agency (USEPA) 1977. *Temperature Criteria for Freshwater Fish: Protocol and Procedures.* Report from the Environmental Research Laboratory, USEPA, Duluth, Minnesota. Report No: EPA-600/3-77-061.

Vachon, J. and K. Sullivan. 2007. *Rediscover… The Lost Art of Winter*. New Hampshire Wildlife Journal July/August 2007. Available at: http://www.wildlife.state.nh.us/Wildlife_Journal/WJ_sample_stories/WJ_d07_Winter_flounder.pdf.

Washington State Department of Ecology (WDOE) 2002. *Evaluating Standards for Protecting Aquatic Life in Washington's Surface Water Quality Standards. Temperature Criteria. Draft Discussion Paper and Literature Summary*. Publication No. 00-10-070. December.

Wismer, D.A. and A. Christie 1987. *Temperature Relationships of Great Lakes Fishes: A Data Compilation.* In: Great Lakes Fishery Commission document Spec. Pub 87-3.