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316(b) Site Evaluation Report
Public Service of New Hampshire
Merrimack Power Station, Bow, NH

Under contract 68-C-02-108, Tetra Tech was contracted by EPA's Office of Wastewater Management and EPA Region I to visit several facilities in New England, evaluate the cooling water intake structure (CWIS) and fish protection technologies, and provide technical support in developing 316(b) permit conditions based on best professional judgement (BPJ) for the upcoming permit reissuance. Tetra Tech conducted a site visit at the Merrimack Power Station (Merrimack) in Bow, New Hampshire on July 19, 2005. This report discusses Tetra Tech's evaluation of the facility with respect to the biological characteristics of the waterbody from which Merrimack withdraws and the effectiveness of any fish protection technologies in place.

A second report will follow that continues Tetra Tech's evaluation of Merrimack and will address potential technological solutions for Merrimack to meet BTA and the estimated costs of those solutions.

1.0 Introduction

Merrimack is the Public Service of New Hampshire's primary base load plant. It operates continuously and has an output of 478 MW. The facility supplies electricity to 189,000 residential, commercial, and industrial customers. It began operation in 1960 and consists primarily of two coal-fired steam turbines. There are also two combustion turbines that are used as peaking units.

The facility has two CWISs with a total design intake flow (DIF) of 287 million gallons per day (mgd).[1] The facility operates continuously, with an average flow of approximately 220.8 mgd.[2] See Figure 1 for an aerial view of the facility.

Merrimack is located on the Merrimack River, a freshwater river formed at the confluence of the Pemigewasset and Winnipesaukee Rivers. The Merrimack River flows 110 miles to the Atlantic Ocean and drains an area of approximately 5,000 square miles. Nearly 100 dams have been built to provide water for hydropower generation and other industrial uses. The facility is approximately 3 miles from a dam in both the upstream and downstream directions. Merrimack is located on a reach of the river that is nearly 1000 feet wide.

2.0 Biological Impacts of Cooling Water Intake Structures

Section 316(b) of the Clean Water Act (CWA) addresses the adverse environmental impact of CWISs at facilities requiring National Pollutant Discharge Elimination System (NPDES) permits. In addition to effects related to thermal discharges, the operation of a

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[1] The DIF for the CWIS for Unit 1 is 85 MGD and the DIF for Unit 2 is 202 MGD.

[2] Average intake flow based on data from the facility's 316(b) industry questionnaire, using the years 1996-1998. Detailed Industry Questionnaire: Phase II Cooling Water Intake Structures—Traditional Steam Electric Utilities. January 2000.

CWIS may adversely affect the environment in two ways: first, from the entrainment of fish eggs and larvae and other aquatic life through the plant's cooling system; and second, from the impingement of fish and other aquatic life on the intake screens. A brief description of the characteristics of the Upper Merrimack River and local biota in the vicinity of Merrimack is provided here, in order to evaluate the potential impacts to the biota of the Upper Merrimack from the CWIS.

2.1 Waterbody Characteristics

As noted above, Merrimack is located on the Merrimack River, a freshwater river according to the 316(b) regulations. The facility is located between the Hooksett Dam and Garvins Falls Dam and withdraws water from the Hooksett Pool, a freshwater impoundment. The Hooksett Pool is approximately 350 acres, has an average depth of 6-10 ft, and has a hydraulic retention time of about 8 hours under mean annual flow and 5 days under 7Q10 flow conditions. (Normandeau Assoc. 2005)

Merrimack is located within the section of the river designated as the "Upper Merrimack." The land uses within 3/4 miles of this section of the river section are nearly 80 percent undeveloped forest, farm, or wetland. The river maintains a high level of water quality and the ability to support valuable wildlife and plant habitat. The Merrimack River corridor provides significant wintering habitat for the federally endangered bald eagle, and is seasonally important to the state-threatened Osprey. The karner blue butterfly, an endangered species in New Hampshire, is known to occur along the river. The New Hampshire Natural Heritage Inventory also identified the following rare species in the river corridor: fowler's toad, blanding's turtle, blue-gray gnatcatcher, blunt-leaved milkweed, wild senna, ram's head lady slipper, golden heather, wild lupine, pink wintergreen, burgrass, and fall witchgrass. Based on the occurrences of these populations and other natural, valued resources within the Upper Merrimack basin, the Upper Merrimack has been included in the New Hampshire Rivers Management and Protection Program and is eligible for inclusion in the National Wild and Scenic Rivers System. (NH DES 1997b)

The Upper Merrimack River is a highly visible waterbody in the northeast region of the United States, and the quality of the water and biological community is of great interest to the communities within the watershed. In 1995, the Upper Merrimack River Local Advisory Committee created a volunteer water quality monitoring program in cooperation with the New Hampshire Department of Environmental Services and the Merrimack River Watershed Council.

The section of the upper Merrimack in the vicinity of the facility exhibits physical characteristics and associated biota common to both lentic and lotic environments due to its location within an impoundment (the Hooksett Pool). However, due to the short residence time of water within the Hooksett Pool (less than 7 days at 7Q10 flow conditions), the source waterbody for Merrimack is considered to be a freshwater river or stream for compliance with the Phase II Rule. (Normandeau Assoc. 2005)

2.2 Local Biology--Common and Notable Species Present

The Upper Merrimack River contains a diverse fish population (Table 1). The Merrimack River supports an excellent resident sport fishery, including smallmouth and largemouth bass, rainbow and brook trout, yellow perch, walleye, and bullhead. (Normandeau Assoc. 1997) The Upper Merrimack is a cold water fishery that provides habitat for at least 24 resident and anadromous species, including at least 11 species of sport and recreational importance (Table 1). The New England River Protection and Energy Development Project ranked the Upper Merrimack River "of highest significance" as an anadromous fishery and "highly significant" as an inland fishery. (NH DES 1997b) Anadromous fish species are beginning to return to both the Lower and Upper Merrimack River sections as the result of a cooperative state-federal restoration program that began in 1969. (NH DES 1997a and 1997b) New and improved fish passage facilities and on-going research efforts are directed toward the return of the native Atlantic salmon, American shad, alewife, and blueback herring to waters as far north as the Pemigewasset River. The endangered shortnose sturgeon (*Acipenser brevirostrum*) has also been found in the Lower Merrimack River. (NH DES 1997a)

Although the Upper Merrimack primarily provides cold water fish habitat, the Hooksett Pool supports primarily a warm water finfish community dominated by sunfish, bass, minnows, white suckers, and bullhead due to habitat alterations associated with the three electrical power generating facilities along the Upper Merrimack. (Normandeau Assoc. 1979) The pool contains 19 resident species, with several other transient species (e.g., trout and smelt). Atlantic salmon and American shad were stocked into the pool and upstream waters around 1975 and, as mentioned above, are returning to upstream waters due to the installation of fish passage structures. Anadromous species (e.g., Atlantic Salmon, alewife and American shad) pass through this section of the Merrimack during their seasonal spawning runs, although only alewives were reported in the fish survey data reviewed for this report. Table 1 contains a list of larval and adult fish captured during the source water sampling conducted in the vicinity of the Merrimack's CWISs and also during other historic sampling within the upper Merrimack. (Normandeau Assoc. 1997; Merrimack River Basin Commission 2003)

2.3 Entrainment and Impingement

Several studies have been conducted to investigate the potential impact of Merrimack River power generating stations on the ichthyofaunal community. Studies in the upper Merrimack have focused on the impacts of the Merrimack Generating Station. The New Hampshire Fish and Game Department, PSNH, and Normandeau Associates, Inc. have conducted thermal and biological studies of the river since 1967, to examine the effect of the Merrimack's thermal plume and impingement/entrainment impacts on the aquatic biota of Hooksett Pond.

The quantity of organisms entrained and impinged is generally a function of the intake structure's location, design, flow capacity (and resulting intake velocity), frequency of operation, and the abundance of organisms within the influence of the cooling water intake current. The biological community of the Hooksett Pool, coupled with the location of the Merrimack's CWISs in the relatively warm and species-rich impoundment provides conditions that could potentially lead to high rates of impingement mortality and entrainment. The following section discusses the potential for impacts to aquatic organisms as a result of the operation of the Merrimack's CWISs.

2.3.1 Entrainment Impacts

Fish eggs and larvae, and other aquatic organisms small enough to pass through the mesh of intake screens, are entrained in water drawn into a facility's cooling system. Organisms carried through the cooling system are exposed to high shear stress and a rapid increase in water temperature as heat is transferred to the cooling water from the facility's condensers. Finally, after being discharged, organisms that survive traveling through the facility's cooling water system may then be exposed to rapid decreases in water temperature as the heated cooling water mixes with the receiving waters. These physical, chemical, and thermal stressors, individually or in combination, can kill or injure the entrained organisms. In the absence of site-specific studies demonstrating a different mortality rate, 100% mortality of entrained organisms was assumed in order to determine impacts to local fish and shellfish populations. This assumption is consistent with the recently issued 316(b) regulations for Phase II facilities.[3]

Entrainment effects at Merrimack were measured by Normandeau Associates in 1975, 1978, and 1995. It was reported by Normandeau Assoc. (2005) that fish eggs were not collected during any of these studies. However, the mesh size used (500 micron) during entrainment sampling was larger than that typically used to sample icthyoplankton (i.e., 333 micron), and sampling was not conducted in every month. Therefore, the potential impacts of these CWISs on the egg stage of fish species that occur within Hooksett Pool could not be thoroughly evaluated.

Sampling of larval fish in these studies showed that white sucker, yellow perch, sunfish species, bluegill, spottail shiner, rainbow smelt, common shiner, and golden shiner larvae are commonly entrained. (Normandeau Assoc. 2005) Bluegill larvae were the most abundant species in entrainment samples in the 1995 study with a maximum rate of 7.2 larvae per 50 m^3 (i.e., over 15,000 larvae per day). Similar to egg sampling, larval entrainment effects were not evaluated throughout the year, and data from the 1995 study indicated that larval fish were present in the water body prior to the sampling period. Therefore, the potential impacts of these CWISs on the larval stage of fish species that occur within Hooksett Pool, and in particular re-introduced anadromous species, could not be thoroughly evaluated.

Table 2 indicates that the critical period where egg and larval fish (for the species that may occur in the vicinity of the CWISs) are expected to be most abundant is March through

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[2] See 69 Fed. Reg. 41620, *Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities*, July 9, 2004.

August. Entrainment of shellfish larvae was not discussed in any of the existing monitoring reports.

2.3.2 Impingement Impacts

The impingement of organisms occurs when water is drawn into a facility through a CWIS and organisms become trapped against the traveling screens. Impinged fish may suffer from improper gill movement, de-scaling, starvation, or exhaustion while trapped against intake screens. If an organism is returned to the waterbody through a debris return trough, it may suffer further injuries from contact with debris in the trough. Upon being returned to the waterbody, injured or disoriented organisms may be more susceptible to predation.

Impingement at Merrimack has been measured during low flow periods (i.e., when the Goff Falls gauge drops below 900 cfs) over the past 30 years, but monthly impingement monitoring has not been conducted since 1977. (Normandeau Assoc. 2005) Annual impingement estimates (for both CWISs combined) totaled 1,449 fish representing 20 species in 1976, and 2,504 fish representing 16 fish taxa in 1977. The most abundant species in the impingement samples were minnow species which collectively accounted for 74% of impinged fish. Game species such as smallmouth and largemouth bass made up about 4.7% of the impingement in 1976 and only 0.7% in 1977. Additional impingement monitoring for effects on anadromous Atlantic salmon or American shad did not indicate that any salmonid smolts were impinged and only 1 shad juvenile was impinged. Impingement of shellfish was not measured or discussed in the studies.

While it is important to understand an intake structure's potential to impinge organisms, it is also important to assess the capability of the intake system's design and operation to effectively return impinged organisms back to the receiving waters alive and uninjured. Merrimack has a spray wash system that cleans the revolving screens of impinged organisms and other material. This material is then transported back to the river via an 18 inch corrugated steel pipe, which empties onto a steel grate on the river bank. Survival studies are not described in the existing monitoring reports, but it is likely that survival rates are nearly zero.

Other important issues are that the data do appear to indicate a change in the fish community in the Merrimack River since 1977 and that recovery efforts are underway for anadromous species that will pass through the Hooksett Pool.

2.3.3 Summary of Entrainment and Impingement

The biological monitoring results from studies at Merrimack indicate that the biological impacts from the operation of CWISs may be minimal. These conclusions however, were derived from sampling regimes that do not sample all life stages adequately nor are seasonal impacts associated with migrating or resident fish species appropriately addressed. Given the general lack of rigorous data on annual entrainment impacts on fish eggs and larvae, the volume of withdrawals by the facility, and fact that anadromous and endangered species are attempting to re-establish healthy populations in the Merrimack

River, it would be advisable to maintain an assessment program to evaluate the entrainment impacts of this facility. In addition, predicted months of occurrence of egg and larval fish (for the species that may occur in the vicinity of the CWISs) indicate that entrainment sampling should be conducted from March through August to accurately characterize entrainment impacts to these species.

Impingement survival studies are not described in the existing monitoring reports. Even if the return system were to discharge into the water, it is likely that survival rates would be low, given that impinged fish and debris are washed into a common return system. Noting the change in the fish community in the Merrimack River since 1977, and the recovery efforts that are underway for anadromous species that will pass through the Hooksett Pool, impingement mortality impacts should be re-evaluated, and should be evaluated year-round.

In addition, the impact of the CWISs on larval shellfish is not mentioned in any of the existing biological studies.

3.0 Evaluation of Current Cooling Water Intake Structure Configuration

The discussion below provides an evaluation of the location, design, construction, and capacity of Merrimack's CWISs. In addition to reviewing relevant documentation provided by Merrimack and participating in discussions with Merrimack personnel familiar with the CWIS and their operation, a site visit was conducted on July 19, 2005 to assess the facility's CWIS design and operation.

3.1 Location of the cooling water intake structures

The location of a CWIS in the waterbody is an important factor in assessing the impacts of the CWIS. In evaluating the location of a CWIS, its location in the waterbody (such as proximity to a shoreline), the type of waterbody, and the depth of the intake structure were considered.

3.1.1 Description of Location

The facility has two shoreline CWISs on the western shore of the river, located approximately 50 yards apart (see Figure 1). The waterbody is approximately 10 feet deep in the vicinity of the intake structures. The CWIS for Unit 1 withdraws from the center of the water column (through an opening at a depth of approximately 4-9 feet below the water surface) whereas the CWIS for Unit 2 withdraws from nearly the entire water column (the intake opening begins approximately one foot from the river bottom). The area in front of each intake structure is dredged annually to maintain the desired intake depth.

The Merrimack River is a highly managed waterbody with a large number of dams and other obstructions. As such, the natural ecosystem that might be expected in a freeflowing (i.e., lotic) freshwater river is generally not present. Instead, the Merrimack River exhibits many characteristics of a reservoir or other lentic system.

3.1.2 Evaluation of Location

Merrimack is located on one of several pools on the Merrimack River formed by hydroelectric and other dams. While freshwater rivers are generally thought to be less productive in an ecological sense than some other types of waterbodies (e.g., estuaries), individual rivers (or portions of rivers) may be of concern. In the case of the Merrimack River, the existing biological data does not appear to indicate a serious problem with impingement and entrainment. However, as noted above, the sampling programs employed to collect these data were not thorough enough to convincingly state that the facility is causing minimal impacts due to the use of its CWISs. In addition, ongoing efforts to restore anadromous and threatened and endangered fish species in the river may affect the assessment of the impact due to the intakes.

3.2 Design, Construction, and Operation of the Cooling Water Intake Structures

The design, construction and operation of a CWIS are additional important factors in assessing biological impacts. The fish protection technologies in place at a CWIS can reduce impingement and entrainment effects if properly designed, installed, and maintained.

3.2.1 Description of Design, Construction, and Operation

Each CWIS consists of a two intake bays, with one pump and one screen in each bay. The screens are washed at least twice per day and may be cleaned more frequently during the summer and autumn when debris loading is higher. The screenwash is triggered manually and operates for a period of 8 minutes. Water from the Merrimack River is used to wash the screens at a pressure of 130 psi. According to the facility's industry questionnaire, the design intake (through-screen) velocity at the two intakes is approximately 1.5 and 1.82 feet per second for Units 1 and 2, respectively.

The first layer of screening is a trash rack (3 inch spacing), which excludes large debris. Both CWISs also use single entry traveling screens (see Figure 3). The screens are standard 3/8" mesh and are cleaned by a single spray wash, which discharges into a single return pipe for debris and impinged aquatic organisms. The return pipe is an enclosed corrugated metal pipe that runs parallel to the shoreline from the Unit 1 pumphouse for approximately 250 feet (merging with the return pipe from the second intake about 150 feet downstream), and continues another 100 feet downstream along the bank of the river. The pipe then discharges onto a metal grate on the shoreline, where the washwater trickles through concrete and rip-rap into the river (leaving any debris or organisms on the grate).

Merrimack has regularly scheduled maintenance outages for both units—Unit 1 on an annual basis and Unit 2 every 18 months. The shutdown periods are 4-6 weeks long and occur typically in the spring or fall when electricity demand is lowest. Only one unit is shut down at a time.

No biocides or other chemicals are used at the intake structures.

3.2.2 Evaluation of Design, Construction, and Operation

This combination of intake technologies (standard traveling screens and a combined debris and fish return) is generally designed to optimize facility operations but does not adequately address impingement and entrainment effects. The intake screens were installed in the late 1950s and primarily function to exclude debris. The large mesh size is not effective for entrainment protection. Most impinged organisms simply fall off the screen once the screen reaches the water's surface, subjecting the organism to immediate re-impingement and further injury or exhaustion. The intake screens do not incorporate fish buckets or another structure to carry impinged organisms to the return as expeditiously as possible. Once impinged, the high-pressure spray wash can cause injury or death to impinged organisms. The return system is also not effective from a biological perspective, as it returns impinged organisms to a grate on the shoreline instead of to the waterbody.

3.3 Capacity

"Capacity" refers to the potential withdrawal rate for a given CWIS operating at its maximum (or design) flow rate. Capacity is another important factor in assessing the biological impacts of CWIS. As noted in the 316(b) Phase I regulations, the volume of water withdrawn has a direct influence on the numbers of organisms entrained, especially with regard to pelagic (free-floating) eggs and larvae (see 66 FR 65273). A reduction in water withdrawals is one of the most effective methods to reduce entrainment and impingement.

3.3.1 Description of Capacity

The CWISs supply cooling water for a once-through cooling water system (CWS). Each CWIS has two large capacity pumps (DIF of 287 mgd) and generally operates only one pump at a time to best meet the cooling water needs of the power plant.

Approximately 10% of the water withdrawn is directed to the sluice slag, but the remaining water is for non-contact cooling. Merrimack also uses groundwater for some non-cooling water activities, such as sanitary uses and boiler water.

Facility representatives stated that the CWIS operates continuously; this assertion is supported by data from Merrimack's industry questionnaire, which indicated a utilization rate of over 85% for this intake.

3.3.2 Evaluation of Capacity

The intake is capable of withdrawing a large volume of water (up to 287 mgd) and does not recirculate any flow. As currently operated, the CWISs can withdraw over 10% of the mean annual flow of the Merrimack River.[4]

As currently operated, the CWIS is withdrawing less than its DIF. While the existing monitoring data does not show serious impingement and entrainment impacts, the data is also incomplete, as it did not adequately sample all life stages of organisms, seasonal variability, or shellfish species. It can be assumed that at increased withdrawal rates, higher levels of impingement and entrainment would be expected.[5]

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[4] The facility's industry questionnaire listed the mean annual flow of the river as 4344 cubic feet per second. Using the facility's DIF (see the Phase II rule at § 125.94(b)(2)(ii)(B)), the potential withdrawal by Merrimack is 10.22% of the mean annual flow of the waterbody.

[5] See 69 FR 41612, *Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities*, July 9, 2004.

Figure 1. Aerial View of Merrimack

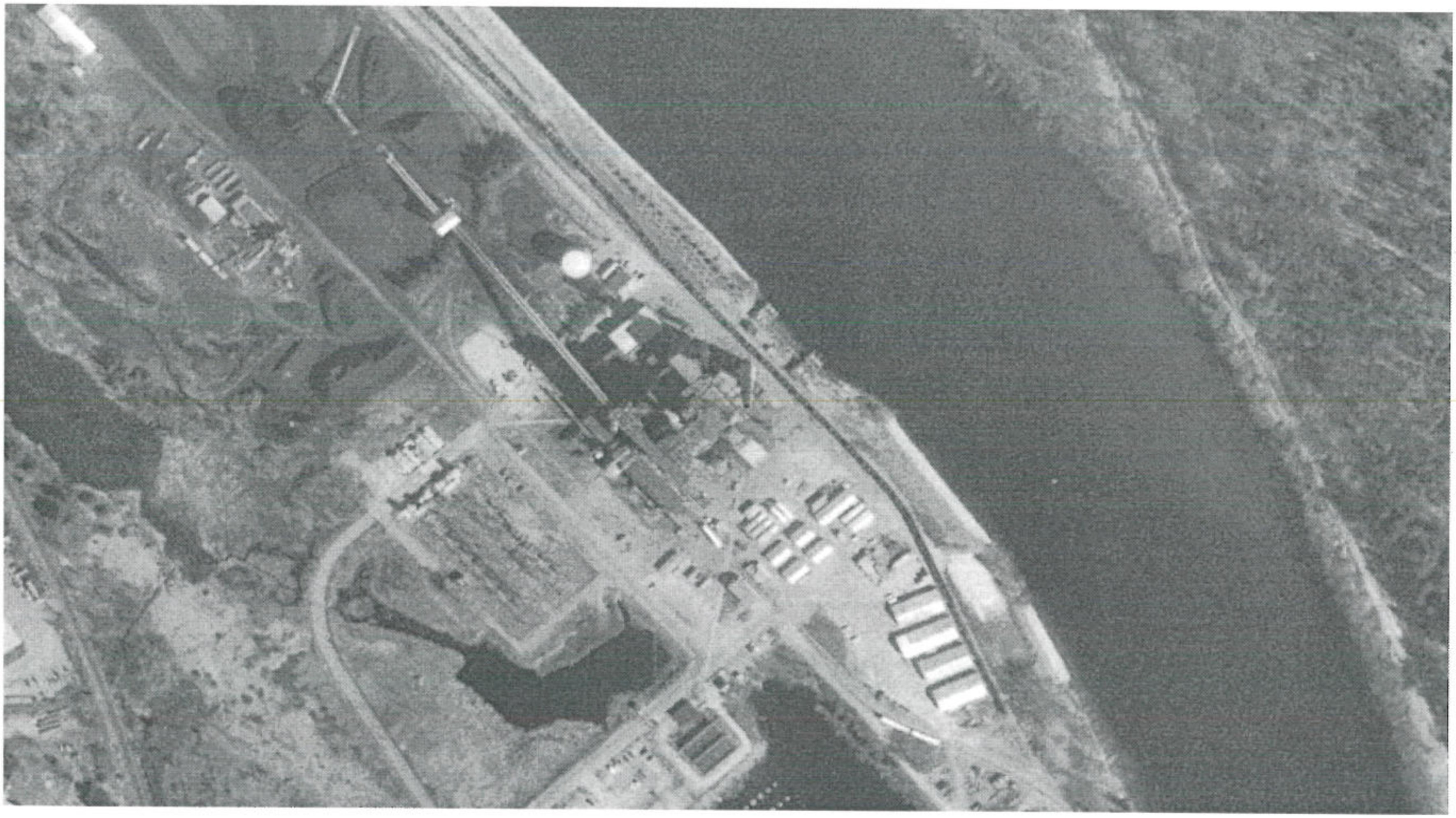


Image courtesy of USGS and TerraServer

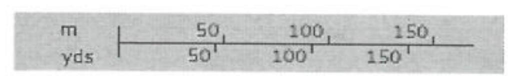


Figure 2. Topographic map of Merrimack

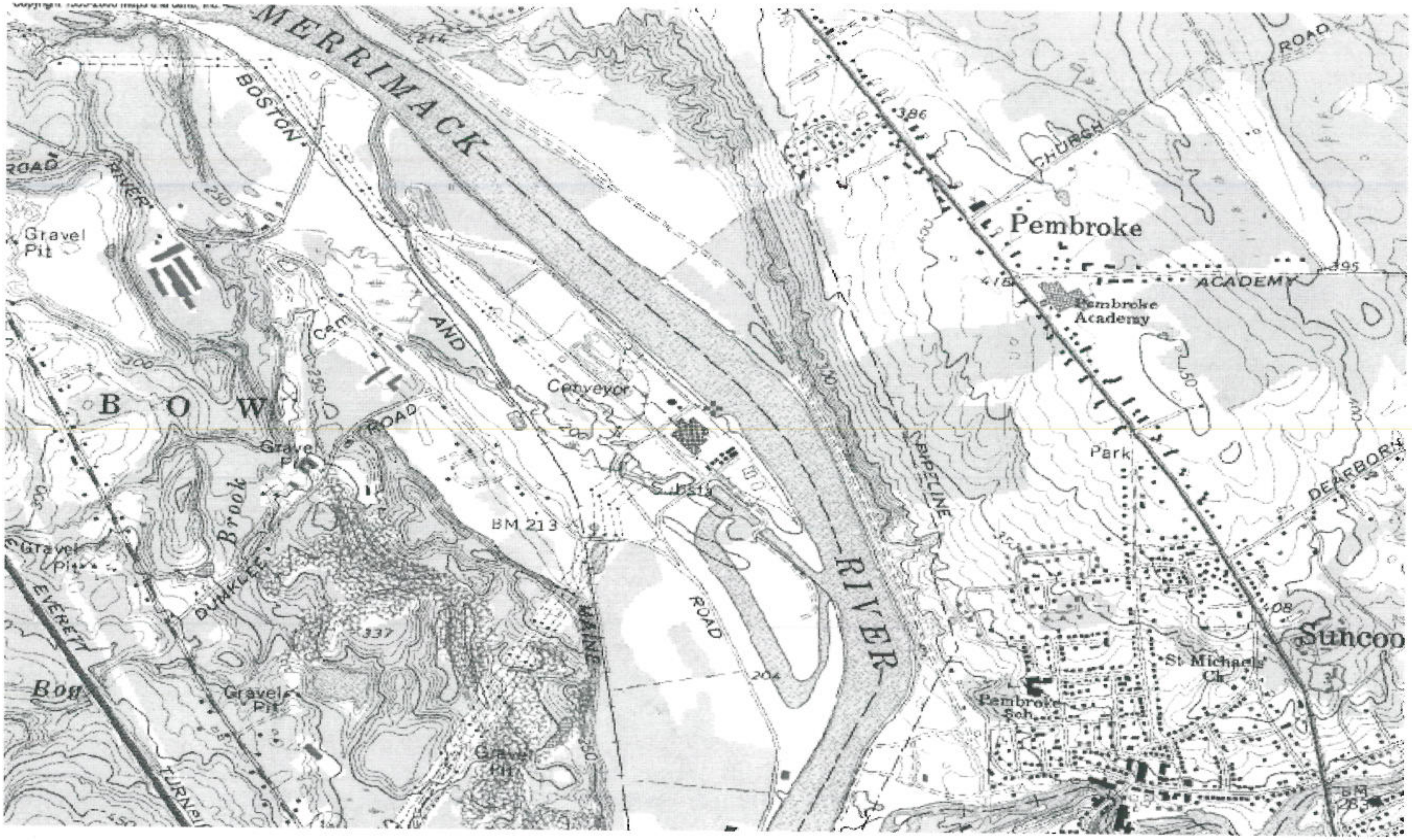


Image courtesy of TopoZone. The red symbol indicates the approximate location of the CWSs.

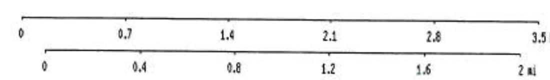
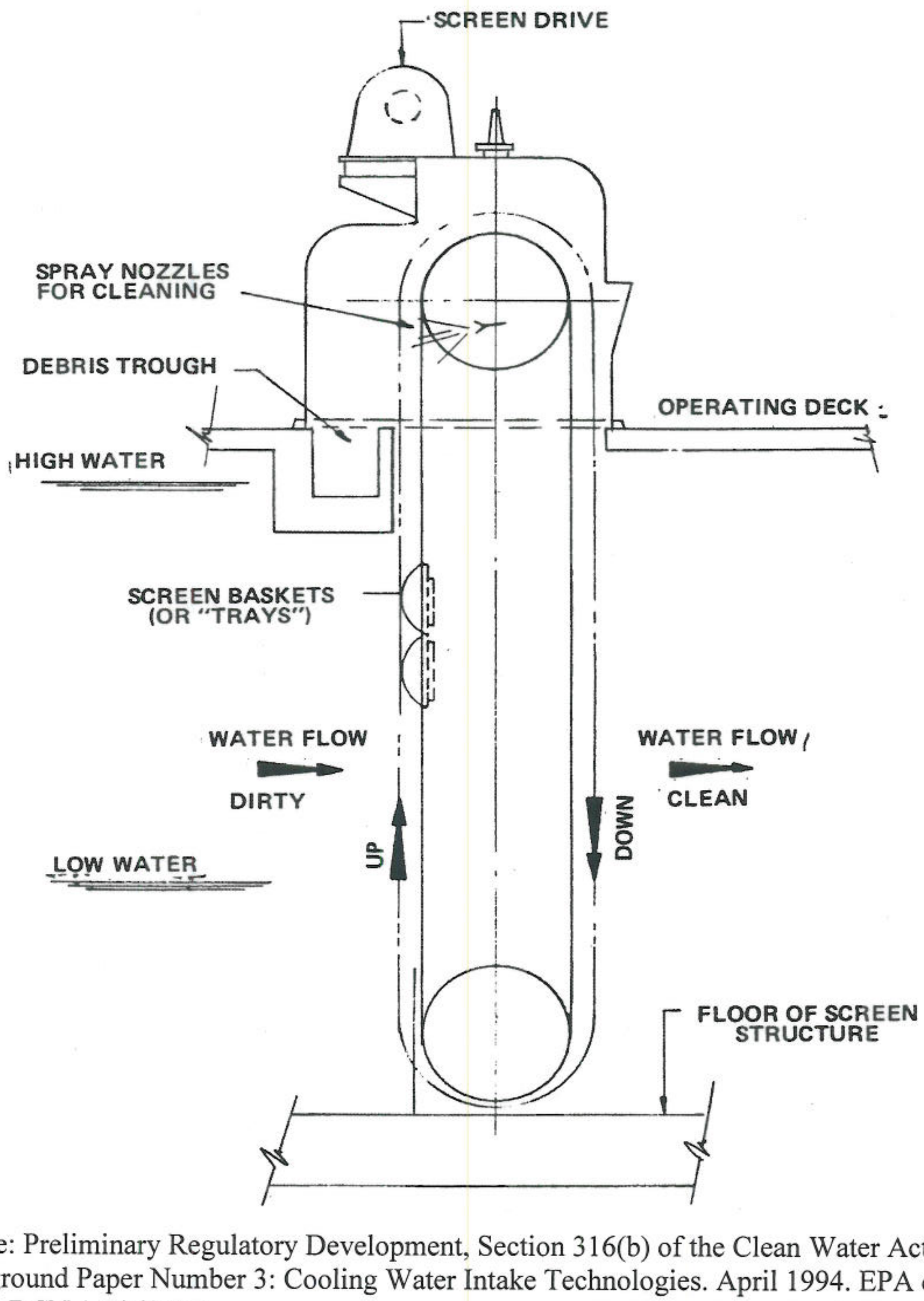


Figure 3. Single entry traveling screen

The single entry traveling screen is the standard intake screen technology for most facilities. It consists of screen panels mounted on a belt that rotates vertically through the water.



Source: Preliminary Regulatory Development, Section 316(b) of the Clean Water Act: Background Paper Number 3: Cooling Water Intake Technologies. April 1994. EPA docket W-00-03, DCN 1-5069-PR.

Table 1. List of fish species that were collected in the 1994-95 Merrimack Station fishery study of Hooksett Pool (first three columns) (Normandeau Assoc. 1997) and additional fish species that currently or historically have been found in the Merrimack River and have the potential to be transient through the Hooksett Pool ("Other") (Merrimack River Basin Community Coalition 2003).

Scientific Name	Common Name	Ichthyo-plankton	Electrofishing	Fyke Nets	Other
Anguillidae	Freshwater eels				
Anguilla rostrata	American eel		X	X	
Cyprinidae	Carps and minnows				
Carassius auratus	goldfish				X
Cyprinus carpio	carp				X
Luxilus cornutus	common shiner	X	X		
Notemigonus crysoleucas	golden shiner	X	X	X	
Notropis atherinoides	emerald shiner		X		
N. hudsonius	spottail shiner	X	X	X	
N. bifrenatus	brindle shiner				X
Rhinichthys cataractae	longnose dace				X
R. atratulus	blacknose dace				X
Semotilus atromaculatus	creek chub		X		
S. corporalis	fallfish	X	X	X	
Catostomidae	Suckers				
Catostomus commersoni	white sucker	X	X	X	
Ictaluridae	Bullhead catfishes				
Ameiurus natalis	yellow bullhead		X	X	
A. nebulosus	brown bullhead		X	X	
Ictalurus catus	white catfish				X
I. punctatus	channel catfish				X
Noturus gyrinus	tadpole madtom				X
N. insignis	margined madtom		X		
Esocidae	Pikes				
Esox lucius	northern pike				X
E. niger	chain pickerel		X	X	
Osmeridae	Smelts				
Osmerus mordax	rainbow smelt	X			
Salmonidae	Trouts				
Oncorhynchus mykiss	rainbow trout			X	
Salmo trutta	brown trout				X
S. salar	Atlantic salmon				X
Salvelinus fontinalis	brook trout				X
Percichthyidae	Temperate basses				
Morone saxatilis	striped bass				X
M. americana	white perch	X	X	X	
Centrarchidae	Sunfishes				
Ambloplites rupestris	rock bass	X	X	X	
Enneacanthus obesus	banded sunfish				X
Lepomis auritus	redbreast sunfish	X	X	X	
L. gibbosus	pumpkinseed	X	X	X	
L. macrochirus	bluegill	X	X	X	
Micropterus dolomieu	smallmouth bass		X	X	
M. salmoides	largemouth bass		X	X	
Pomoxis nigromaculatus	black crappie				X
Percidae	Perches				

Scientific Name	Common Name	Ichthyo-plankton	Electrofishing	Fyke Nets	Other
Etheostoma fusiforme	swamp darter				X
E. olmstedi	tessellated darter	X	X		
Perca flavescens	yellow perch	X	X	X	
Stizostedion vitreum	walleye			X	
Gadidae					
Lota lota	burbot				X
Petromyzontidae					
Petromyzon marinus	sea lamprey				X
Acipenseridae					
Acipenser brevirostrum	shortnose sturgeon				X
A. oxyrinchus oxyrhinchus	Atlantic sturgeon				X
Clupeidae					
Alosa aestivalis	blueback herring				X
A. pseusoharengus	alewife				X
A. sapidissima	american shad				X
Dorosoma cepedianum	gizzard shad				X
Atherinopsidae					
Menidia menidia	Atlantic silverside				X
Cyprinodontidae					
Fundulus heteroclitus	mummichog				X
F. diaphanous	banded killifish				X
Gasterosteidae					
Apeltes quadracus	fourspine stickleback				X
Gasterosteus aculeatus	threespine stickleback				X
Pungitius pungitius	ninespine stickleback				X
Syngnathidae					
Sygnathus fuscus	northern pipefish				X
Ammodytidae					
Ammodytes hexapterus	sand lance				X