NORTHEAST UTILITIES

FEASIBILITY STUDY OF COOLING WATER SYSTEM ALTERNATIVES TO REDUCE WINTER FLOUNDER LARVAL ENTRAINMENT AT MILLSTONE UNITS 1, 2, AND 3

millstone
nuclear power station

JANUARY 1993

NORTHEAST UTILITIES SERVICE COMPANY
Berlin, Connecticut

0001- 0001601

FEASIBILITY STUDY
OF
COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE WINTER FLOUNDER
LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1, 2, AND 3

JANUARY 1993

NORTHEAST UTILITIES SERVICE COMPANY
Berlin, Connecticut

0001- 0001602

SUMMARY TABLE OF CONTENTS

SUMMARY TABLE OF CONTENTS (Cont)

ACKNOWLEDGEMENTS

This study could not have been done without the interest and cooperation of engineers and scientists from both Stone & Webster Engineering Corporation (Stone & Webster) and Northeast Utilities Service Company (NUSCO). We wish to acknowledge the excellent cooperation from both organizations.

The following Stone & Webster engineers contributed to the development of this report:

Dr. Y.G. Mussalli	Project Engineer
T.A. Adams	Principal Mechanical/Hydraulic Engineer
J.J. Elder	Cooling Tower Specialist
R.L. Stevens	Condenser Specialist
P.M. Veneto	Principal Civil/Structural Engineer
R. DeConto	Principal Geotechnical Engineer
D.R. Crouthamel	Geotechnical Engineer
R.W. Sanders	Electrical Engineer
P.J. Slatkavitz	Cost Estimator
F. J. Trainor	Construction Manager

The following NUSCO employees contributed to the development and/or review of this report:

M.P. McNamara	Project Engineer
D.A. Errichetti	Senior Engineer, Corporate Planning
B.W. Nichols	Senior Engineer, Plant Engineering
E. Krinick	Senior Engineer, Nuclear Fuels
A. Elms	Unit 3 Plant Engineering
D. Danila	Senior Scientist, NU Environmental Laboratory
J.D. Miller	Senior Scientist, NU Environmental Laboratory
Dr. E. Lorda	Principal Scientist, NU Environmental Laboratory
W.A. Kramer	Mechanical Engineer
D.A. Gilbane	Attorney

The following NUSCO Departments provided input and/or review of material contained in this report:

Mechanical Engineering
Electrical Engineering
Civil Engineering
Balance-of-Plant Systems Engineering
Plant Operations Department
Plant Maintenance Department
Civil and Mechanical Design Department
Cost and Scheduling
Generation and Environmental Licensing
Legal Department

Part II, "Environmental and Biological Evaluation," of this report was also critically reviewed by Dr. C.F. Sears, Dr. L.E. Bireley, and P. Jacobson of NUSCO Environmental Services Division and by the following members of the Millstone Ecological Advisory Committee: Dr. J. Tietjen (City University of New York), Dr. N. Marshall (emeritus, University of Rhode Island), Dr. S. Saila (emeritus, University of Rhode Island), and Dr. W. Pearcy (Oregon State University).

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the results of a comprehensive feasibility study of cooling water system design alternatives and operational strategies to reduce the entrainment of winter flounder larvae at Millstone Nuclear Power Station (MNPS) and fulfills a condition of the recently renewed MNPS National Pollutant Discharge Elimination System (NPDES) permit.

The report consists of an "Engineering Evaluation" (Part I) that provides an overview of available technologies for entrainment mitigation including those mitigation schemes proposed for study by the Connecticut Department of Environmental Protection (DEP). Part I also includes preliminary design development of selected mitigation measures for MNPS Unit 3, order of magnitude cost estimates, construction schedules, and outage durations.

Part II, "Environmental and Biological Evaluation," of this report contains a background discussion of winter flounder larval entrainment, the environmental considerations for selected mitigation schemes, a discussion of replenishment of winter flounder (fish hatchery), the rationale for the selection of outage durations to mitigate entrainment, and the bases for the NUSCO stochastic population dynamics model (SPDM). This numerical model was used to assess the effectiveness of mitigating winter flounder larval entrainment.

The following alternatives were evaluated as mitigation measures:

- Natural-Draft Cooling Towers
- Offshore Intake
- Fine-Mesh Screens
- Wedgewire Screens
- Diversion Sills and Curtain Walls
- Infiltration Systems
- Operational Strategies
  - Reduced power/flow
  - Variable-speed pumps
  - Scheduled refuel outages
  - Forced outages
- Replenishment of Fish

PRESENT PLANT DESIGN

The existing seawater intakes for MNPS consist of three separate, shoreline, surface intakes: one for each generating unit. The intakes are similar in design, having vertical wet-pit type circulating water pumps (non-nuclear safety related) and service water pumps (nuclear safety related). Each intake is equipped with traveling water screens, coarse-bar racks, and curtain walls extending below the lowest water level. Each intake draws water directly from Niantic Bay. Total station withdrawal of seawater during normal full-power operation of all three units is 4358 cubic feet per second (cfs). Unit 3 withdrawal (2097 cfs) is approximately ½ of the total with Unit 2 (1282 cfs) and Unit 1 (979 cfs) each using approximately ¼ of the total.

ENTRAINMENT OF WINTER FLOUNDER LARVAE AT MNPS

MNPS primarily affects winter flounder by entraining larvae through the condenser cooling-water system. Most (>90 percent) larvae are entrained in April and May. Since 1976, annual entrainment estimates have ranged from 31 to 219 million, but since three-unit operation began in 1986, these estimates have exceeded 100 million larvae each year. The average fecundity of Niantic River females is approximately 572,000 eggs per fish. From about ¼ to ½ of the entrained winter flounder larvae were estimated to have originated from the nearby Niantic River spawning stock. Based on indirect methods (i.e., mass-balance calculations), it was determined that from 8 to 20 percent of the annual production of this stock are entrained at MNPS. The objective of this study was to evaluate the technical feasibility and effectiveness of cooling-water system alternatives with potential to mitigate entrainment mortality of Niantic River winter flounder larvae by at least 25 percent. Because

half of the cooling-water flow occurs at Unit 3, engineering design efforts focused on alternatives for this unit.

ENGINEERING EVALUATION

Each of the alternatives examined is briefly discussed below.

COOLING TOWERS

Cooling towers could reduce intake entrainment by reducing intake circulating water flow to only that required for cooling tower makeup, which for a full-size natural-draft cooling tower would be less than one-tenth of the current circulating water flow rate. Two salt water cooling tower alternatives for Unit 3 were evaluated: a 100-percent capacity tower and a ⅔-capacity tower. With the ⅔-capacity tower, ⅓ of the existing Unit 3 circulating water system would remain once-through. For both alternatives, the proposed location for the tower would be in the wooded area to the east of the switchyard. A new pump station would be located at the cooling tower, and piping would be routed to the north and west of the station in a common cut and cover trench. The condenser would be converted to two-pass operation. The existing once-through circulating water system would remain intact and operational. Valves would be provided to operate the station either once-through or on the cooling tower.

A cooling tower option would reduce cooling-water demand and larval entrainment without posing insurmountable operational difficulties. However, the cooling tower option would require further environmental evaluations (e.g., chlorination to control biofouling, a waste treatment facility, dechlorinization of the blowdown, aesthetics, and noise). A full-size natural-draft cooling tower for MNPS would be 535 feet high and, therefore, a significant visual intrusion on the coastline near Millstone Point. Construction would be very challenging, given all the present underground utilities that would require re-routing or removal. A cooling tower would also pose a severe economic burden due to the capital cost of construction and performance penalty resulting from lost generating capacity. Maintenance and operating costs could also be substantial; however, they were not addressed.

The total estimated cost for the cooling tower is $88 million for the full size and $70 million for the ⅔ size.

OFFSHORE INTAKE

An offshore intake, placed outside of the confines of Niantic Bay, would draw a larger proportion of winter flounder larvae from Long Island Sound rather than from the Niantic River population. A rock tunnel design was developed which would place the Unit 3 intake approximately 1 mile south into Long Island Sound. A booster pump station would be provided on the shoreward end to overcome head losses in the tunnel. Cooling-water flow from the offshore tunnel and shafts would enter a sheet pile-enclosed forebay that would isolate the existing intake structure from Niantic Bay. A separate flow bypass for the nuclear safety-related service water pumps would also be provided.

An offshore intake would require substantial environmental reviews and significant input from regulatory agencies, such as the Connecticut Siting Council, U.S. Army Corps of Engineers, U.S. Coast Guard, U.S. EPA, and the National Marine Fisheries Service. Like the cooling tower, this option would be a considerable construction project and would be prone to difficulties common with tunneling. It would also be extremely expensive. The probable entrainment impact on larval populations in the vicinity of the offshore intake is difficult to predict, but increased impact to some species (e.g., bay anchovy, tautog) could occur. Maintenance and operating costs could be significant, but were not addressed.

The total estimated cost for this option is $117 million.

FINE-MESH SCREENS

Fine-mesh screens can reportedly block fish and larvae from entering the intake. Fish and larvae collected on the fine-mesh screens would be transported to a sluicing system and returned to Niantic Bay. Approach flow velocities to fine-mesh screens would be limited to 0.5 feet per second (fps) to prevent debris overloading and also to protect the larvae. This would require an approximate doubling of the screening area of the current intake. A design was developed for Unit 3 which would incorporate eighteen 10-foot wide traveling screens. An entirely new screen structure constructed in front of the existing intake and connected to it by sheet pile walls would be needed to support the new screens. The new screen structure plan dimensions would be approximately 270 feet long by 40 feet wide. A separate safety-related bypass would be required for service water. Alternate fine-mesh screen arrangements, including angled screens and drum screens were evaluated, but not cost estimated.

While fine-mesh screen technology can be effective in reducing entrainment of certain sizes of larvae, there is little evidence that it would be successful in protecting winter flounder larvae at MNPS. Fine-mesh screens used at the Brayton Point (Mass.) Generating Station

resulted in only a 6.5 percent survival of winter flounder larvae. These screens were subsequently removed from operation. There are also significant concerns over the ability of fine-mesh screens to control debris fouling, which has previously resulted in numerous plant outages at MNPS.

The total estimated cost for this option is $52 million.

WEDGEWIRE SCREENS

Wedgewire screens could reduce or eliminate entrainment of fish and larvae by taking advantage of natural cross currents to sweep fish and larvae past the submerged screen units. Screen slot width would be selected to block entry of small organisms such as fish larvae. A wedgewire screen design developed for Unit 3 would consist of an array of submerged wedgewire screen units extending up from collector conduits placed in the sea floor. Six 9-ft diameter collector conduits, each equipped with nine 84-inch diameter screen units, would extend out from a plenum structure that would be constructed directly in front of the existing intake structure. The array would be staggered to promote more effective natural flushing of screen units. An automated air burst system would be required to backflush the screens, one unit at a time. An alternate bulkhead design was also developed consisting of two circular bulkhead structures containing the wedgewire screen units that would be constructed in front of the existing intake and joined to it by a plenum and inlet conduits. The bulkhead arrangement would offer the advantage of being able to hoist the screen units to an operating deck for cleaning.

Wedgewire screen technology offers some advantage in limiting impingement and entrainment of some fish. However, the few installations currently using this technology require much smaller volumes of water than Unit 3. This design is not appropriate for the flow rate at MNPS and would result in new biofouling and corrosion problems. Because of their size, winter flounder larvae would probably not be significantly protected using the screen slot sizes that would be required at MNPS.

The total estimated cost for this option is $65 million.

DIVERSION SILLS/CURTAIN WALLS

While there are no known installations of barriers or sills for the purpose of diverting fish larvae away from intake structures, hydraulic diversions are commonly used and the principles well-understood. Diversion sills and curtain walls can possibly divert a portion of winter flounder larvae away from the intakes. Concrete sills, such as Jersey-type barriers, would be

placed on the sea floor in front of the intakes, and offer a passive means of diverting a portion of the larvae away from the intake. A design for the Unit 3 intake would consist of a V-shaped barrier that would be constructed in front of the intake. Additional angled vanes placed upstream of the sill would be required to enhance silt diversion.

An alternate concept to the sill for diverting a portion of the larvae away from the intake would be a floating curtain wall with an air bubble floatation system. The curtain wall, constructed of nonmetallic composite materials, would be supported by piles driven into the sea floor. The floatation system would consist of multiple diffuser pipes installed on the sea floor in front of the floating barrier. Compressed air would be supplied to these diffuser pipes by blowers that would be located on the shore. Larvae would be "floated" to the surface by the rising air bubble curtain. They could then be diverted away from the intake by the floating curtain wall.

Because winter flounder larvae are planktonic, particularly at night when most entrainment occurs, it is unlikely that a diversion sill would appreciably reduce entrainment. Further, any larvae diverted may be entrained at Units 1 and 2, particularly during ebb tides. The air bubble curtain wall is unproven technology in preventing larval fish entrainment. It should be noted that these options would require significant additional study and modeling to validate the degree of effectiveness.

The total estimated cost for the concrete sill option is $1.8 million.

INFILTRATION SYSTEM/BEHAVIOR BARRIERS

Infiltration systems consist of arrays of perforated pipes installed in aquifers. Water enters the piping array by percolating through the overlaying sand and collector pipe screens. These systems would prevent the entry of fish larvae, however infiltration is not a viable concept for MNPS. Infiltration systems have not been used on large flows at the MNPS intakes, and clogging and maintenance are common problems when a silty overlay forms on the sea floor. Therefore, infiltrative systems and behavioral barriers were not pursued beyond a preliminary evaluation. Behavioral barriers (e.g., lights, noise) were not considered credible mitigation alternatives for winter flounder larvae.

PLANT OPERATIONAL STRATEGIES

Entrainment mitigation through reduced cooling-water flow could be accomplished by using fewer circulating water pumps during power generation or by the installation of variable-speed circulating water pumps. With the present plant design, power reduction does not result in

a corresponding reduction in cooling-water flow requirements; also flow reduction has a negative effect on plant efficiency, safety, and economics. Circulating water pump flow reduction achieved through the operation of fewer pumps is possible but not practical because it jeopardizes plant safety. Variable-speed drives for the circulating water pumps could allow reduction in circulating water flow during the spring season. Reduced flow through the condenser would promote increased tube fouling and potentially result in an outage. A small reduction in power would also be likely.

Refueling outages scheduled for each spring could reduce entrainment because cooling-water requirements are much reduced during outages. Many of the MNPS refueling outages have and will continue to occur during the spring season. However, fuel nucleonics, scheduled maintenance activities, unplanned outages, and other factors preclude a guaranteed refueling outage each and every spring. A forced outage each spring is possible but extremely expensive.

The estimated costs associated with forced spring outages range from $214 to $519 million. The total estimated cost for conversion to variable-speed circulating water pumps is $32 million.

REPLENISHMENT OF WINTER FLOUNDER

Several programs established in the United States and Japan to culture flatfishes were found to have had limited or no success. No evidence exists that large-scale production of winter flounder has successfully augmented natural wild stocks. To produce enough young winter flounder to offset entrainment mortality would require a considerable area (an estimated 33.6 ha, or 83 acres) for rearing ponds, which is unavailable at MNPS, and may be very expensive elsewhere along the Connecticut coast. Food and nutritional requirements, predator and disease control, water quality, genetic issues, production costs, and a means to ascertain success of stocking remain uncertain. A conceptual engineering design for a fish hatchery was not developed or cost estimated due to the uncertainties associated with this alternative.

COST ESTIMATE SUMMARY

The cost estimates prepared for the alternatives investigated, are shown in Tables ES-1 and ES-2. The costs for entrainment mitigation would most likely be shared by ratepayers, although this would require approvals by regulatory agencies such as the Connecticut Department of Public Utility Control.

TABLE ES-1

TOTAL COST ESTIMATE SUMMARY[1,2]
(All Dollars in 000s Present Day)

Description	Cooling Tower 100%	Cooling Tower ⅔	Offshore Intake	Fine-Mesh Screens	Wedgewire Screens	Two-Speed Motor	Concrete Sills
Direct Costs	$44,100	$35,100	$61,000	$19,300	$12,100	$2,300	$1,300
Total Capital Costs	$62,100	$49,300	$89,100	$28,200	$17,600	$3,200	$1,800
Performance Penalty Costs	$14,700 [3]	$9,800 [3]	$4,600 [4]	N/A	N/A	$16,800 [3]	N/A
Lost Generation (Outage) Costs	$12,000 [5]	$12,000 [5]	$24,000 [5]	$24,000 [5]	$48,000 [5]	$12,000 [5]	N/A
TOTAL COST	$88,800	$71,100	$117,700	$52,200	$65,600	$32,000	$1,800

<u>NOTES:</u>

1. Operation and maintenance costs are not included, although they could be considerable.

2. These estimates are for comparison of relative costs and due to their conceptual nature could be significantly less than actual costs.

3. 1992 cumulative net present value of replacement power costs, assuming 2 months of operation per year, over the years 1993-2010 for NUSCO's share of Unit 3 grossed up to full output.

4. Same as Note (1) except replacement power is needed for all months.

5. Based on the cost to replace NUSCO's share of Unit 3 output on average in 1993 grossed up to full output and discounted to 1992 dollars.

TABLE ES-2

FORCED OUTAGE COST ESTIMATE FOR 25 PERCENT ENTRAINMENT MITIGATION

Scenario	Cumulative Replacement Power Costs in Millions of 1992 $
Unit 1 offline 4/2 to 6/13	$214
Unit 2 offline 4/2 to 6/13	$307
Units 1 and 2 offline 4/2 to 6/13	$519
Unit 3 offline 4/2 to 6/6	$310
Units 1, 2, and 3 offline 4/22 to 5/12	$318

NOTES:
1. Estimates are 1992 $ grossed up to full output for each scenario.
2. Some years had no replacement power cost because a scheduled refueling overlaps the time period.
3. Costs estimated from 1993 through 2010.
4. Dates offline are approximate; Part II of this report discusses rationale for date selection.
5. Maximum attainable mitigation for Unit 2 is 13 percent.

ASSESSMENT OF THE EFFECTIVENESS OF MITIGATION ALTERNATIVES

The long-term effects of MNPS operation on the Niantic River winter flounder population have been addressed using the SPDM. This numerical model has been used to approximate the decrease in abundance or biomass of the Niantic River female spawning stock and its eventual recovery under various scenarios of plant operation. Concurrent mortality by fishing, which greatly affects winter flounder abundance, was also included in the model projections. A baseline time-series was simulated that included current or projected rates of mortality from fishing, impingement, and entrainment (i.e., under current MNPS mode of operation). This was a reference series against which increases in spawner biomass as a result of several levels of reduction in entrainment mortality (10, 20, 25, and 50 percent) could be measured. The model simulations showed that proposed reductions in fishing would be of much greater benefit to the Niantic River female winter flounder spawning stock, than concurrent entrainment mitigation. The calculated mean gain in biomass as a result of a 25 percent mitigation of entrainment would be 1,274 lb per year. The calculated cumulative total increase would only be 50,959 lb over a 40-year period. If an average weight of 1 lb per female spawner is assumed, biomass and numbers of fish become equivalent. These values

0001-0001615

represent a modest (≤ 4.3 percent) gain in the annual Niantic River winter flounder spawning stock biomass. Further, this would represent a very small (≤ 0.25 percent) fraction of the combined sport and commercial winter flounder catches in Connecticut since on average, the Niantic River stock accounts for less than 5 percent of the Connecticut winter flounder resource.

Probabilistic risk assessment was used to examine the probability that the stock could fall to less than 25 percent of the maximum spawning biomass (a critical fisheries reference point) at six selected points in time. The analysis indicated that in 1993, before simulated reductions in fishing and entrainment mitigation alternatives were put into effect, the spawning stock biomass was already ($p = 0.94$) less than 25 percent of the maximum biomass. However, once fishing was reduced, the probability of a critically reduced stock quickly fell to 0.02 by 1998 and became zero for subsequent years. This would occur with or without larval entrainment mitigation. By the time the small contribution in biomass attributable to 25 percent mitigation (0 lb for the first 3 years followed by 626 lb average for the next 3 years) became effective, the stock would no longer be depressed below a critical size.

CONCLUSIONS

This study has evaluated cooling-water intake designs with respect to mitigating the impact of MNPS entrainment of Niantic River winter flounder larvae. Known mitigation methods were reviewed and some new ideas were evaluated. Some of the alternatives are not technically feasible (e.g., infiltration systems) or have safety and operability concerns (e.g., wedgewire screens, variable-speed pumps). Several alternatives (e.g., natural draft cooling tower, offshore intake) are possible to construct and operate, but are extremely expensive, as are forced shutdowns. Concrete sills were a simple and relatively inexpensive option, but it is highly unlikely that sills could prevent the entrainment of planktonic winter flounder larvae. Mitigation of larval entrainment mortality by any technology would have minimal effects, as demonstrated by the SPDM simulations. Model results indicate that the planned reduction in fishing would be the primary factor responsible for increases in the Niantic River winter female flounder spawning stock, rather than concurrent entrainment mitigation.

There have been no technological or operational strategies that have significantly advanced cooling-water intake designs since the extensive reviews performed in the NUSCO Final Safety Analysis Report and the Environmental Report prepared for Unit 3. The relatively small increase projected in Niantic River female winter flounder spawner biomass (mean annual increase of 1,274 lb) does not warrant the millions of dollars required for entrainment

mitigation. The projected costs that would have to be met by ratepayers are wholly disproportionate to the ecological benefits gained. Open-cycle cooling using the existing intake structures and equipment at MNPS remains the best available technology at a reasonable economic cost with respect to larval winter flounder entrainment.

Steven Scace
Vice President
Millstone Station

Eric DeBarba
Vice President
Nuclear Engineering
Services

C. Frederick Sears
Vice President
Environmental Services

INTRODUCTION

BACKGROUND

The Millstone NPDES Permit No. CT0003263 renewal application was submitted in December 1989. The existing permit expiration was June 5, 1990. The plants continued to operate under the previous permit under the Clean Water Act provision of a timely reapplication submittal. Over the past several years, staff of Northeast Utilities Service Company's (NUSCO) Environmental Laboratory and the Connecticut Department of Environmental Protection's (DEP) Marine Fisheries Division met numerous times to discuss the status of the Niantic River winter flounder (*Pleuronectes americanus*) population and the affect of impingement and entrainment on various flounder life stages of that population.

After several meetings among personnel from DEP Water Management Bureau, DEP Marine Fisheries Division and NUSCO Environmental Services Department, the DEP directed that a feasibility study of winter flounder larval mitigation be conducted.

Accordingly, in December of 1992, the Millstone station NPDES permit was renewed with a condition that the feasibility study be completed and submitted by February of 1993. The scope of the study as directed by the DEP in earlier correspondence to NUSCO was as follows:

> The proposed study of the feasibility of reducing entrainment of winter flounder larvae at Millstone Nuclear Power Station should investigate several alternatives. The study should review intake structure alternatives including screening devices and physical barriers such as sills, baffles, and curtain walls.

The study should also review cooling system design alternatives such as recirculating cooling towers and an offshore intake. Finally, the study should review operational alternatives such as reduced cooling-water flow (higher Delta T and Maximum Delta T), reduced power generation, and the scheduling of maintenance shutdowns. Each alternative should be reviewed with regard to technological feasibility, effectiveness, and costs.

SCOPE OF WORK

As a result, a project assignment was initiated and funded for the purpose of conducting the study. A scope of work describing the study was developed and submitted to the DEP on May 29, 1992.

This study selects and evaluates alternative mitigation measures to reduce entrainment of Niantic River winter flounder larvae into the MNPS intakes. The study consists of an engineering evaluation of existing intake technology as it could be applied at MNPS and an environmental/biological evaluation of the effectiveness of selected measures for reducing entrainment of larvae. The estimated costs for selected measures are also provided.

Engineering Evaluation

The engineering evaluation consists of an overview of existing technologies which could potentially reduce entrainment of winter flounder larvae into the station intakes. The following types of mitigation measures for minimizing entrainment of fish larvae are included in the review:

- Those designed to reduce the volume of cooling water required for the station.
- Those designed to prevent larvae from entering the plant by obstructing the larvae or by changing the source of cooling water.
- Those designed to reduce the number of larvae entering the plant by obstructing or diverting the flow.

Under these categories of mitigation measures are the following designs:

Flow Reduction

- Convert the Unit 3 circulating water system to a closed-loop system with cooling towers.
  - Natural-draft
  - Mechanical-draft

- Convert ⅔ of the Unit 3 circulating water system to a closed-loop system with cooling towers.
- Reduced flow through isolation of circulating water pumps.
- Variable-speed circulating water pumps.
- Scheduled and forced outages.

<u>Prevent Entrance of Larvae at Intakes</u>

- Offshore intake
- Fine-mesh screens
- Angled screens
- Wedgewire screens
- Infiltration systems

<u>Reduce Larvae Entrance at Intakes</u>

- Weir, sills, and curtain walls
- Air bubble flotation system
- Behavioral barriers

<u>Replenish Fish</u>

- Fish hatchery

Based on the initial overview, a select number of alternative measures were chosen for preliminary design and detailed evaluation. The detailed evaluations consisted of a preliminary design of major components for each selected alternative. Because Unit 3 accounts for approximately 50 percent of the cooling-water flow at MNPS, designs were developed for Unit 3 only. The preliminary designs addressed geotechnical considerations, developed preliminary civil engineering designs for all major structures, sized major mechanical equipment and piping, and developed preliminary designs for electric power and control equipment. From these designs, quantity estimates were taken and preliminary order of magnitude cost estimates developed. Operation and maintenance costs associated with the alternatives discussed in this study could be considerable, but have not been addressed. A constructibility review and preliminary construction and unit outage schedule was developed for each alternative. The following alternative measures were selected for preliminary design:

- Natural-draft cooling towers (100 and 66.7 percent capacity)
- Offshore intake
- Fine-mesh screens
- Wedgewire screens
- Diversion sills and curtain walls

- Operational strategies
  - Reduced power/flow
  - Variable-speed pumps
  - Scheduled refueling outages
  - Forced outages

ENVIRONMENTAL AND BIOLOGICAL EVALUATION

The early life history of the winter flounder is briefly summarized in Part II. Winter flounder larval entrainment at MNPS and methods of quantifying this impact are discussed. Various mitigation alternatives were considered for environmental and biological effects that could result from their implementation. The evaluations include most of the engineering measures, and include a natural-draft cooling tower, offshore intake, fine-mesh screens, wedgewire screens, and diversion screens and curtain walls. The replenishment (i.e., fish hatchery operation) of winter flounder as a mitigation alternative was also considered. The rationale for the selection of dates used for the evaluation of plant shutdowns as a mitigation alternative is given. The effectiveness of various mitigation alternatives was quantitatively assessed using the NUSCO stochastic population dynamics model. The estimation or sources of information for key model parameters and rates are presented. Particularly important are the rates of mortality due to fishing, which were projected to decrease. Model output consists of the annual increase in Niantic River female winter flounder spawning stock biomass for various reductions in entrainment mortality. The cumulative gains in biomass over time was also calculated, and probabilistic risk assessment used to investigate the effectiveness of entrainment mitigation.

PART I

ENGINEERING EVALUATION

TABLE OF CONTENTS - PART I

TABLE OF CONTENTS (Cont)

0001- 0001624

TABLE OF CONTENTS (Cont)

LIST OF TABLES - PART I

LIST OF TABLES (Cont)

LIST OF FIGURES - PART I

1

PRESENT INTAKE DESIGN AND OPERATION

There are two main heat dissipation systems for each of the three Millstone Nuclear Power Station (MNPS) units that draw water from Niantic Bay:

- Circulating Water Systems (non-nuclear safety related)
- Service Water Systems (nuclear safety related)

The pumps for both circulating and service water systems are installed in common intake structures. Each unit has its own separate intake structure. Both systems draw water from Niantic Bay, pass the water through either steam surface condensers (circulating water systems) or heat exchangers (service water systems) where the water temperature is increased. The heated water is discharged into the quarry and ultimately into Twotree Island Channel. The location of the intake and discharge facilities for each unit is shown on Figure 1-1.

The circulating water systems condense steam by means of once-through steam surface condensers. The waste heat from the condensing process is transferred to the circulating water as it passes through the condenser tubes. In the normal operating mode, the service water system provides cooling water to numerous station facilities. Major users are the reactor plant component cooling heat exchangers and the turbine plant component cooling heat exchangers. In the event of an accident, such as a loss of primary coolant in the reactor (LOCA), service water is diverted to the containment recirculation coolers to remove heat from the reactor and the emergency generator diesel engine coolers.

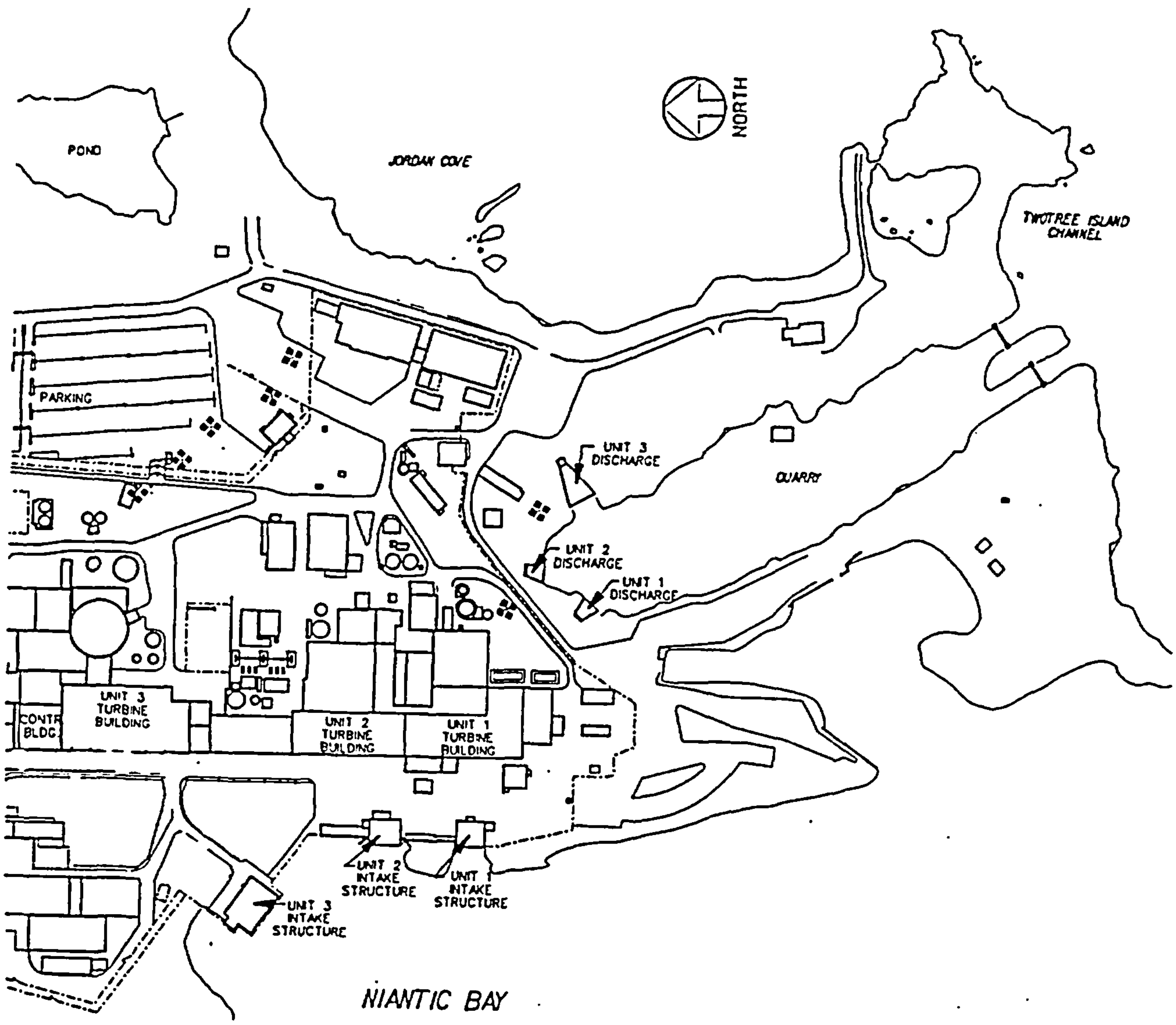


Figure 1-1 Intake and Discharge Facilities for Millstone Units 1, 2, and 3

The intake structures for each unit are similar in design. Each intake structure contains service and circulating water pumps in common bays. The intakes have traveling water screens with ⅜-inch (9.5 mm) mesh, coarse-bar racks, and curtain walls which extend below lowest water level. The coarse-bar rack excludes debris and fish larger than 2-inch in size and the mesh size of ⅜-inch prevents smaller fish and debris from entering the pump forebay. The curtain wall prevents warm surface water, ice, and surface marine organisms from entering the intake. Each intake has lateral fish passageways installed in the bay walls upstream of the traveling screens to allow fish to escape the screen faces. A typical intake section, which is similar for the intake structures of Units 1, 2, and 3, is shown on Figure 1-2.

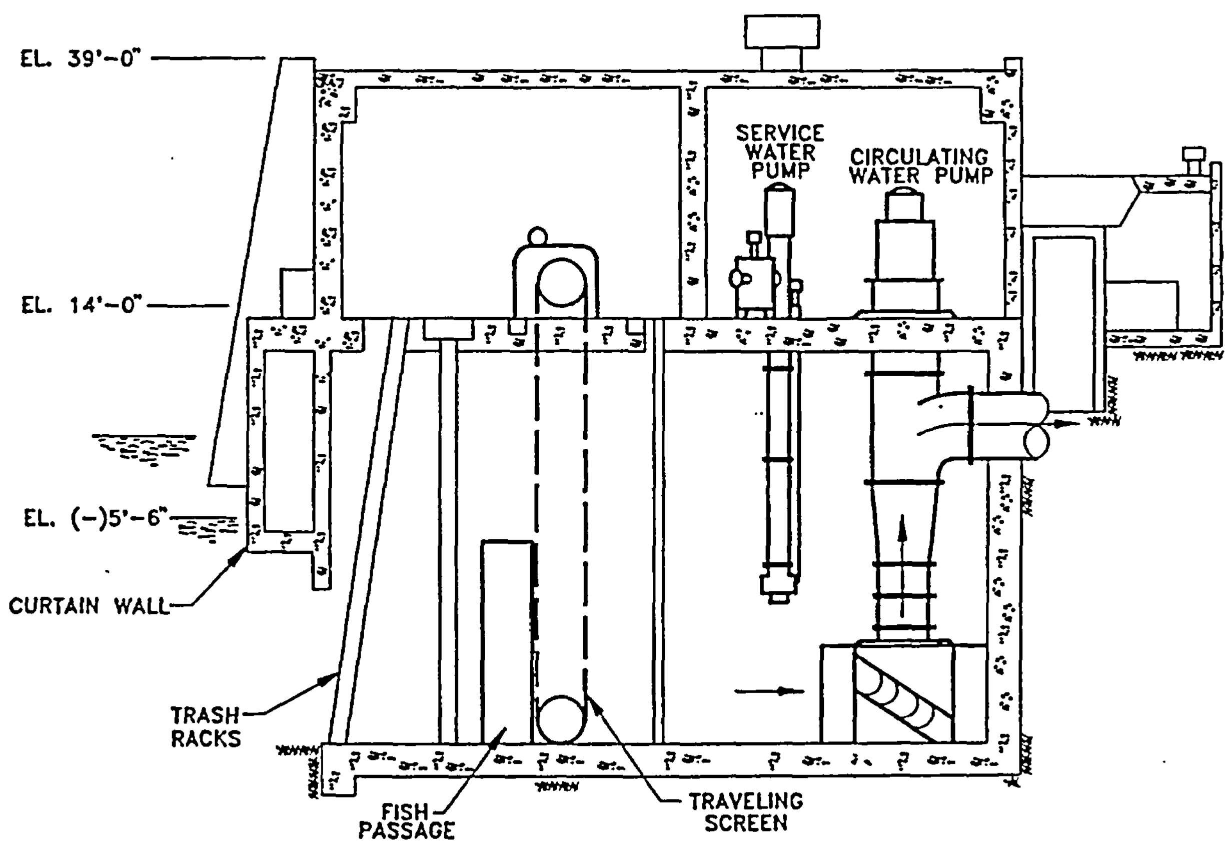


Figure 1-2 Units 1, 2, and 3 - Typical Section of Circulating Water Intake Structures

The intake structure for Unit 1 contains four circulating water pumps which deliver 420,000 gpm (935 cfs) of cooling water to the condenser and four service water pumps, each rated at 10,000 gpm (22.3 cfs). Normal service water flow is 20,000 gpm. The service water pumps are in the center bay of the 5-bay intake structure. The water velocity approaching the traveling screen is in the range of 0.5 to 0.9 fps.

The intake structure of Unit 2 contains four circulating water pumps which deliver 548,000 gpm (1,220 cfs) of cooling water to the condensers. The intake also contains three service water pumps, each rated at 14,000 gpm (31 cfs) each. The normal service water flow is 28,000 gpm. The water velocity approaching the traveling screen is approximately 0.5 fps.

The intake structure for Unit 3 houses six circulating water pumps, each rated at 152,000 gpm, for a total circulating water flow of 912,000 gpm (2,030 cfs). The intake also contains four service water pumps, each rated at 15,000 gpm. Normal service water system flow is 30,000 gpm (67 cfs). Traveling screen approach velocity is in the range of 0.5 to 1.0 fps.

Table 1-1 provides a summary of station flow withdrawals from Niantic Bay.

TABLE 1-1

MILLSTONE NUCLEAR POWER STATION
FLOW WITHDRAWAL FROM NIANTIC BAY

Unit	System	Flow Withdrawal (cfs)
Unit 1	Circulating Water	935
	Service Water	44
Unit 2	Circulating Water	1,220
	Service Water	62
Unit 3	Circulating Water	2,030
	Service Water	67
	Total Station Withdrawal	4,358

2

OVERVIEW AND PRELIMINARY ASSESSMENT OF AVAILABLE MITIGATION MEASURES

NUSCO extensively reviewed alternate intake structures in its Final Safety Analysis Report (FSAR) (1) and Environmental Report (ER) (2). This review demonstrated that open-cycle cooling using the existing intake structures was the Best Available Technology at MNPS. NUSCO's basic conclusions remain accurate and valid. However, since several years have elapsed since the submittal of the FSAR and ER, it is useful to provide an information update, especially in regard to fish larval impingement and entrainment.

2.1 OVERVIEW

Biologists and engineers have, over the years, conducted extensive research to develop methods to protect fish and larvae at water intakes. Most of the research that is pertinent to MNPS was conducted from the late 1960s to the early 1980s and focused on the biological effectiveness and engineering practicability of screening systems for use at steam electric stations. In the early 1980s, the design and construction of new steam electric plants in this nation came to a near standstill. From the mid-1980s to the present time, fish protection research has continued at a reduced level of effort for steam electric stations, but has increased greatly for application to hydroelectric facilities. Some of the information derived from ongoing efforts at hydroelectric facilities, however, is pertinent to the issue of fish impingement and entrainment at MNPS and is presented to provide the best information available for the evaluation of alternatives.

Most fish protection systems in use today are designed primarily to protect juvenile and adult fish from impingement. Few such systems and devices are both biologically effective in reducing entrainment, and at the same time practical to operate, cost-effective, and acceptable to regulatory agencies.

There are several types of mitigation measures for minimizing the entrainment of fish larvae at cooling-water intakes. The various general categories with specific means for application are as follows:

Flow Reduction

- Cooling towers
- Variable-speed pump driver
- Outages

Prevent Entrance of Fish Larvae at Intakes

- Offshore intake
- Fine-mesh screens
- Angled screens
- Wedgewire screens
- Infiltration systems

Reduce Entrainment of Fish Larvae at Intakes

- Weirs, sills, and curtain walls
- Air bubble floatation systems
- Behavioral barriers

Replenish Fish

- Fish hatchery

The above mitigating measures were screened to determine if they were feasible for application at MNPS. As a result of this preliminary review, the infiltration system design and behavioral barriers were eliminated from further analysis. The reasons for rejection are listed below:

2.2 INFILTRATION SYSTEMS

Infiltration systems consist of a system of horizontal perforated water collection conduits installed in the aquifer below or adjacent to a water body. The collector conduit system then conveys the water to a common collector chamber where the filtered water can be pumped to cooling systems. The system utilizes the filtering action of the bottom soil or an engineered filter media to remove suspended solids (including biota) from the water. An infiltration system would eliminate entrainment of fish and fish larvae into an intake. Engineered filter media systems placed over the field of collector pipes can be used to increase permeabilities and thereby allow for higher flow rates.

Two companies specializing in the design and construction of infiltration-type intake system, were consulted regarding the application of an infiltration-type water collection system for the Unit 3 intake. These companies are the Ranney Division of Hydro Group, Inc., Westerville, Ohio, and M&S Systems International Ltd of Qawra, Malta.

After reviewing the geologic conditions and flow rate of the Unit 3 intake, Ranney concluded that an infiltration gallery system would be marginal and would be an extrapolation of the technology to flow capacities much larger than any existing system placed by them. The limitation to application at MNPS is the very high flow capacity. The typical yield from a radial collector can be limited to between 1000 and 3000 gallons per minute (gpm). Given the normal 912,000 gpm operating flow to the Unit 3 intake, a large number of collector wells would be required. The City of Belgrade, Yugoslavia, utilizes a series of 40 collector wells installed around an inland lake to develop a municipal water supply (approximately maximum system capacity 80,00 gpm); based on this data, approximately 500 wells would be required for Unit 3. An infiltration gallery may also be installed, consisting of horizontally oriented media as much as 2000 feet in length. However, the long-term yield of these systems appears limited to 1000 to 2000 gpm, based upon years of experience with installations of this type. For both the infiltration gallery system and the collector wells, the individual wells/galleries need to be properly spaced, resulting in large seafront property requirements.

M&S Systems International Ltd presented a design similar in concept to the Ranney infiltration system. M&S claims it can achieve higher yields than the Ranney-type system through the use of specially designed filter media systems installed around the infiltration pipes. M&S claims a 40 percent capacity increase over the Ranney system. The proposed design for Unit 3 would consist of an array of collector pipe screens with media, covering an area of 3800 m^2. The collection system would supply cooling water to a single pumping facility. A review of the M&S filter media concept indicated that this system could be subject to clogging in the high detrital environment of the MNPS intakes.

It was concluded that an infiltration system is not a viable technology for the large operating flow rate of Unit 3. This conclusion was based primarily on Ranney's previous attempts to build and operate high capacity infiltration systems. The maintenance and screen plugging problems are likely to occur particularly during the periods of high kelp and high eelgrass loadings. The spring period of high flounder larval activity is also a period of high detrital loading at the MNPS intakes. The M&S system, although possibly an improvement on the Ranney design, would be subject to the same clogging and maintenance problems. Also, there is no experience in the United States with the M&S system.

2.3 BEHAVIORAL BARRIERS

Behavioral barriers such as lights or sound devices are not considered effective measures for preventing the entrainment of early larval life stages of fish into intakes. Even if larval fish react to lights or sound, they do not have the swimming capability to overcome the flow velocities approaching or entering the intakes. For this reason, behavioral barriers were eliminated from further consideration as potential measures for reducing entrainment of winter founder larvae into the MNPS intakes (3).

2.4 SELECTED MEASURES FOR PRELIMINARY DESIGN AND COST ESTIMATING

All of the alternative measures listed in Section 2.1 with the exception of infiltration systems and behavioral barriers have potential for mitigating entrainment of winter flounder larvae at MNPS. Preliminary designs for the following alternative measures are presented in Section 3 with cost estimates and construction schedules presented in Section 4:

- Cooling towers
- Offshore intake
- Fine-mesh screens
- Wedgewire screens
- Diversion sills and curtain walls with air floatation
- Operational Strategies
    - Reduced power/flow
    - Variable-speed pumps
    - Scheduled refuel outages
    - Forced outages

The fish hatchery is discussed in Part II.

2.5 REFERENCES

1. Millstone Nuclear Power Station, Unit 3; Final Safety Analysis Report; Docket No. 50-423.

2. Millstone Nuclear Power Station Unit 3, Environmental Report; Docket No. 50-423.

3. E.P. Taft. Assessment of Downstream Migrant Fish Protection Technologies for Hydroelectric Application. Palo Alto, California: Electric Power Research Institute, 1986. AP-4711.

3

ENGINEERING DESCRIPTION OF SELECTED MITIGATION DESIGNS

In this section, preliminary designs for selected cooling system alternatives were developed for the Unit 3 intake. Unit 3 draws approximately ½ of the total station intake flow. Elimination or reduction of larval entrainment into the Unit 3 intake would produce a reduction in station entrainment. The selected designs offer the potential for a reduction in entrainment of winter flounder larvae. The designs were developed to a level of detail adequate to develop order of magnitude cost estimates.

Previous studies evaluating cooling towers at Unit 3 were done during the initial licensing work for the station in the early 1970s and subsequent studies conducted during the 1980s. The results of these evaluations were incorporated into the selection of the type of cooling tower (natural-draft) to be used for preliminary design and specific system design parameters used in this study. Design criteria and construction experience for the Seabrook Nuclear Power Station offshore intake and discharge tunnels were used to develop the preliminary design for the proposed offshore intake system for Unit 3. The most current U.S. and foreign design criteria were used to develop preliminary designs for fine-mesh screens, wedgewire screens, and diversion sills and curtain walls.

In all cases the nuclear safety-related service water system operation would remain the same. The service water pumps would remain in the existing Unit 3 intake structure and function as they currently do. In the cases of the offshore intake, fine-mesh screens and wedgewire screens, where the existing intake would be enclosed by a forebay, a separate nuclear safety-related water passageway would be required. This passage system would consist of a combination of an automatic safety-related valve or gate system and collapsible panels. The actual design and cost estimate for these systems were not included in the report.

Because the service water system is nuclear safety related, the design would be nuclear safety-related Category I and would be subject to Nuclear Regulatory Commission review and approval. This area was not addressed in detail.

3.1 GEOLOGY AND GEOTECHNICAL CONSIDERATIONS

Much of the geology at MNPS was well documented during the licensing and construction phases of the three units. The most current information is described in Section 2.5 of the Final Safety Analysis Report (FSAR) (1). Boring, seismic refraction surveys, bathymetric surveys, laboratory data and geologic mapping during excavation provide information on the properties of the rock and soil types expected elsewhere in the site vicinity. Bedrock at the site is overlain by glacial deposits consisting of basal till, ablation till, stream deposits, beach sands and artificial fill. All major Unit 3 structures, ducts and pipelines were founded on basal till or bedrock and no unusual conditions were encountered during excavation or construction. It should be noted that the variable nature of the top of rock surface does not allow for an accurate prediction of overburden thicknesses elsewhere at Millstone Point using Unit 3 data. Therefore, estimates of rock and soil quantities are difficult.

The predominant site bedrock is Monson gneiss. It is a uniformly foliated (layered) metamorphic rock, composed of thin segregated layers of quartz, feldspar, and mica. The Monson gneiss is intruded by sills of younger Westerly granite, generally parallel to the foliation. The Westerly granite is most prevalent at the discharge area and near shore in the vicinity of the intakes. Both rock types are hard, dense, crystalline rocks that are mostly unweathered, except in the vicinity of fault zones, and serve as excellent foundation materials. The determined allowable bearing capacity for these rock types is 200 ksf (kips per square foot) (FSAR Table 2.5.4-23). According to the site bedrock map (FSAR Figure 2.5.1-13), the Monson gneiss extends offshore into Niantic Bay, where it contacts the Brimfield Formation. This rock is a garnet-mica schist and gneiss and is expected to have physical properties similar to the Monson gneiss.

According to FSAR Figure 2.5.4-39 the rock elevation is generally highest at the eastern portion of the Unit 3 site (22 feet) and drops to -32 feet at the Unit 3 intake. Site grade is 24 feet and rises gradually to the north of the Unit 3 structures to 30 feet. It is expected that rock elevations pertinent to this study are similar to those found in the area of Unit 3 (between 10 to 20 feet). Offshore, the top of the rock surface is inferred from seismic refraction data which indicates highly variable elevations (0 to -180 feet).

The bedrock surface is overlain by a dense basal till of variable thickness (5 to 40 feet). It consists of a poorly sorted mixture of clay, sand, silt and cobbles that was compacted by glacial ice. The allowable bearing capacity is 12 ksf and its shear strength is relatively high, making this soil suitable for use as a foundation material in some cases. Overlying the basal till are less dense deposits consisting of ablation till; stream deposits, which are found mainly on the west side of the site; beach sands; and artificial fill. The physical properties of these materials were not considered well suited for foundation of major structures. Therefore, during foundation preparation, these materials were removed until basal till or bedrock was exposed. The same general procedure is assumed for foundation of the structures addressed in this estimate. Previous excavations indicate the basal till can maintain a 1H:1V slope while the overlying looser soils require a 2H:1V slope for stability purposes. Analysis of Unit 3 soils indicates that liquefaction is not a concern. However, a re-evaluation will be required if there are any major modifications to the shore front slopes and channels in the vicinity of the intake.

Geologic features which may influence design and construction include rock discontinuities, rock stress concentrations, soil deposits of poor bearing capacity, and groundwater conditions. Discontinuities that form planes of weakness that must be considered for structural stability in rock excavations and tunnels are the foliation, joints and faults. These planes of weakness can form unfavorable geometries singularly or in combination when they intersect an excavation. The foliation at the site is uniform and the average orientation is N67W/48NE. The jointing (fracturing) of the rock is well developed. The dominant orientation is N03W/63NE and two lesser sets are N02W/78NE and N48W/07NE. The joint spacing is generally 3 to 5 feet and the joint apertures are generally closed or thin. Depending on rock excavation orientations, some stabilization may be necessary through use of rock bolts. Excessive rock stress concentrations were not observed during excavation and this is not considered an issue.

Eleven fault zones were uncovered during mapping as shown in FSAR (1) Figure 2.5.1-18 and more can be anticipated during future excavation. The fault zones generally trend north-south, are nearly vertical, and can produce fragmented and crushed zones a few feet in width adjacent to the fault plane. Although faults did not pose significant foundation or stabilization problems during construction, they can act as conduits for groundwater flow during tunnel construction.

Groundwater elevations prior to excavation at the Unit 3 site are shown in FSAR Figure 2.5.4-37. They indicate that original groundwater elevations are at elevation 20 feet and drop seaward. The overall groundwater gradient appears to be from northeast to southwest. Since the tills are relatively impervious, groundwater movement is mainly restricted to the more pervious materials overlying the till. Hydraulic conductivity for granite

gneiss and granite typically range from 10^{-4} and 10^{-8} cm/s and is mainly a function of the density and orientation of fracturing. Pressure tests in the site rock indicate permeabilities are extremely low. This was confirmed by the lack of infiltration during excavation and construction.

3.2 NATURAL-DRAFT COOLING TOWERS

Two cooling tower alternatives were addressed including a full-size natural-draft cooling tower with accompanying closed-loop circulating water systems for Unit 3 and a similar but smaller natural-draft cooling tower system for Unit 3 designed to reject ⅔ of the unit waste heat to the atmosphere. The objective of these cooling tower alternatives was to reduce flounder larval entrainment by reducing station saltwater withdrawal rate from Niantic Bay. These two cooling tower alternatives were selected to provide representative current capital cost estimates, unit performance impacts, and construction schedules for converting Unit 3 wholly or partially to a closed-loop circulating water system. The results of studies prepared for MNPS Unit 3 during the initial licensing process (1) and evaluations conducted during the 1980s addressing closed-loop cooling systems using various cooling tower configurations were used as a basis for this updated study; however, new calculations were performed to design the cooling towers.

Both cooling tower system designs would allow either full-time or part-time operation with the existing once-through cooling systems remaining intact and operational. Performance impacts were estimated for both full- and part-time operation.

The nuclear safety-related service water system for Unit 3 would remain as is with both cooling tower alternatives; however, extensive regulatory approvals would be required. This area was not discussed.

3.2.1 FULL-SIZE COOLING TOWER SYSTEM

This alternative consists of conversion of the existing once-through circulating water system for Unit 3 to a closed-loop system utilizing a natural-draft saltwater cooling tower. The heat rejected by condensing steam would be rejected to the atmosphere, primarily by evaporation of the saltwater in the cooling tower. The service water system would remain the same.

The objective of this alternative would be to reduce total station (Units 1, 2, and 3) intake flow from Niantic Bay to approximately ½ of its current volume. The current flow withdrawal rates for Units 1, 2, and 3 are shown on Table 1-1. The total withdrawal rate of saltwater

from Niantic Bay is 4373 cfs. The cooling tower would reduce the required Unit 3 circulating water flow withdrawal from 2030 cfs to 90 cfs for cooling tower makeup resulting in a total station withdrawal of about 2430 cfs. This would be a 44 percent reduction. This reduction in station flow withdrawal from Niantic Bay would result in a corresponding reduction in the number of winter flounder larvae entrained.

Both natural-draft and mechanical-draft cooling tower configurations for Unit 3 were evaluated during the original licensing process. The results of these studies have been summarized in the Final Environmental Statement for Unit 3 (2). The results of these studies showed that the total cost for mechanical-draft and natural-draft cooling tower systems were similar. The natural-draft cooling tower was selected for this study to develop current representative costs for conversion of the Unit 3 circulating water system from once-through to closed-loop. The advantage of the natural-draft cooling tower is that it eliminates the power requirements for fan operation.

The natural-draft saltwater cooling tower alternative would consist of the tower located in the wooded area to the east of the switchyard as shown on Figure 3-1. The cooling tower would have a new circulating water system with the new pump station at the tower location. The existing condenser operation would be changed from the current single-pass configuration to a two-pass configuration. This change would be necessary to maintain high condenser tube velocities for efficient heat transfer with the reduced circulating water flow rate in the closed-loop system. The existing condenser has adequate pressure rating (80 psi) and valving to allow operation in a two-pass mode with no modifications. The proposed circulating water piping from and to the cooling tower would be routed to the north and west of the station and would be manifolded into the existing circulating water piping on the west side of the station as shown on Figure 3-1. Piping would be installed in a common cut and cover trench. Valving would be provided at the tie-in point of the new closed-loop circulating water system piping and existing circulating water piping to allow operation of Unit 3 either on the cooling tower or once-through.

New makeup water pumps would be required in the existing Unit 3 intake structure. The cooling tower blowdown would be discharged to the quarry.

3.2.1.1 Natural-Draft Cooling Tower

The natural-draft saltwater cooling tower for Unit 3 would be designed to operate in summer conditions. The tower would be a massive structure, 450 feet in diameter at the base and 535 feet tall. The tower design would be the counterflow configuration with the fill located within the tower shell just above the air inlet. The fill mass would be disc-shaped covering

the full plan area of the tower and would be approximately 4 feet in thickness. A system of channels, pipes, and spray headers would distribute the circulating water evenly over the fill area. Provisions for ice control, such as a spray curtain ring covering the circumference of the air inlet and fill zoning, could be incorporated into the design. Special structure provisions for salt water would include galvanized or epoxy-coated rebar and Type II Portland cement. The polyvinylchloride (PVC) fill is unaffected by salt water.

Specific design parameters for the cooling tower are as follows:

Circulating Water Flow	630,000 gpm
Cooling Range	25°F
Approach Temperature	14°F
Wet Bulb Temperature	27°F
Dry Bulb Temperature	89°F
Evaporation Rate	2.1%
Drift Rate	0.002%
Concentration Factor	1.5

Drift elimination technology has improved since the early 1970s when cooling towers were originally evaluated for Unit 3. At that time, a drift rate of 0.00375 percent of the circulating water flow was used for evaluation. Current drift eliminator designs can reduce the drift rate to 0.002 percent of the circulating water flow. The original conclusion on the affects of salt drift from a natural-draft cooling tower for Unit 3 by the United States Atomic Energy Commission was that naturally occurring levels of salt drift from Long Island Sound would be an order of magnitude higher than levels predicted for the cooling tower (2). A modern cooling tower would generate even less drift than that predicted by the original study. It is concluded, therefore, that salt drift from a natural-draft cooling tower at MNPS should not create an adverse environmental impact.

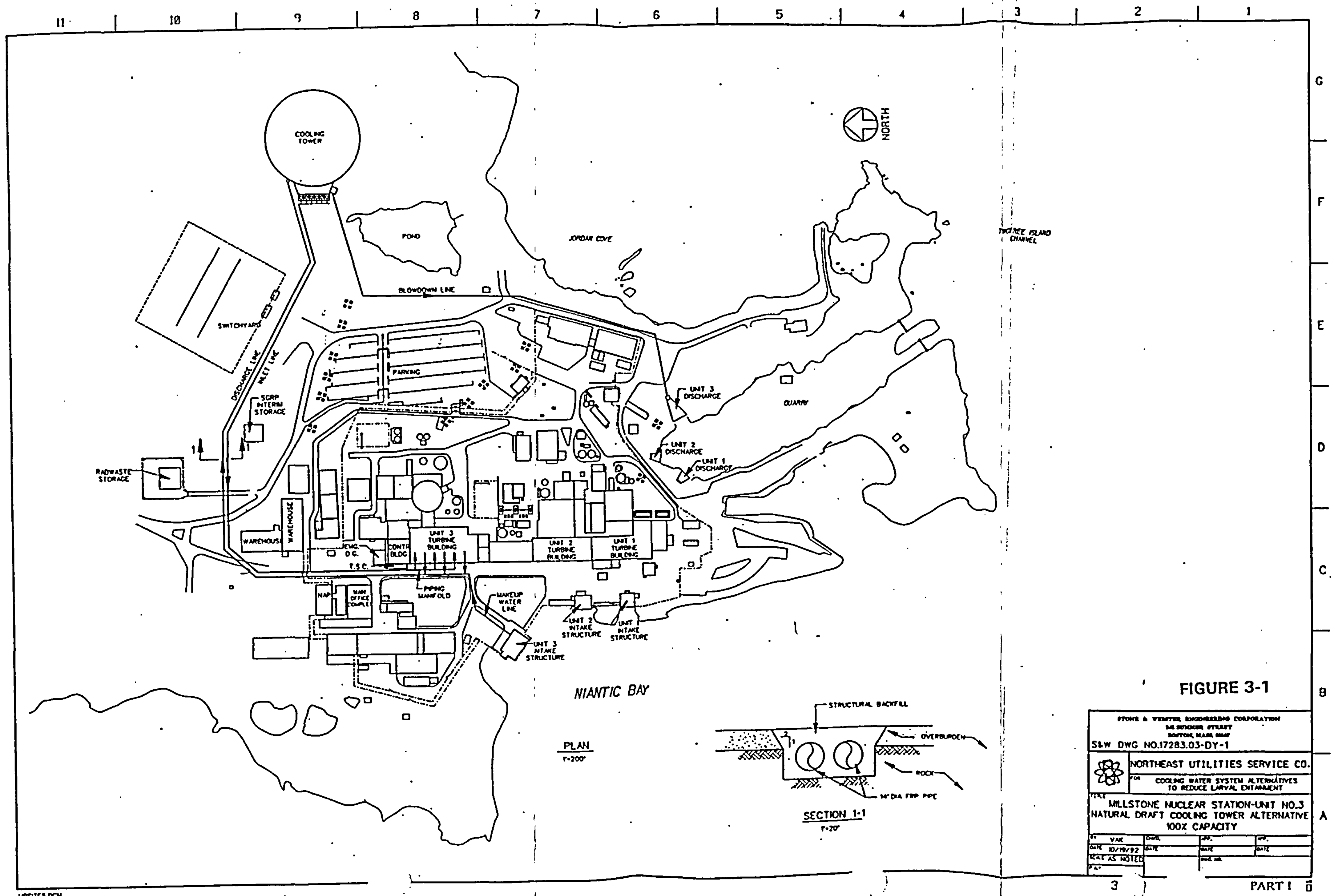

COOLING TOWER
POND
JORDAN COVE
NORTH
BLOWDOWN LINE
SWITCHYARD
DISCHARGE LINE
INLET LINE
PARKING
SGRP INTERIM STORAGE
RADWASTE STORAGE
WAREHOUSE
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
UNIT 3 DISCHARGE
UNIT 2 DISCHARGE
UNIT 1 DISCHARGE
QUARRY
T.S.C.
PIPING MANIFOLD
MAKEUP WATER LINE
UNIT 2 INTAKE STRUCTURE
UNIT 1 INTAKE STRUCTURE
UNIT 3 INTAKE STRUCTURE
NIANTIC BAY
PLAN
STRUCTURAL BACKFILL
OVERBURDEN
ROCK
SECTION 1-1
STONE & WEBSTER ENGINEERING CORPORATION
S&W DWG NO.17283.03-DY-1
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
NATURAL DRAFT COOLING TOWER ALTERNATIVE
100% CAPACITY
VAK
10/19/92
AS NOTED
PART I

FIGURE 3-1

A chlorination system to control biofouling in the cooling tower fill and the condenser tubes would be required and a dechlorination system would probably also be required for the blowdown. Costs for these systems were not addressed.

The required makeup water flow to the cooling tower to maintain the concentration factor in the closed-loop circulating water system at 1.5 or less at all times would be 90 cfs (40,400 gpm). Makeup flow would be pumped into the circulating water return line near the condenser discharge manifold as shown on **Figure 3-1**. Approximately 55 feet of pumping head would be required to pump the makeup water into the system. Required pump motor horsepower for the makeup water pump would be 720 horsepower. Two full-size makeup water pumps would be provided. A 42-inch diameter line would be required for makeup water.

Blowdown would be discharged from the cooling tower basin at an overflow weir structure that would be located on the cooling tower discharge flume. The discharged blowdown would be carried by gravity to the quarry by a 60-inch line buried in a cut and cover trench. Blowdown piping would be routed to the existing discharge flume at the quarry. Blowdown flow would range from 27,000 to 40,000 gpm.

3.2.1.2 Closed-Loop Circulating Water System

The circulating water system for the cooling tower would consist of a pump station containing six circulating water pumps and motors located at the cooling tower basin, a buried circulating water conduit which would convey cooled circulating water from the cooling tower to the condenser and would return heated water from the condenser back to the cooling tower, valves, electric power, and control equipment. The proposed pipe routing is to the north of the station and then south and to the west side of the condenser as shown on **Figure 3-1**.

Flow rate for the closed-loop circulating water system would be 1,400 cfs (630,000 gpm). Total system head loss and static lift to pump circulating water to the cooling tower fill distribution system would be approximately 100 feet. The head would include friction losses in conduit; losses in the two-pass condenser; form losses at bends, fittings, and junctions; and an estimated 45-foot static lift to the cooling tower fill distribution system. To meet these flow and head requirements, six circulating water pumps would be required, rated at 105,000 gpm at 100 feet total dynamic head. This would require 3,300 horsepower per pump for a total pumping energy requirement of 19,800 horsepower. This equated to approximately 14,800 kW of electric power.

The six circulating water pump discharges would be manifolded into a single 14-foot diameter inlet conduit which would convey the circulating water to the west side of the Unit 3 condenser. This piping would be manifolded to join three of the six 84-inch inlets to the condenser. Valving at the manifolded junction would consist of three 84-inch motor-operated butterfly valves in the three inlet lines from the cooling tower. These valves, in conjunction with the existing pump discharge valves and condenser valves, would allow operation of the system either on the cooling tower or once-through. Water would make two passes through the reconfigured condenser and exit the condenser from the alternate three 84-inch lines on the west side of the condenser. These existing 84-inch lines would be cut and manifolded into a single 14-foot diameter return line which would convey heated circulating water back to the cooling tower. Pipe material selected for the circulating water pipe for this study would be fiberglass-reinforced plastic (FRP). Advantages of FRP pipe as compared to concrete cylinder pipe include lighter weight for easier handling during construction, longer sections resulting in shorter placement time, and no corrosion in saltwater. Carbon steel pipe would not be considered suitable in saltwater service due to high corrosion rates.

Electric power for the new circulating water pumps at the cooling tower, the makeup water pumps to be located in the existing Unit 3 intake structure, HVAC for the cooling tower pumphouse, and cooling tower lighting would be taken from buses 34A and B in the existing Unit 3 pump structure. Ten new breakers would be required on buses 34A and B presently feeding the existing circulating water pumps. The breakers would feed the six new 3,500 horsepower circulating water pumps located in the cooling tower pumphouse, the two new 750 horsepower makeup pumps which would be located in the existing circulating and service water pumphouse, and a new double-ended 480-V load center would be located in the cooling tower pumphouse. The addition of the breakers to bus 34B would impair access to the switchgear room. It has been assumed that buses 34A and B have adequate capacity to power the increased load. Because air blast breakers are no longer manufactured, vacuum breakers would be used instead.

A 2,800-foot ductline would be required for power cables running from the existing intake structure to the cooling tower. The ductline would follow the same route as the proposed new cooling tower circulating water inlet and discharge lines.

A detailed electrical design was not performed and the information developed for this study is considered preliminary and only conceptual in nature. Existing electrical loads and location of utilities could have a significant impact on the conceptual design.

3.2.1.3 Impact on Unit Performance

The natural-draft cooling tower would result in added power demand for operation of the higher horsepower circulating water pumps and added cooling tower makeup water pumps. Also, the average circulating water temperature would be higher in the closed-loop cooling tower system resulting in higher average turbine back pressure and reduced turbine performance, particularly during the summer months.

The existing circulating water pumps are 1,500 horsepower pumps which draw a total of 6,700 kW of electric energy. The closed-loop circulating water system would require six new circulating water pumps, each rated at 3,300 horsepower, and two makeup water pumps, each rated at 750 horsepower. Normally, all six circulating water pumps and one of the two makeup water pumps would operate continuously. This would result in a net increase in pumping energy consumption of 8,600 kW.

The annual average net loss to Unit 3 performance resulting from the higher circulating water temperatures in the closed-loop system and the accompanying higher turbine back pressure would be 18,500 kW. These losses would occur primarily during the warm weather months of May through September. This estimated performance penalty was based on the unit operating on the cooling tower 100 percent of the time. Operation of the full-size cooling tower only during the months of April and May when flounder larval activity is greatest would result in reductions to unit performance of 14,900 kW in April and May.

Switching plant operation from cooling tower to once-through and back to cooling tower would likely require an outage. The performance penalty associated with this outage was not included in the estimated cost.

3.2.2 TWO-THIRDS SIZE COOLING TOWER

This alternative is similar to the full-size cooling tower except that four of the six condenser paths would be converted to a closed-loop system integrated with the natural-draft cooling tower, and the remaining two condenser paths would remain once-through. The objective of this alternative is to provide a reduction to station intake flow from Niantic Bay, at a reduced capital cost and reduced performance penalty, as compared to the full-size cooling tower.

The ⅔-size cooling tower would reduce Unit 3 withdrawal rate from Niantic Bay from 912,000 gpm (2,030 cfs) to 304,000 gpm (677 cfs) plus 27,000 gpm (600 cfs) cooling tower makeup. This would result in a net reduction in total station withdrawal from Niantic Bay from 4,343 to 3,050 cfs. This would be a 30 percent reduction.

The proposed cooling tower location and circulating water pipe routing for the ⅔-size system would be similar to that proposed for the full-size system and is shown in Figure 3-2. The four condenser paths requiring conversion to closed-loop would be changed to a two-path type flow, using existing condenser valving and waterbox cross connections. In this case, as with the full-size system, circulating water would enter and exit the condenser on the west side. Valves would be required at the manifolded junction to allow operation of the system with ⅔ cooling derived from the cooling tower or fully once-through. The two full-size (27,000 gpm) makeup water pumps would be installed in the circulating water pump bays in the existing Unit 3 pump structure.

3.2.2.1 Two-Thirds Size Natural-Draft Cooling Tower

A natural-draft cooling tower sized to reject ⅔ of the Unit 3 heat load would be approximately 400 feet in diameter at the base and approximately 460 feet high. Specific design parameters for the ⅔-size cooling tower are as follows:

Circulating Water Flow	422,000 gpm
Cooling Range	25°F
Approach Temperature	14°F
Wet Bulb Temperature	77°F
Dry Bulb Temperature	89°F
Evaporation Rate	2.1%
Drift Rate	0.002%
Concentration Factor	1.5

The drift rate for the ⅔-size tower would be anticipated to be about ⅔ of that resulting from the full-size tower. (Refer to the discussion of salt drift in Section 3.2.1.1.) Required makeup flow to the ⅔-size cooling tower to maintain a concentration factor in the closed-loop circulating water system at 1.5 or less would be 27,000 gpm (60 cfs). Makeup water pumps would be rated at 27,000 gpm at 55-foot head. Horsepower requirements for the makeup pump would be 480 horsepower. Two full-size pumps would be required. A 36-inch diameter makeup water line would be required.

Blowdown would be discharged from the cooling tower basin at an overflow weir structure located on the cooling tower discharge flume. The discharged blowdown would be discharged by gravity to the quarry by a 48-inch line buried in a cut and cover trench. Blowdown piping would be routed to the existing Unit 3 discharge flume at the quarry. Blowdown flow would range from 18,000 to 27,000 gpm.

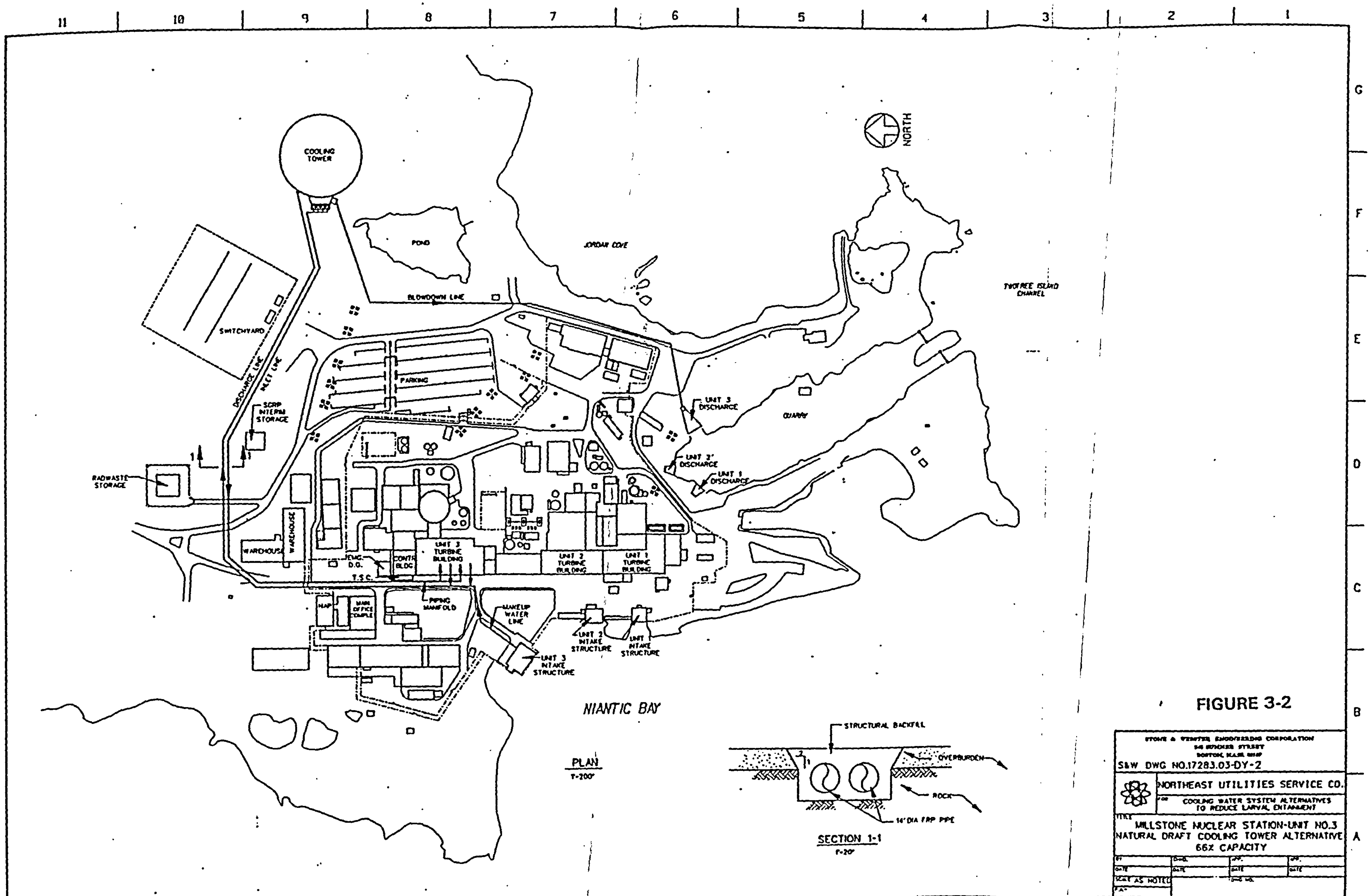

COOLING TOWER
POND
JORDAN COVE
TWOTREE ISLAND CHANNEL
NORTH
BLOWDOWN LINE
SWITCHYARD
PARKING
DISCHARGE LINE
INLET LINE
SCRP INTERIM STORAGE
RADWASTE STORAGE
WAREHOUSE
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
EMG. D.G.
CONTR BLDG
T.S.C.
PIPING MANIFOLD
MAIN OFFICE COMPLEX
MAKEUP WATER LINE
UNIT 3 INTAKE STRUCTURE
UNIT 2 INTAKE STRUCTURE
UNIT 1 INTAKE STRUCTURE
UNIT 3 DISCHARGE
UNIT 2 DISCHARGE
UNIT 1 DISCHARGE
QUARRY
NIANTIC BAY
PLAN
SECTION 1-1
STRUCTURAL BACKFILL
OVERBURDEN
ROCK
14' DIA FRP PIPE
S&W DWG NO.17283.03-DY-2
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTRAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
NATURAL DRAFT COOLING TOWER ALTERNATIVE
66% CAPACITY
SCALE AS NOTED

FIGURE 3-2

3.2.2.2 Closed-Loop Circulating Water System

The closed-loop circulating water system for the ⅔-size cooling tower would be similar in design and layout to that proposed for the full-size cooling tower. The circulating water pump station would be located at the cooling tower and would contain four ¼-size pumps, each rated at 105,000 gpm for a total circulating water flow rate of 420,000 gpm (936 cfs). These four circulating water pumps would discharge to a single 12-foot diameter pipe. Both supply and return circulating water lines would be routed to the north and to the west of Unit 3 in a common cut and cover trench as shown on Figure 3-2. Each circulating water pump would have a motor-operated discharge valve. Existing 84-inch lines and valves at the condenser would be utilized by the new closed-loop system. Two 12-foot x 7-foot two-pipe manifolds would be required on the west side of the condenser to make the connection between the new 12-foot diameter cooling tower supply, return lines, and the existing piping. The two northerly condenser waterboxes would be converted to the closed-loop system. The two manifolded 84-inch inlet lines from the cooling tower would have motor-operated valves installed. These valves, in conjunction with the existing pump discharge valves and condenser valves, would allow operation of the system either on the cooling tower or once-through. The southerly waterbox would remain once-through. The system head losses for the ⅔-size circulating water system would be essentially the same as that for the full-size system. The four circulating water pumps would be rated for 105,000 gpm at 100-foot total dynamic head. Pump motors rated at 3,300 horsepower would be required.

Eight new breakers would be required on buses 34A and B feeding the existing circulating water pumps. The breakers would feed the four new 3,500 horsepower circulating water pumps located in the cooling tower pumphouse, the two new 600 horsepower makeup pumps which would be located in the existing circulating and service water pumphouse, and a new double-ended 480-V load center located in the cooling tower pumphouse. The addition of breakers to bus 34B would impair access to the switchgear room. It also was assumed that buses 34A and B have adequate capacity to provide power for the increased load. When obtaining estimating prices for new 4,160-V air circuit breakers and switchgear to match existing, GE stated that they no longer manufacture such equipment and they proposed vacuum breakers instead.

A 2,800-foot ductline would be required for power cables running from the existing intake structure to the cooling tower. The ductline would follow the same route as the new cooling tower circulating water inlet and discharge lines.

3.2.2.3 Impact on Unit Performance

Four 3,300-horsepower pumps would also be required for closed-loop circulating water flow. These pumps would operate continuously if the cooling tower were operating. In addition to the higher horsepower circulating water pumps, two 480-horsepower cooling tower makeup pumps would also be required. These pump changes would result in a net power increase for pumping of 5,700 kW.

The annual average net loss to Unit 3 performance resulting from operation of ⅔ of the circulating water system closed-loop would be 12,300 kW. Operation of the ⅔-size cooling tower only during the months of April and May during highest flounder larval activity would result in reduction in unit performance of 9,900 kW in April and May.

Switching plant operation from cooling tower to once-through and back to cooling tower would likely require an outage. The performance penalty associated with this outage was not included in the estimated cost.

3.2.3 GEOTECHNICAL CONSIDERATIONS

The topography in the proposed cooling tower area is characterized by a wooded easterly sloping ground surface with elevations ranging between 15 and 25 feet. No geotechnical explorations have been performed in the vicinity of the proposed cooling tower area to characterize the subsurface in that area. Some rock exposures are noted near the proposed cooling tower structure location on the U.S. Geological Survey map, suggesting the top of rock surface may be near the ground surface. The overburden in that area is considered to be thin (10 feet or less) glacial deposits of outwash and till.

The ground surface in the area of the proposed cooling tower discharge and inlet lines is largely flat due to modifications by construction activities and generally ranges from elevation 24 feet in the plant area to about elevation 30 feet north of the main plant. The proposed locations of these structures are in areas where subsurface data are absent, except where boring was completed in support of the Temporary Radwaste Facility and Interim Storage Facility for the Steam Generator Replacement Project. These borings suggest that top of rock elevation is variable, ranging from 15 to 24 feet above mean sea level in that area. A few feet of fill material was found at the surface and denser glacial till overlies the rock which was described as granite gneiss.

Since the overburden is presumed to be thin in the cooling tower area and the foundation grade may consist of both rock and soil, it would be recommended that the overburden

materials be removed and the structure be founded entirely on bedrock to limit differential settlements. The average maximum bearing capacity of the rock based upon Unit 3 field investigations is 200 ksf. The soil overburden's bearing capacity is considerably less and more variable. Thus, the overburden properties may not be sufficient to limit differential settlements for a structure of this type.

The proposed conduits for the discharge and inlet lines would be constructed through a cut and cover procedure. It was estimated that 50 to 60 percent of the excavation would be in rock; therefore, conduit construction would require controlled blasting methods to limit vibrations near existing structures. Some local rock support, such as rock bolts, may be necessary depending on excavation height and rock geometry. Soils would require 2H:1V slopes and bracing where slopes are not feasible.

There could be considerable difficulty in coordinating the required activities in excavating areas adjacent to the condenser/turbine building. There are numerous buried utilities in this area, including some that are nuclear safety related. Numerous plant outages would be required. This has not been addressed in the study and could add significantly to the cost estimate.

3.3 OFFSHORE INTAKE

The offshore intake alternative would consist of extending the Unit 3 intake approximately 1 mile south into Long Island Sound utilizing a submerged offshore intake, a rock tunnel, and a booster pump station that would be located in front of the existing Unit 3 intake structure. The proposed design is shown on **Figure 3-3**. The objective of the offshore intake would be to place the Unit 3 intake south into Long Island Sound past the confines of Niantic Bay such that significant numbers of Niantic River flounder larvae would not be entrained in the Unit 3 intake. Those flounder larvae that would be entrained by the proposed new Unit 3 offshore intake would come from the Long Island Sound population as a whole.

3.3.1 DESIGN BASIS

The offshore intake system would be designed for a flow rate of 958,000 gpm (2134 cfs) which is 5 percent greater than the present design flow of the Unit 3 circulating water system (912,000 gpm). The inlet velocity cap structure would be sized for an inlet velocity of 0.5 fps to minimize fish entrainment. The offshore conduit would be sized for a flow velocity of 5 fps to minimize head losses. These criteria result in an offshore conduit I.D. (inside diameter) of 24 feet. The head loss in the offshore intake system, assuming biofouling in the tunnel and risers, would be approximately 5 feet. The onshore booster pump facility would be designed

to provide pumping head to compensate for head losses in the offshore intake. The booster pumps would be sized to pump a minimum of 5 percent excess flow into a new forebay that would lead to the existing Unit 3 intake. An excess flow would be provided to prevent surging between the two in-line pumping systems. The forebay walls would be designed to spill the excess flow into Niantic Bay.

Biofouling of the offshore intake, shafts, and tunnel in the form of mussels and other marine organisms could become severe and difficult to control. A chlorination system which introduces chlorine at the inlet and possibly at multiple locations along the tunnel would be required. Continuous chlorination during the fouling season may be required to control biofouling of the tunnel, shafts and offshore inlet. This chlorination would kill flounder larvae. A dechlorination system would also be required for the circulating water discharge. The cost of these systems was not addressed.

3.3.2 GEOTECHNICAL CONSIDERATIONS

In the absence of borings along the proposed tunnel alignment and offshore intake, the geology was inferred from the nearshore boring, seismic refraction surveys, and bathymetric surveys. The seafloor bottom along the proposed intake generally slopes seaward from the coast to about -40 feet at the proposed offshore intake. According to seismic refraction surveys, which cover approximately 4,000 feet of the initial proposed 5,000-foot tunnel, the top of rock surface along the alignment is irregular with top of rock elevations ranging from -40 to -120 feet (FSAR Appendix 2.5 K). Thus the overburden along the alignment is expected to be between 0 and 80 feet thick.

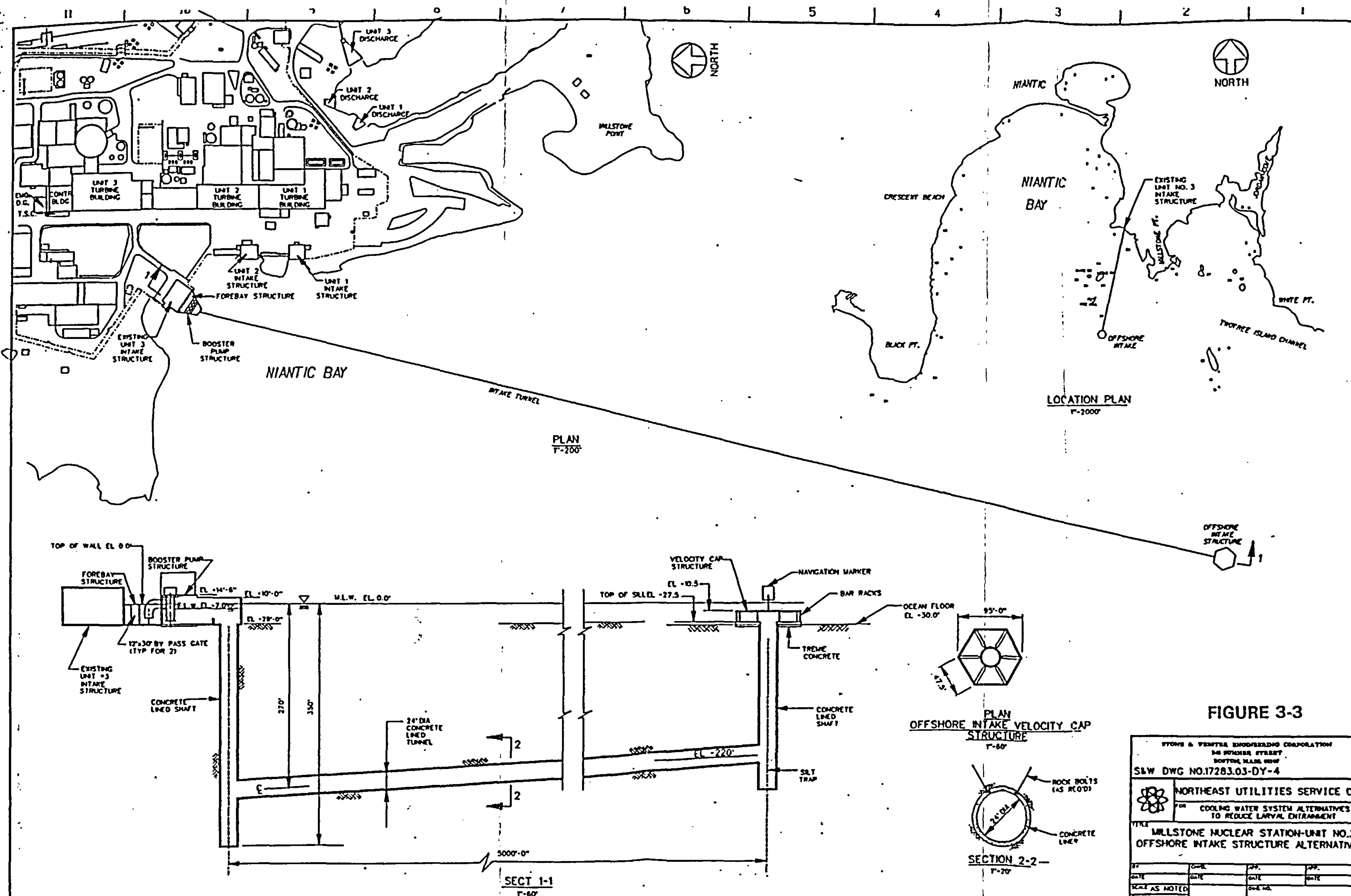

NORTH
MILLSTONE POINT
UNIT 3 DISCHARGE
UNIT 2 DISCHARGE
UNIT 1 DISCHARGE
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
UNIT 2 INTAKE STRUCTURE
UNIT 1 INTAKE STRUCTURE
FOREBAY STRUCTURE
EXISTING UNIT 3 INTAKE STRUCTURE
BOOSTER PUMP STRUCTURE
NIANTIC BAY
INTAKE TUNNEL
PLAN
1"=200'
OFFSHORE INTAKE STRUCTURE
NIANTIC
CRESCENT BEACH
NIANTIC BAY
EXISTING UNIT NO. 3 INTAKE STRUCTURE
MILLSTONE PT.
WHITE PT.
TWOTREE ISLAND CHANNEL
OFFSHORE INTAKE
BLACK PT.
LOCATION PLAN
1"=2000'
TOP OF WALL EL 0.0
FOREBAY STRUCTURE
BOOSTER PUMP STRUCTURE
EL +14'-6"
EL +10'-0"
M.L.W. EL 0.0'
EL -29'-0"
12"x30" BY PASS GATE (TYP FOR 2)
EXISTING UNIT +3 INTAKE STRUCTURE
CONCRETE LINED SHAFT
270'
350'
24' DIA CONCRETE LINED TUNNEL
VELOCITY CAP STRUCTURE
NAVIGATION MARKER
TOP OF SILL EL -27.5
EL +10.5
BAR RACKS
OCEAN FLOOR EL -30.0'
TREMIE CONCRETE
CONCRETE LINED SHAFT
EL -220'
SILT TRAP
5000'-0"
SECT 1-1
1"=60'
95'-0"
47.5'
PLAN
OFFSHORE INTAKE VELOCITY CAP STRUCTURE
1"=60'
ROCK BOLTS (AS RCO'D)
CONCRETE LINER
24' DIA.
SECTION 2-2
1"=20'
STONE & WEBSTER ENGINEERING CORPORATION
S&W DWG NO.17283.03-DY-4
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTRAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
OFFSHORE INTAKE STRUCTURE ALTERNATIVE
SCALE AS NOTED

FIGURE 3-3

The nature of the overburden cannot be determined from the seismic velocity data. It was assumed that a dense basal till of varying thickness overlies the bedrock and looser silty sands overlie the till.

The type and quality of bedrock along the alignment was assumed to be similar to those mapped at the Unit 3 intake structure. The rock types are gneiss and granite with the fractures oriented north-south and dipping near vertical. A conservative range for hydraulic conductivity of a rock mass of this type was assumed to be between 10^{-4} to 10^{-6} cm/s.

Both cut and cover and deep rock tunnel schemes were evaluated for conveyance of water from the offshore intake.

3.3.2.1 Cut and Cover Offshore Twin Tube Tunnel

The cut and cover scheme would involve the fabrication of two parallel pipes, approximately 12 feet I.D. each, that would be placed in a single common trench. A 5,000-foot long trench would be dredged at a constant elevation from the intake structure to the offshore intake port. The trench would be excavated to a depth of approximately 15 feet (3 feet deeper than the tunnel heights), 26 feet wide (at the bottom), and covered with a protective gravel cover after the pipes were placed. Due to the thin nature of overburden in some areas, it was estimated that 10 to 15 percent of the trench would require underwater blasting. Based upon current offshore data, it would be expected that nearly 90 percent of the trench would be dredged in relatively dense overburden. Major technical concerns of such an operation would be:

1. Disturbance of potentially contaminated sediments during dredging operations and their disposal plus the disturbance of marine life may pose a significant environmental concern.
2. Limited available construction period (late spring to early fall).
3. Impact of underwater blasting on marine life and project cost.
4. Numerous regulatory reviews and approvals would be required by both state and Federal agencies.

Soil tests and surveys would be necessary to verify adequate thickness of the overburden, suitability for direct pipe support, and need for structural backfill. While a cut and cover tunnel would appear less challenging from a technical point of view than subsurface tunneling, the environmental impact during construction must be weighed in considering this scheme.

The cut and cover conduit approach would be given further evaluation to include geotechnical investigations of sea floor subsurface conditions along the proposed route prior to any final design.

3.3.2.2 Subsurface Tunnel

The subsurface tunnel scheme would require a vertical shaft near the Unit 3 intake structure, sunk to a depth of approximately 300 feet below low mean sea-level. The shaft must be sunk 30 to 50 feet deeper than the bottom of the tunnel to provide space for loading and storage of. muck. A circular tunnel approximately 270 to 250 feet below low mean sea-level (minimum rock cover of 125 to 150 feet), and 26.5 feet in drilled diameter (24 feet inside lined diameter) would be initiated from the shaft and excavated entirely in rock. The tunnel would be sloped down from the offshore intake structure 1 percent towards the pumphouse at a descending grade to assure adequate flow and minimize ponding during scheduled shutdown. The offshore intake shaft could employ either a single or multiple "dry tap" construction scheme to intersect the tunnel. The dry tap scheme would use a circular steel caisson grouted in-place on the sea floor bottom. Water would be pumped out of the caisson, and the shaft sinking operation initiated. Similar operations have been performed at the Oswego Steam Plant and at the Seabrook Nuclear Power Plant. The major geotechnical constraints for the tunnel scheme were determined to be:

1. Control of water seepage into the tunnel during construction. (exploratory boring in the rock may indicate that this may not be a concern).

2. High costs of offshore shaft construction.

3. Development of access shaft for muck transfer to the surface and a subsurface lay down area for equipment. At the surface, a temporary hoist system would be necessary to lift muck from the shaft and lower excavation equipment.

4. Muck transfer facilities from the access shaft (barge and/or conveyor) would be necessary, as well as a lay down area at the surface for underground equipment, ventilation, etc.

The criteria for 125 to 150 feet of depth was based primarily upon estimated rock permeability, rock structure, and manageability of water inflows during construction. Based upon the above assumptions, overall tunnel seepage rates could be expected to range from less than 300 gpm to 3,000 gpm. Groundwater inflows of several hundred gpm in a short tunnel section could adversely impact tunnel advance rates, even when ground support is not affected. The tunnel advance rate problems are related to inefficient muck removal and

production of extra fines. The extra fines would make cleanup slow (often by hand) and lengthen the drill and blast cycle. The water would also make support installation more difficult. The impact of high water conditions on grouting usage would be much higher, resulting in longer standby time, and more difficult overall machine maintenance/operation (electric drill jumbos, scaling, rock bolt and liner installation).

During shaft excavation, water inflows could be expected at the rock/soil interface and from open joints in weathered rock below the interface. Therefore, pre-grouting would probably be necessary to reduce inflow rates at the interface and in areas of high permeability. Ground freezing was not expected to be necessary and was not considered in the costs.

Both drill and blast and tunnel boring machine (TBM) excavation methods were evaluated. Although the TBM advancement rates are faster, this method would require a TBM erection chamber at both the head and tail shaft and tunnel intersections. Additionally, drill and blast would be more versatile and less risky in excavations of poor or variable ground and potentially high water inflows. This method would be recommended until a more detailed analysis of other factors including equipment capital costs, labor costs and availability, machine delivery lead times, site considerations, geological considerations, and geometry/space constraints was performed.

Based on available rock elevation data, the proposed tunnel elevation at the near shore access shaft would be 270 feet. The tunnel would slope upward at a 1 percent grade towards the offshore intake structure to elevation 220 feet. Preliminary layout of the offshore tunnel scheme indicates that the long axis of the tunnel would parallel the regional geological structure. Thus the formation of unstable wedges as the tunnel face advances, prior to liner installation, would be likely. To prevent eccentric loading of the final tunnel liner due to unstable rock wedges and to provide for worker safety, temporary ground support would be necessary. As a preliminary estimate, patterned rock bolting may be necessary along most of the tunnel's length. The rock bolts would be relatively light in size (No. 8) and would be used primarily above the tunnel springline (60 percent utilization). Additional rock bolts would be used as necessary, as dictated by field conditions, below the springline.

Because of potential environmental problems and uncertain geological conditions associated with the cut and cover offshore twin tube tunnel, the subsurface rock tunnel alternative was selected to develop preliminary cost and schedule estimates for the offshore intake alternative. The proposed tunnel design is shown on Figure 3-3.

3.3.3 OFFSHORE INLET

For preliminary design, a single riser shaft and velocity cap would be proposed. The large velocity cap could be constructed and placed in sections. An alternate approach would be to use multiple smaller riser shafts each having a smaller velocity cap. This single large riser could have cost advantages over multiple smaller shafts. A detailed evaluation of cost and construction issues would be required prior to detailed design.

The offshore inlet would consist of a hexagonal velocity cap structure supported on the sea floor by a tremie concrete mat centered over the vertical inlet shaft as shown on Figure 3-3. The inlet would be 95 feet wide from point to point. The hexagon and the inlet would be 15 feet high beginning at a sill located 3 feet off the sea floor to minimize entrainment of sand and silt. The inlet entrances would be protected by bar racks. The rack spacing would be 1 foot O.C. (on center). These bar racks would protect the inlet from the coarsest forms of debris. Inlet approach velocity would be 0.5 fps.

The offshore intake would extend up 19.5 feet from the sea floor in 30-feet deep water and would create a hazard to navigation. The proper warning buoy would have to be provided with the design.

3.3.4 BOOSTER PUMP STATION

The 24-foot I.D. concrete-lined inlet tunnel including riser shafts on either end would be 5,400 feet in length. It is anticipated that a tunnel would become significantly fouled with mussels and barnacles, causing significant hydraulic resistance. Head losses were estimated at 5.0 feet. The existing circulating water pumps, based on the model test report (3), have very little margin for degraded suction conditions. For this reason, it was considered necessary to include a booster pump station at the onshore end of the offshore intake system.

The booster pump station would require four low head, high flow pumps each rated at 240,000 gpm at 7.0 feet total dynamic head. Each pump would require 525 horsepower. The total pumping energy requirement for the booster pump station would be 2,100 horsepower (1,600 kW). The pumps would be vertical wet pit type. Each would be located in its own pump bay. The pump bays would be 24 feet wide by 52 feet long with an invert elevation of 28 feet. The pumps were sized to draw water from an elevation of -7 feet. The overall plan dimensions of the pump structure would be 106 feet wide by 54 feet long. The pump structure would be constructed of reinforced concrete, and would include a protective building which would enclose the pumps, motors, electrical equipment and controls. The pump structure would be joined upstream by a transition structure constructed over the

24-foot diameter riser shaft from the tunnel. This transition structure would contain a submerged weir to spread inflowing water evenly to the four pump bays. The pump structure and transition structure are shown on Figure 3-3.

The transition structure connecting the vertical tunnel riser shaft to the booster pump station would also serve as a surge chamber. The chamber would not be covered and the top of the walls and would serve as an emergency spillway in the event of surge.

The existing Unit 3 intake structure would be joined to the offshore intake system by sheet pile walls forming a forebay between the two structures and isolating the Unit 3 intake from Niantic Bay. A section of the top of these sheet pile walls would be designed to function as overflow weirs to discharge the excess flow pumped by the booster pumps into Niantic Bay. A 12 foot x 30 foot gate would be required in each of the forebay walls designed to pass ½ of the circulating water flow in the event of failure of the offshore intake system.

A separate Category I flow passage (not shown) would be provided for the service water pumps. The system would consist of flow passages constructed in the forebay walls with flow controlled by automatic motor-operated gates or valves. Separate openings with collapsible panels would also be required as a backup. Because the service water system is nuclear safety related, the design would be nuclear safety-related Category I and would be subject to Nuclear Regulatory Commission review and approval. This area was not addressed in detail.

Four additional 4,160 V breakers would be required for the four new pumps. The new booster pumps would be located in a new intake structure that would be located in front of the existing circulating and service water pumphouse. It was assumed that buses 34A and B have adequate capacity to provide power for the four new pump motors.

When obtaining estimating prices for new 4,160 V air circuit breakers and switchgear, GE stated that they no longer manufacture such equipment and they proposed vacuum breakers instead with a transition section to the existing switchgear. Finally, an 800-foot ductline would be required. The ductline would follow the same route as the ductline to the existing circulating service water pumphouse. A detailed electrical design was not performed and the information developed for this study is considered preliminary and only conceptual in nature. Existing electrical loads and location of utilities could have a significant impact on the conceptual design.

3.3.5 OFFSHORE INTAKE EXPERIENCE AT SEABROOK NUCLEAR POWER STATION

Two deep bedrock tunnels, extending into the Atlantic Ocean to provide cooling-water requirements, were constructed for the Seabrook Nuclear Power Station located in Seabrook, New Hampshire. These tunnels are similar in design to the rock tunnel alternative proposed for Unit 3. Both an intake and a separate discharge tunnel were constructed, each over 3 miles in length (17,156-foot intake, 16,500-foot discharge) (4). The design flow rate for the Seabrook tunnels is 850,000 gpm at a flow velocity of 6 fps. One of the primary reasons for choosing the offshore intake and discharge with deep rock tunnels at Seabrook was to minimize any damage to the coastal environment (4).

Geological conditions at Seabrook necessitated deep rock tunnels. Vertical shafts were used on both ends of the tunnels to connect the offshore water ports and the plant cooling-water systems. At land's end, the tunnels are 260 feet below sea level and 180 feet below sea level at the seaward ends. The tunnel shafts are concrete lined. The bore diameter is 22 feet and the liner thickness is 1.5 feet with a tunnel I.D. of 19 feet. Rock bolts were used as necessary along the top of each tunnel.

The Seabrook intake tunnel terminates on the seaward end with three 9-foot 5-inch diameter shafts located approximately 7,000 feet off the Hampton Beach shoreline at a water depth of 60 feet. Mounted on each shaft at the sea floor are 30.5 feet in diameter velocity cap structures of similar design to that proposed for Unit 3. The velocity caps are clad over their entire exterior surfaces with copper nickel sheeting to minimize marine growth. On the shoreward end the vertical shaft terminates with a surge chamber. The circulating water pump station is located in an excavated chamber adjacent to the surge chamber.

The Seabrook discharge tunnel connects to the ocean by means of eleven 4-foot 11-inch diameter vertical shafts located approximately 5,000 feet off the Seabrook Beach shoreline.

The Seabrook tunnel construction was accomplished by means of two tunnel boring machines operating concurrently. Offshore construction was done using a jack-up barge. Offshore vertical shafts were drilled and prefabricated steel shaft liners installed from the jack up barge (5). Work began in the summer of 1978. Tunnel and vertical shaft excavation was completed in the spring of 1981. Concrete lining of the tunnels was completed by the end of 1982.

The total project cost for the Seabrook tunnel was approximately $125 million.

3.4 FINE-MESH SCREENS

Mesh sizes smaller than 9.5 mm are considered to be "fine mesh" and may be effective as a barrier to the passage of fish eggs and larvae with mesh sizes in the range of 0.5 to 1.0 mm. Various types of traveling screens, such as through-flow, dual-flow, center-flow, and drum screens, can be fitted with fine-mesh screens. Traveling screens are normally cleaned automatically by high and low pressure sprays. Wedgewire screens are also sometimes considered to be a type of fine-mesh screen and are discussed in Section 3.5.

3.4.1 ENGINEERING CONSIDERATIONS

Several stations have installed fine-mesh traveling water screen systems, although conditions at MNPS are generally significantly different and more severe than at these stations. The screen systems in use include:

- Big Bend Station, Tampa Electric Company — continuously traveling dual-flow screens with 0.5 millimeter screen mesh and specially designed organism troughs, buckets, and spray washes. The design flow for Units 3 and 4 is about 242,000 gallons per minute each (salt water).

- Brayton Point Unit 4, New England Power Company — 1.0 millimeter screen mesh, 260,000 gallons per minute with angled screens (salt water, but with much lower levels of total suspended solids and debris). Fine-mesh screens are no longer in service at Brayton Point.

- Prairie Island Nuclear Units 1 and 2, Northern States Power Company — 0.5 millimeter screen mesh, 630,000 gallons per minute (Mississippi River, with no biofouling, or salt marsh debris problems).

- Barney Davis Station, Central Power and Light Company, Corpus Christi, Texas — 1.0 millimeter screen mesh, 340,000 gallons per minute with heavy sea grass loading (salt water).

- Somerset Station, New York State Electric and Gas Company — 1.0 millimeter screen mesh, 195,000 gallons per minute with limited debris (Lake Ontario).

- Brunswick Nuclear Station, Carolina Power Company — 1.0 millimeter screen mesh, 990,000 gallons per minute with additional barrier screens on intake canal (salt water).

- Danskammer Station — 0.5 millimeter screen mesh tested on the Hudson River

3.4.2 ADVANTAGES AND DISADVANTAGES OF FINE-MESH TRAVELING WATER SCREENS

A fine-mesh traveling water screen intake system minimizes entrainment but increases impingement. In addition, the incorporation of rubber seals between baskets and between baskets and frame would minimize the passage of organisms around the screen. The disadvantages of the fine-mesh traveling water screen concept include:

- Effective sealing of spaces between screen baskets, screen baskets and structure, and structure and bay walls is difficult.
- Increased impingement of organisms and debris.
- Screens are subject to icing conditions including frazil ice and floe ice.
- Mesh size of 1 to 2 MM may be insufficient to block stage 3 winter flounder larvae.

Additional screen wash capability may be required, and current problems with this system could be exacerbated. The growth of barnacles and mussels and the buildup of silt can clog the spray wash system. Chlorination of the screen wash system could help to control biofouling, but would defeat the purpose of the fine-mesh screen concept because the chlorine could kill larvae. It could also result in existing NPDES permit violation. Periodic inspections would be necessary to maintain the screens, and the use of nontoxic coatings on some screen components may reduce marine growth.

Continuously operating fine-mesh screens would accumulate greater quantities of trash than coarse-mesh screens. Debris handling systems would include a large capacity sluicing system similar to the existing system.

3.4.3 ALTERNATIVE FINE-MESH INTAKE DESIGN CONCEPTS

Alternative fine-mesh intake design concepts include replacing the existing through-flow vertical traveling screens with continuously operating fine-mesh screens and constructing a new screening facility in front of the existing circulating water intake incorporating new, through-flow, dual-flow, drum, or angled fine-mesh screens with a low approach velocity of 0.5 fps. Dual-flow, centerflow, and drum screens are primarily of English/European design, although some are currently in service in the United States. The angled screen is a special application of the through-flow screens where the screen units are placed at an angle to the incoming flow to divert fish to a fish bypass system. The Electric Power Research Institute (EPRI) reviewed the performance of these screen configurations (7). Facilities were visited at several utilities throughout the United States.

3.4.3.1 Through-Flow Fine-Mesh Screens

The existing through-flow traveling screens cannot be replaced by continuously operating fine-mesh screens. The original screens at Unit 3 had a 3/16-inch (5 mm) opening. The clogging potential of the 3/16-inch opening resulted in numerous plant outages and screen failures. The screen openings were increased to ⅜ inch (9.5 mm) in 1991, which has helped to eliminate the clogging potential experienced previously. The higher clogging rate of the fine-mesh would require that the screens be capable of operating continuously at speeds up to 50 feet or greater per minute. Also, to reduce the loading of large debris on the fine-mesh screens, the existing bar racks and mechanical rake system may require replacement with traveling trash rakes. Because the effective performance of fine-mesh screens is sensitive to flow velocities, flow distributors and more frequent maintenance dredging may also be required to maintain approach flow velocities of 0.5 fps or less to the fine-mesh screens.

3.4.3.2 Dual-Flow/Center-Flow Fine-Mesh Screens

The vertical dual-flow traveling screen is similar in mechanism to the through-flow design, but the screen would be turned 90 degrees so that its faces would be parallel to the incoming water flow. Water would enter both the ascending and the descending screen faces, then flow out between the two faces. The primary advantage of this screen configuration is the elimination of debris carryover. This screen configuration has a possible advantage over the through-flow screen in terms of fish protection only when applied in the so-called "no-well" design. In this case, the screens hang in the water from a platform and would be coupled directly to the circulating water pump, eliminating the pump bay which can form a fish trap (7),(8). Because of the open platform structure supported on piles, the no-well intake configuration is only suitable for warm climates where freezing is not a concern. This type of structure, therefore, is not recommended for MNPS. The dual-flow fine-mesh screen configuration also has been shown to produce low survival rates for fish larvae, which is the principal problem at the MNPS intakes. The longer impingement time for organisms impinged on the descending fence of the screen may result in higher mortality rates. For these reasons, the dual-flow fine-mesh screen configuration was eliminated from further consideration.

The centerflow screen configuration is a European design and is similar in configuration to the dual-flow screens except the flow path is reversed. Flow would enter the centerflow screen at a key hole and pass into the screen between the screen faces and out through the screen faces. The flow velocity entering the key hole between the screen faces of the centerflow screen is usually high, which is a disadvantage from a fish protection standpoint (6). Because of the disadvantages in terms of potential survival of entrained and impinged flounder larvae, the centerflow fine-mesh screen configuration was eliminated from further consideration.

3.4.3.3 Angled Screens

Angled screens are a special application of through-flow screens where the screen faces would be arranged at an angle of approximately 25 degrees to the incoming flow. The normal through-flow screen arrangement, as discussed earlier in this section, would place the screen faces normal or 90 degrees to the incoming flow. The objective of the angled screen arrangement would be to divert fish to a fish bypass system without impinging them on the screens. Fish would not be lifted out of the water but would be diverted back to the receiving water by screw-type centrifugal fish pumps. The angled screens, as proposed for MNPS, would incorporate fine-mesh, a fish and larval lifting bucket, and a standard sluicing system for handling impinged fish and larvae in addition to the fish bypass system. A conceptual layout for an angled fine-mesh screen structure for Unit 3 is shown on Figure 3-4.

Fine-mesh angled screen facilities were formally in place at New England Power's Brayton Point Station on Mount Hope Bay (9), are currently operating at Niagara Mohawk Power Corporation's Oswego Steam Station Unit 6 on Lake Ontario (10), and were tested at Central Hudson Gas & Electric Corporation's Danskammer Point Generating Station (11) on the Hudson River.

3.4.3.4 Fine-Mesh Drum Screen Facility

Another type of fine-mesh screen is the drum screen that is used in Europe. A preliminary design was developed using double-entry rotating drum screens to determine if they would offer a significant cost savings as compared to the through-flow screens. Drum screens are of British design and are similar to a ferris wheel in construction. They operate with the screen mesh mounted along the circumference of the screen. In the double entry arrangement, the drum would be installed with its axis normal to the incoming flow with the plane of the wheel vertical. The wheel would be mounted in an enclosed chamber with all moving parts including the axle mounts above normal high water level. The operating machinery would be located on the deck of the screen structure. Unscreened water would enter the screen from channels on either side and would flow into the screen at semicircular openings on either side of the screen chamber. The water would be screened by passing from within the screen out through the screen mesh mounted on the circumference of the drum. The screened water would pass into a chamber below the drum screen and then to the pumps. Fish baskets would be mounted on the outside of the screen and would function in the same manner as with the through-flow screens.

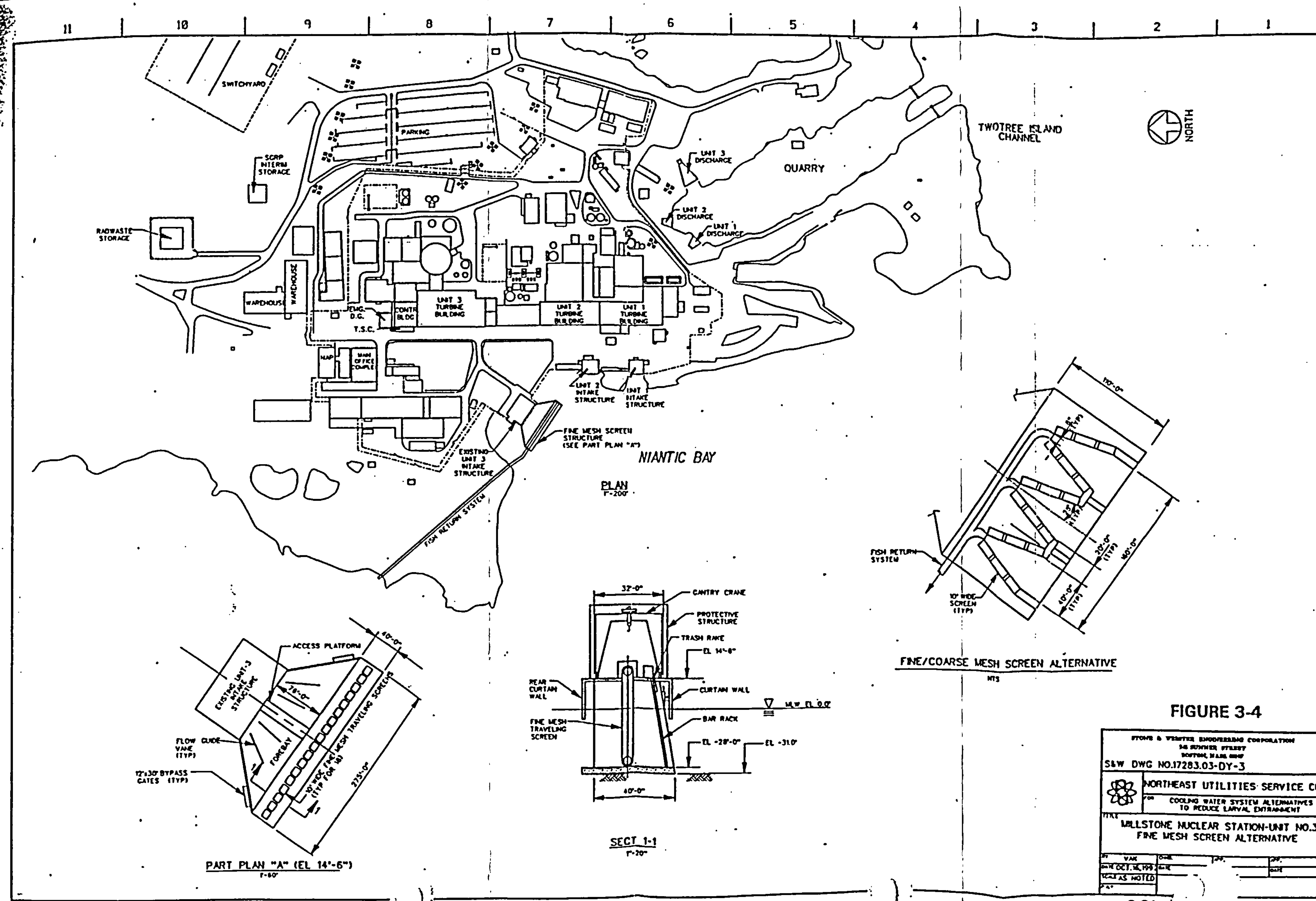

SWITCHYARD
PARKING
SCRP INTERIM STORAGE
RADWASTE STORAGE
WAREHOUSE
EMG. D.G.
T.S.C.
CONTR BLDG
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
UNIT 2 INTAKE STRUCTURE
UNIT 1 INTAKE STRUCTURE
UNIT 3 DISCHARGE
UNIT 2 DISCHARGE
UNIT 1 DISCHARGE
QUARRY
TWOTREE ISLAND CHANNEL
NORTH
FINE MESH SCREEN STRUCTURE (SEE PART PLAN "A")
EXISTING UNIT 3 INTAKE STRUCTURE
FISH RETURN SYSTEM
NIANTIC BAY
PLAN
ACCESS PLATFORM
EXISTING UNIT 3 INTAKE STRUCTURE
FLOW GUIDE VANE (TYP)
12'x30' BYPASS GATES (TYP)
FOREBAY
PART PLAN "A" (EL 14'-6")
GANTRY CRANE
PROTECTIVE STRUCTURE
TRASH RAKE
EL 14'-6"
REAR CURTAIN WALL
CURTAIN WALL
FINE MESH TRAVELING SCREEN
BAR RACK
EL -28'-0"
EL -31'0
SECT 1-1
FISH RETURN SYSTEM
10' WIDE SCREEN (TYP)
FINE/COARSE MESH SCREEN ALTERNATIVE
NTS
STONE & WEBSTER ENGINEERING CORPORATION
S&W DWG NO.17283.03-DY-3
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTRAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
FINE MESH SCREEN ALTERNATIVE
VAK
OCT.16,1992
AS NOTED

FIGURE 3-4

Having fewer moving parts, and with many moving parts located out of the water, the drum screen may offer some reliability advantages over the through-flow traveling screen. Drum screens have been used extensively at large intake facilities throughout the world (6) with service records comparable to through-flow screens.

Six 10-meter diameter by 4-meter width (32.8 feet by 13.1 feet) drum screen units would be required to screen the full design flow to the Unit 3 intake. This preliminary sizing was based on sizing charts provided by Hawker Siddeley Bracket Ltd. of Britain for a fine-mesh application (3 mm or less). These drum screens would require a structure approximately 255 feet wide by 50 feet long. Deck and channel inlet elevations would be the same as for the through-flow screen design. The screened water collection chamber would have to extend about 10 feet deeper under the screen to a depth of about -39 feet. The top of the rock is at about -40 feet in the proposed area.

The structure required for drum screens would be similar in size although different in detail to that for the through-flow screen structure. Based on the preliminary design, the drum screen arrangement does not offer major cost advantages compared to the through-flow arrangement. Pilot-scale testing for at least 1 year would also be required to confirm the effectiveness of the drum screen in handling flounder larvae and returning them to Niantic Bay alive.

3.4.4 REQUIRED TESTING

Full-scale prototype testing would be required to determine impingement and entrainment rates and the related mortality rates for the fine-mesh traveling screens. The debris removal capability of fine-mesh traveling screens would require testing to determine if an increase in debris matting or "stapling" brought about by the fine-mesh can be removed adequately. In addition, extensive testing would be required to verify the ability of fine-mesh traveling screens to perform reliably in the silty and corrosive environment of MNPS. The effects of increasing the screen travel speed to over 50 feet per minute would also require further evaluation and testing.

3.4.5 FINE-MESH SCREEN FACILITY FOR UNIT 3

For the reasons noted above, replacing the existing ⅜-inch opening screens with fine-mesh screens, is not a reliable technology for MNPS. Further, it is possible fine-mesh screens might cause as much mortality by increased impingement as they saved in entrainment.

The preliminary design for fine-mesh screens, as shown on **Figure 3-4**, would consist of constructing an entirely new through-flow screen structure for Unit 3 in front of the existing screen structure. The existing intake structure would remain functional with the existing traveling screens serving as backup screens in the event the fine-mesh screens become blocked. Bypass gates would be provided to direct flow around the fine-mesh screen structure.

Fine-mesh screens, applied to Unit 3 for winter flounder larvae, would be designed to block the larvae from entering the circulating water system and to safely transport impinged larvae back to Niantic Bay. The stage 3 larvae, which are most susceptible to entrainment into the MNPS intakes, are from 4.5 to 7.5 mm in length. The existing seasonal heavy trash loading at the MNPS intakes of eelgrass and kelp would require a design screen approach velocity of 0.5 fps for fine-mesh screens to prevent overloading of the screens during periods of heavy trash loading. The April and May time frame for greatest winter flounder entrainment is also a period of heavy eelgrass influx at the Unit 3 intake.

Full-scale prototype testing of a fine-mesh screen facility to confirm impingement and entrainment rates and the related mortality rates for winter flounder larvae is required before committing to this technology. Also the reliability of fine-mesh screen operation in the heavy detrital loading environment at MNPS would have to be confirmed during this prototype testing.

Design parameters for the screen structure are as follows:

Deck elevation	14 feet 6 inches
Invert elevation	-28 feet 0 inches
Design flow	912,000 gpm (2032 cfs)
Approach flow velocity to fine-mesh screen	0.5 fps
Screen unit width	10 feet

The deck elevation, invert elevation, and design flow would be the same as the existing intake. The 10-foot screen unit width would be selected because experience has shown that wider screen widths tend to result in less reliable operation and more maintenance. Through-flow screen units are available in widths up to 14 feet.

The number of screen units required was determined by calculating the required cross-sectional area needed to achieve a 0.5 fps approach flow velocity or less to the traveling screen. A 20 percent unscreenable area was assumed to account for the screen boot area and structural metal frame area between screen mesh. Flow velocity calculations were made

at mean low water (0.0 feet). This would result in eighteen 10-foot-wide screen units as shown in Figure 3-4.

The screen structure would be 40 feet wide by 276 feet long. It would include both upstream and downstream curtain walls extending down to a depth of -5 feet for ice, cold weather and floating debris protection. Bar racks would be provided to catch large debris that could damage the traveling screens. The structure would include open sluice fish return and a separate trash removal system. Fish would be sluiced to the west side of Bay Point and returned to Niantic Bay. Equipment included with the structure, in addition to the 18 fine-mesh traveling screens, would be:

- Mechanical trash rake
- Screenwash Systems including 6 screenwash pumps, each rated at 5000 gpm at 200 feet total dynamic head
- Gantry crane
- Fish return sluicing system
- Trash sluicing system
- HVAC for enclosure structure
- Control equipment
- Electric supply equipment

The fine-mesh screen structure would be joined to the existing Unit 3 intake by double sheet pile walls with tremie concrete placed between the sheet pile. Each wall would have a 12 foot by 30 foot bypass gate. These bypass gates would be sized to bypass ½ of the total design flow to the Unit 3 intake. The bypass system would be provided in the event that some or all of the fine-mesh screen units become blocked or inoperable and for the safety-related service water system.

The forebay, formed between the new fine-mesh screen structure and the existing Unit 3 intake, would have a system of flow guide vanes to create uniform flow conditions entering the existing intake. Hydraulic model studies would be required to properly design the guide vane system. The guide vanes shown in Figure 3-4 are conceptual and were used to develop material quantity estimates.

3.4.6 GEOTECHNICAL CONSIDERATIONS

The geology at the intake structure was documented by the "P" series boring on land and the "I" series boring offshore, seismic refraction and bathymetric surveys, and geological mapping during construction. The intake structure is founded directly on bedrock which was excavated where necessary to approximately elevation -40 feet after construction of a temporary offshore cofferdam. Prior to excavation, the bedrock surface was overlain by a dense basal till of approximately 20 feet in thickness. Twenty to 30 feet of glacial deposits of a looser nature and beach sands were found to overlie the till. These deposits were replaced by structural backfill around the Unit 3 intake structure.

In the area offshore of the intake structure, boring conducted 500 feet offshore indicate bedrock elevation is variable, ranging between -20 and -57 feet. Bedrock immediately offshore of the intake is likely at elevation -40 feet. Most borings indicate that bedrock is overlain by several feet of basal till although locally thicker deposits are possible. Overlying the till is a poorly graded, micaceous silty sand which forms the seafloor bottom. The seafloor bottom in the vicinity of the intake was modified during construction of that structure, as well as by dredging after construction. Immediately adjacent to the intake, the seafloor bottom elevation is at about -28 feet according to soundings taken in 1990 and slopes up seaward due to dredging modifications to about -16 feet.

No field permeability tests were conducted in any of the offshore overburden materials. Based on field/laboratory boring log descriptions and grain size distribution curves performed on similar soils obtained from onshore boring at the intake structure, it was estimated that hydraulic conductivity is approximately 10^{-4} cm/sec for the silty sands comprising the seafloor bottom.

3.5 WEDGEWIRE SCREENS

Wedgewire screens are passive and utilize "V" or wedge-shaped cross-section wire, welded to a framing system to form a slotted screening element as shown on **Figure 3-5a**. Where a relatively high velocity ambient current cross-flow exists to carry organisms around and away from the screen, cylindrical wedgewire screens can reduce impingement and entrainment. Ambient currents providing high velocity cross-flow are also necessary to provide continuous flushing of debris. Fixed wedgewire cylindrical screens need an open screen minimum of 40 percent, which requires slots of 1 mm or larger. Reducing the screen slot size to 0.5 to 1.0 mm, to achieve the most effective entrainment reduction, would reduce the open area to about 20 percent. Thus, wedgewire screens are normally less effective at reducing

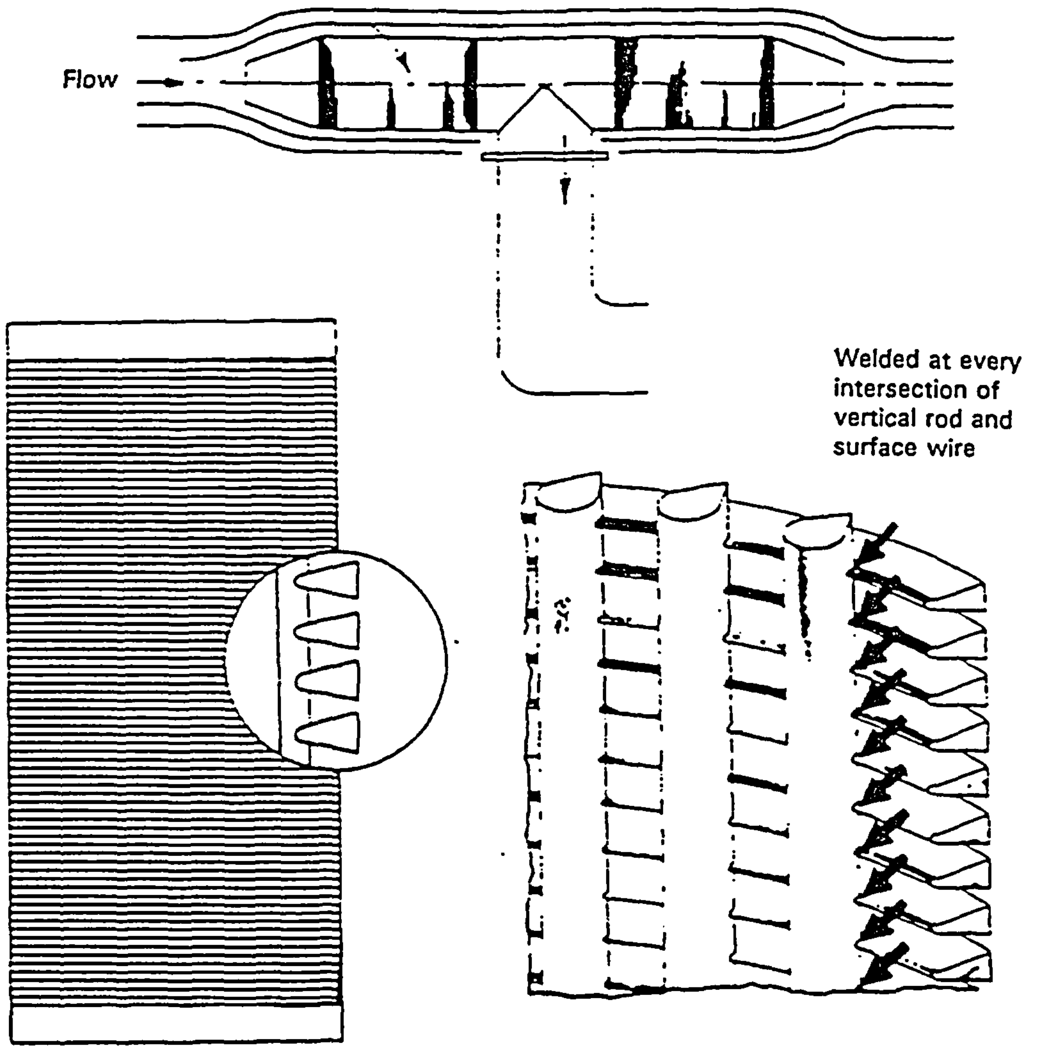


Figure 3-5a Wedgewire Screen Unit

entrainment than impingement, and in either case the effectiveness is highly dependent on the presence of the proper high velocity ambient cross-flows.

The J. H. Campbell Plant Unit 3 on Lake Michigan has employed a wedgewire screen intake system since November 1979 (12). The Campbell Plant's Unit 3 withdraws 340,000 gallons per minute (less than 20 percent of MNPS' total station flow) from an offshore location (3,500 feet from shore in 35 feet of water) through 28 fixed ⅜-inch (9.5-mm) screen units. Difficulties arose in the design and construction phases, but operating experience to date has been satisfactory and there has been no substantial clogging, biofouling, or ice damage. Such operating experience might be expected because of the large screen slot size and because of the relatively low debris loading in Michigan compared to the Niantic Bay near MNPS. Even so, the Campbell Plant has an alternate intake to supplement flow in case of severe blockage of the cylindrical screens. At the Campbell Plant's Unit 3 on Lake Michigan, the stainless steel screens have eliminated impingement of gizzard shad, smelt, yellow perch, alewife, and shiners and have required minimal maintenance. The screens are cleaned annually by water jets to reduce biofouling (algae) and the plant was forced to shut down once (spring 1984) due to anchor ice.

Philadelphia Electric Company installed a wedgewire screen intake system in June 1990 at its Eddystone Station Unit 1 on the Delaware River upstream of Salem (13). The Delaware River at the Eddystone Station is a relatively fresh water regime, although it is under some tidal influence and can be slightly brackish. The design flow for the combined Eddystone Units 1 and 2 is 440,000 gallons per minute, again only 23 percent of the flow at MNPS. The screen slot width is also quite large, ¼ inch (6.4 mm), which would provide no significant entrainment benefits for Unit 3. To date, the wedgewire screen intake system has performed acceptably. The Eddystone screens are backflushed by compressed air. To date, the air backflushing has maintained the pressure drop across the screens at a constant value slightly greater than the manufacturer's design pressure drop. However, it is too early to evaluate problems with biofouling. More severe problems with biofouling and corrosion would be expected at MNPS because of the higher salinities and greater tidal influence in Niantic Bay.

Wedgewire screens are still developmental with respect to MNPS. The flow rate at MNPS is much higher than at either Campbell or Eddystone, and neither of those installations used the small screen mesh sizes necessary to achieve entrainment benefits. The Campbell Plant installation is not estuarine and Eddystone is in an upstream, more fresh-water environment. Total suspended solid and sand loads at MNPS are higher than at the other two plants. Detritus, eelgrass, and kelp loads are also high; MNPS has had a history of screen blockage and collapse. During the years of operation, there was a significant amount of plant outage time attributed to screen problems. Improved traveling screens were installed in the Unit 3

intake in 1991 which alleviated some of these problems. Ambient flow velocities approach zero at slack tides and currents are variable with tide, so that the high velocity cross-flows necessary for screen flushing and biological efficacy are not always assured. Further, under any tidal conditions there is a question of whether the necessary high velocity ambient cross-flows can exist in the presence nearly 1 million gpm plant withdrawal flows. Salinity is higher in the seawater environment than in previous applications. Biological fouling and detritus wrapping around the screens could be resistant to cleaning by compressed air backflush. Thus, biofouling and detrital loading could present very serious operating impediments.

On-site testing and hydraulic modeling would be necessary to determine whether and to what extent the necessary high-velocity cross-flow currents exist, in order to obtain adequate screen cleaning action, and to determine whether: (1) the necessary low velocities could be obtained, given the operating difficulties and (2) adequate ambient high-velocity cross-flow currents exist (particularly at slack tide) to achieve any reduction in entrainment and impingement of aquatic life. Biological and hydraulic research would, in general, be needed to demonstrate the viability and effectiveness of a wedgewire screen system for MNPS.

Both pilot and full-scale testing at the site would be required to determine biological effectiveness, maintainability, effects of silt and biofouling deposits, and material compatibility of the wedgewire screens in the water environment at MNPS. Testing would require installation of a full-scale prototype wedgewire screen intake in front of one or more of the circulating water pumps and operating it for 1 year or longer. Biological considerations, engineering performance, and cost would have to be evaluated. No amount of testing, however, could adequately predict the severity of probable siltation problems with the complete system.

Two alternate intake arrangements utilizing wedgewire screens were developed for application to Unit 3 including the staggered array and the bulkhead design. The first alternative design concept, called the staggered array concept would consist of six collector conduits that would be buried in the sea floor in the area in front of the existing Unit 3 intake. The collector conduits would be equipped with nine wedgewire tee screen units which would extend up from the sea floor. These collector conduits would terminate at a common plenum structure that would be constructed directly in front of the existing Unit 3 intake structure. The Unit 3 intake structure would remain intact and functional. The existing traveling screens would remain in place and would provide backup screening capability in the event the wedgewire screens become blocked. Bypass gates would be provided to bypass ½ of the Unit 3 circulating water flow. An automatic, compressed air system would backflush each of the tee screen units, one at a time. A separate Category I flow passage (not shown) would be

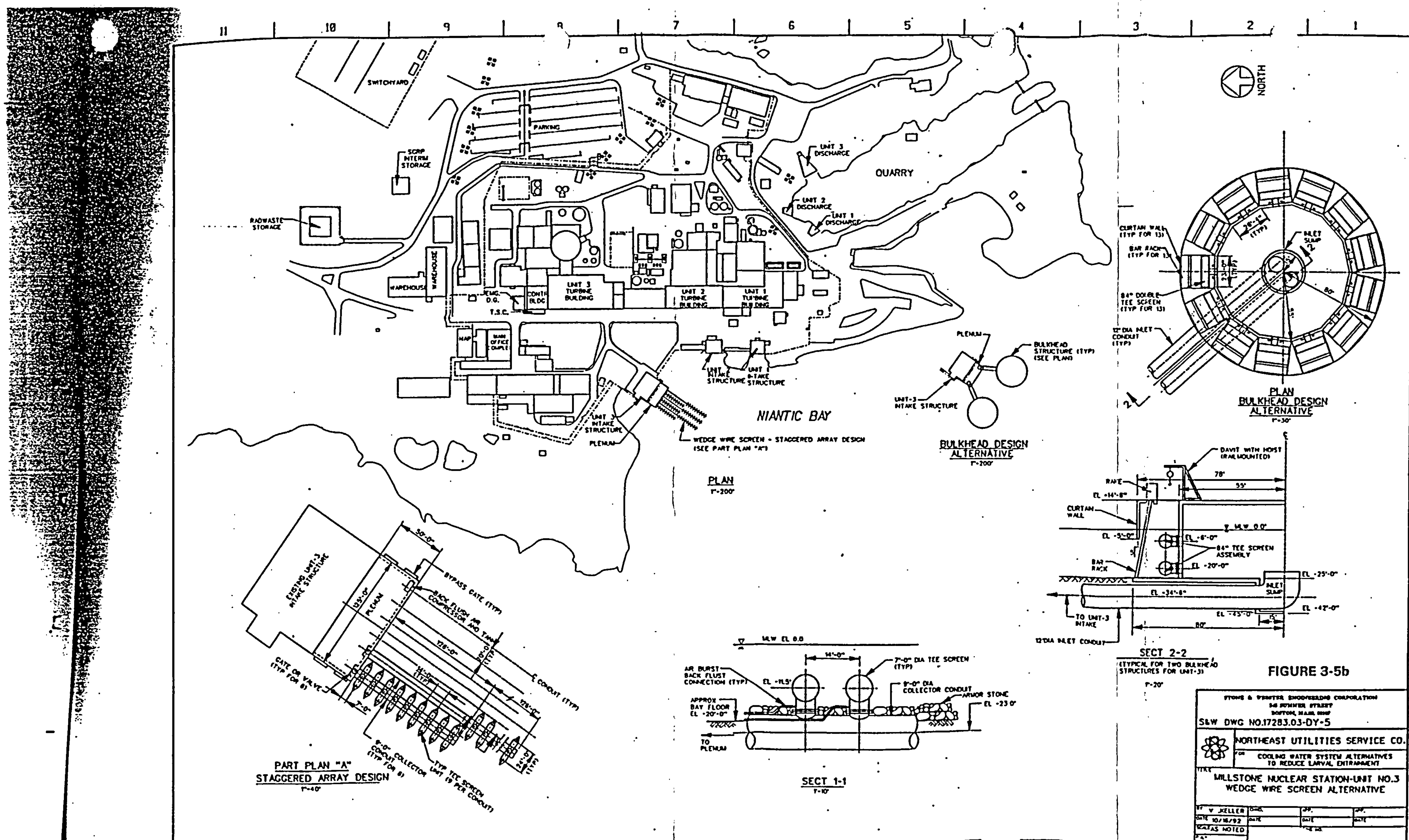
provided for the service water pumps. Cost estimates were developed for the staggered array concept.

The second alternative wedgewire screen arrangement would be a bulkhead design. In the bulkhead design, the tee screen assemblies would be mounted around a 13-sided bulkhead structure. Two of these bulkhead structures, each having 26 tee screens, would be required to handle the full Unit 3 circulating water flow. Water from the bulkhead structures would be directed through buried conduits to a common plenum structure that would be constructed directly in front of the existing Unit 3 intake, similar to the plenum for the staggered array design. The bulkhead design with deck above water would allow lifting, cleaning, and replacement of tee screen assemblies without divers. The bulkhead structures would also have bar racks and curtain walls similar to conventional intakes which would protect the tee screen units from damage caused by large floating debris. The bulkhead design would also incorporate a compressed air system for backflushing the tee screen units. Each bulkhead structure would be joined to the plenum structure by a bridge capable of supporting small vehicles for maintenance. Costs were not developed for the bulkhead concept. The large bulkhead structures would be expected to add significantly to the cost of this alternative as compared to the staggered array design. These proposed conceptual designs are shown on **Figure 3-5b**.

3.5.1 STAGGERED ARRAY DESIGN

The staggered array wedgewire screen intake system would be sized to handle the full Unit 3 circulating water flow of 912,000 gpm. The screen slot width would be selected to exclude the stage 3 winter flounder larvae, which are 4.5 to 7.5 mm in length. For preliminary design, a screen slot width of 1 mm was selected. The manufacturer's sizing criteria for these wedgewire screen units was based on a through-screen-flow velocity of 0.5 fps.

Using this sizing criteria, a total of 54 tee screen units, 85 inches in diameter by approximately 24 feet long, would be required to pass the 912,000 gpm circulating water pump flow to Unit 3. These 54 tee screen assemblies would be arranged on six 108-inch diameter conduits with 9 tee screen units per conduit that would be buried in the sea floor in front of the existing Unit 3 pump structure. The screen arrays on the conduits would be staggered as shown on **Figure 3-5b**. The staggering would prevent crowding of the screens and would promote better natural debris flushing characteristics. The six 108-inch conduits would terminate at a plenum structure that would be constructed directly in front of the existing pump structure. Each conduit would require a sluice gate or knife gate valve at the plenum for isolation.



NORTH
SWITCHYARD
PARKING
SCRP INTERIM STORAGE
RADWASTE STORAGE
WAREHOUSE
UNIT 3 DISCHARGE
UNIT 2 DISCHARGE
UNIT 1 DISCHARGE
QUARRY
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
EMG. D.G.
CONT BLDG
T.S.C.
UNIT 1 INTAKE STRUCTURE
UNIT 2 INTAKE STRUCTURE
UNIT 3 INTAKE STRUCTURE
PLENUM
NIANTIC BAY
WEDGE WIRE SCREEN - STAGGERED ARRAY DESIGN (SEE PART PLAN "A")
PLAN
1"=200'
PLENUM
BULKHEAD STRUCTURE (TYP) (SEE PLAN)
UNIT-3 INTAKE STRUCTURE
BULKHEAD DESIGN ALTERNATIVE
1"=200'
CURTAIN WALL (TYP FOR 13)
BAR RACK (TYP FOR 13)
84" DOUBLE TEE SCREEN (TYP FOR 13)
12" DIA INLET CONDUIT (TYP)
INLET SUMP
80'
PLAN
BULKHEAD DESIGN ALTERNATIVE
1"=30'
DAVIT WITH HOIST (RAIL MOUNTED)
RAKE
EL +14'-8"
CURTAIN WALL
MLW 0.0'
EL -5'-0"
EL -6'-0"
84" TEE SCREEN ASSEMBLY
BAR RACK
EL -20'-0"
EL -25'-0"
INLET SUMP
EL -34'-8"
EL -42'-0"
EL -45'-0"
TO UNIT-3 INTAKE
12'DIA INLET CONDUIT
78'
55'
80'
SECT 2-2
(TYPICAL FOR TWO BULKHEAD STRUCTURES FOR UNIT-3)
1"=20'
EXISTING UNIT-3 INTAKE STRUCTURE
PLENUM
BYPASS GATE (TYP)
BACK FLUSH AIR COMPRESSOR AND TANK
50'-0"
125'-0"
126'-0"
CONDUIT (TYP)
GATE OR VALVE (TYP FOR 8)
9'-0" COLLECTOR CONDUIT (TYP FOR 8)
TYP TEE SCREEN UNIT (9 PER CONDUIT)
PART PLAN "A"
STAGGERED ARRAY DESIGN
1"=40'
MLW EL 0.0
14'-0"
7'-0" DIA TEE SCREEN (TYP)
AIR BURST-BACK FLUSH CONNECTION (TYP)
EL -11.5'
9'-0" DIA COLLECTOR CONDUIT
ARMOR STONE
APPROX BAY FLOOR EL -20'-0"
EL -23.0'
TO PLENUM
SECT 1-1
1"=10'
STONE & WEBSTER ENGINEERING CORPORATION
S&W DWG NO.17283.03-DY-5
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTRAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
WEDGE WIRE SCREEN ALTERNATIVE
V KELLER
10/16/92
AS NOTED
MPSITE9.DGN
OCT 27 1992

FIGURE 3-5b

The plenum structure would be a 50-foot by 125-foot reinforced concrete structure that would provide a common flow chamber to distribute flow to the existing pump bays. The plenum structure would be equipped with gates to bypass the wedgewire screen system in the event it became blocked. A separate Category I bypass (not shown) would be provided for the service water pumps. Because the service water system is nuclear safety related, the design would be nuclear safety-related Category I and would be subject to Nuclear Regulatory Commission review and approval. This area was not addressed in detail.

The wedgewire screen units would be periodically backflushed with a compressed air scouring system. The compressed air or air burst scouring system would consist of an air compressor, a compressed air tank, a compressed air piping system capable of delivering a burst of compressed air to each individual tee screen assembly, one at a time, air-actuated valves, and an automatic control system. Backflushing would be accomplished by discharging the entire compressed air charge in the air tank to the screen assembly to be backflushed. The compressor would then recharge the tank to the required pressure and the process repeated for the next screen assembly to be cleaned. The 84-inch tee screen assemblies are normally supplied with 6-inch air pipe connections. The preliminary design would use 6-inch air pipe and connections. The air compressor and tank would be sized to backflush one tee screen assembly, one at a time, with a ½-hour interval. The required pressure in the compressed air tank would be approximately 150 psi. This would require a compressor size of 40 horsepower. The compressor, compressed air tank, and control system would be located on the deck of the plenum as shown on **Figure 3-5b**.

Biofouling of the 108-inch diameter conduits connecting the screen units to the plenum would be a potential problem and a chlorination injection system could be required. This was not addressed in detail.

The screen units would be fabricated of copper nickel to take advantage of the biocidal properties of the copper to control biofouling.

The design presented and cost estimate developed would be for a full-size installation. This design concept could be used for one circulating water pump or any combination of the six pumps.

3.5.2 ALTERNATIVE BULKHEAD DESIGN

An alternative design concept for wedgewire screens for Unit 3 would be a bulkhead structure. The tidal ebb and flow and periodic high detrital environment of the intake provide a far less than optimum environment for the wedgewire screens. If a significant number of

the tee screen assemblies of the staggered array design were severely blocked by kelp or eelgrass, the air burst backflush system may not be capable of reestablishing flow. In such case, the wedgewire screen system would have to be bypassed and divers employed to clear the blocked screen units. The bulkhead design would incorporate standard coarse-bar racks in front of the wedgewire screen units and a mechanical trash raking system to handle large debris. A mechanical trash rake and trash bin would be mounted on rails along the circumference of the structure for removing debris from the bar racks. This system would provide some protection against blockage by large debris. The bulkhead structure with deck above water would also allow each tee screen unit to be lifted individually from the water for draining and maintenance without the use of divers.

A preliminary bulkhead wedgewire screen structure design is shown on **Figure 3-5b**. Two ½ size structures would be proposed, each sized to handle ½ of the Unit 3 circulating water flow. The outline of the structures would be circular with a diameter of 160 feet. The structure would mount 26 tee screen units that would be arranged in double screen assemblies. The double tee screen assemblies would be mounted on bulkheads forming a 13-sided structure as shown on **Figure 3-5b**. Each tee screen assembly would be mounted in a set of slots which project vertically upward to the structure deck. Track-mounted davits with hoists would be located on the deck and could lift each screen assembly up to the deck for maintenance through the slots provided. Outboard of the tee screen units, the structure would include a curtain wall for protection from floating debris. Two 12-foot diameter inlet conduits would draw water from a central sump in the bulkhead structure. These unit conduits would pass under the bulkhead structures and terminate at a plenum in front of the existing Unit 3 intake, similar in design to that proposed for the staggered array concept. Each inlet conduit would have a sluice gate or valve for isolation (not shown). Each bulkhead structure would be connected to the plenum structure or the adjacent shore by a bridge which would allow truck access to the bulkhead structure deck for maintenance.

Each bulkhead wedgewire screening structure would have its own air burst backflush system, similar in design to that proposed for the staggered array screening system.

The bulkhead wedgewire screening system would be a full-size design using two ½-size bulkhead structures. This design could also be sized for a single circulating water pump.

3.5.3 GEOTECHNICAL CONSIDERATIONS

The geology at the intake structure was documented by the "P" series boring on land and the "I" series boring offshore, seismic refraction and bathymetric surveys, and geological mapping during construction. The intake structure is founded directly on bedrock which was excavated

where necessary to approximately elevation -40 feet after construction of a temporary offshore cofferdam. Prior to excavation, the bedrock surface was overlain by a dense basal till of approximately 20 feet in thickness. Twenty to 30 feet of glacial deposits of a looser nature and beach sands were found to overlie the till. These deposits were replaced by structural backfill around the Unit 3 intake structure.

In the area offshore of the intake structure, borings conducted 500 feet offshore indicate bedrock elevation is variable, ranging between -20 and -57 feet. Bedrock immediately offshore of the intake is likely at elevation -40 feet. Most borings indicate that bedrock is overlain by several feet of basal till although locally thicker deposits are possible. Overlying the till is a poorly graded, micaceous silty sand which forms the seafloor bottom. The seafloor bottom in the vicinity of the intake was modified during construction of that structure as well as by dredging after construction. Immediately adjacent to the intake, the seafloor bottom elevation is at about -28 feet according to soundings taken in 1990 and slopes up seaward due to dredging modifications to about -16 feet.

No field permeability tests were conducted in any of the offshore overburden materials. Based on field/laboratory boring log descriptions and grain size distribution curves performed on similar soils obtained from onshore boring at the intake structure, it was estimated that hydraulic conductivity is approximately 10^{-4} cm/sec for the silty sands comprising the seafloor bottom.

3.6 DIVERSION SILLS AND CURTAIN WALLS

Two alternative diversion system designs were developed. The first was a passive design that would consist of a diversion sill on the bay bottom constructed of precast concrete Jersey-barrier units that would be placed in front of the existing Unit 3 intake structure forming an angled barrier. This design would take advantage of the tendency of flounder larvae to reside at or near the bottom of the bay during daylight hours. It should be noted, however, that this design would not prevent nighttime entrainment. This barrier would divert silt and other debris being carried along the bottom by tidal currents away from the Unit 3 intake. As part of the design, an array of diversion vanes also constructed of Jersey-barrier units would be arranged along the outboard side of the barrier to scour silt away and prevent silt from filling-in the front of the barrier.

The alternative design would be a floating barrier or curtain wall, that would be constructed on piles. An air bubbler floatation system would be used for floating the flounder larvae to the surface. This diversion system would work on the principal that the rising air bubbles

could potentially float the larvae. The curtain wall, arranged at an angle to the intake, would then divert the larvae away from the intake. Preliminary designs for the submerged diversion sill and the curtain wall with air bubbler are shown on **Figure 3-6.**

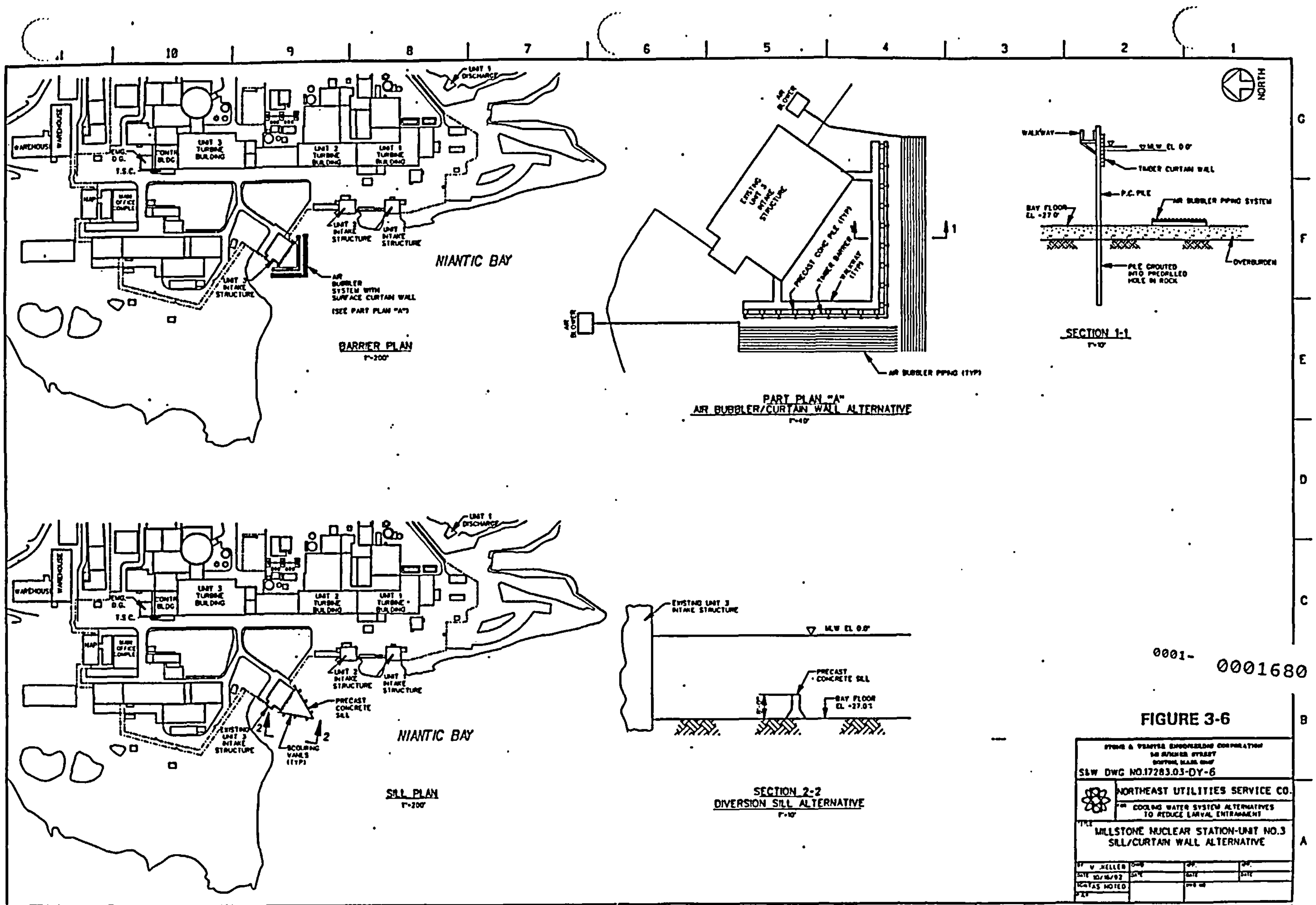
Both options were considered only experimental with respect to entrainment mitigation.

3.6.1 SUBMERGED DIVERSION SILL

The submerged diversion sill is a V-shaped barrier on the bay floor that would be constructed directly in front of the Unit 3 intake as shown on **Figure 3-6.** The barrier would be constructed of Jersey-barrier concrete units, 6 feet in height. This design could divert some portion of flounder larvae away from the intake during daylight hours when they reside at or near the bottom. The V shape with an interior angle of approximately 50 degrees (or 25 degrees to the flow) would be designed to divert the larvae to the sides of the intake in the incoming flow. The 50-degree angle was selected based on the experience with angled screens for fish diversion (9),(10),(11) as effective for diverting fish. It is probable that the larvae would be carried up and over a straight barrier arranged normal to the incoming flow to the intake. Although this design is a passive system, dredging to remove silt build-up may be required.

A build-up of silt, if left uncorrected, would render the sill ineffective as a diversion barrier for flounder larvae. To reduce this potential problem, an array of scouring vanes, arranged along the outboard sides of the diversion sill, would be required as part of the design. Work by Odgaard (14) has shown that arrays of submerged scouring vanes could be effective in diverting silt away from intakes.

The potential effectiveness of the system in diverting winter flounder larvae at MNPS could only be determined by a more detailed analysis, hydraulic modeling and by placing the barrier and testing it in place. There could be considerable difficulty in attempts to quantify the effectiveness of this option and there are no installations which could be used for comparative purposes. The variability of larval density in the water column raises questions on attempts to quantify effectiveness. This option could also disrupt existing flow patterns and possibly increase debris loads and larval entrainment at Units 1 and 2.


NORTH
NIANTIC BAY
UNIT 3 TURBINE BUILDING
UNIT 2 TURBINE BUILDING
UNIT 1 TURBINE BUILDING
UNIT 1 DISCHARGE
WAREHOUSE
T.S.C.
UNIT 2 INTAKE STRUCTURE
UNIT 1 INTAKE STRUCTURE
UNIT 3 INTAKE STRUCTURE
AIR BUBBLER SYSTEM WITH SURFACE CURTAIN WALL
(SEE PART PLAN "A")
BARRIER PLAN
1"=200'
AIR BLOWER
EXISTING UNIT 3 INTAKE STRUCTURE
PRECAST CONC PILE (TYP)
TIMBER BARRIER
WALKWAY (TYP)
AIR BUBBLER PIPING (TYP)
PART PLAN "A"
AIR BUBBLER/CURTAIN WALL ALTERNATIVE
1"=40'
WALKWAY
M.L.W. EL 0.0'
TIMBER CURTAIN WALL
P.C. PILE
AIR BUBBLER PIPING SYSTEM
BAY FLOOR EL -27.0'
OVERBURDEN
PILE GROUTED INTO PREDRILLED HOLE IN ROCK
SECTION 1-1
1"=10'
EXISTING UNIT 3 INTAKE STRUCTURE
PRECAST CONCRETE SILL
SCOURING VANES (TYP)
SILL PLAN
1"=200'
M.L.W. EL 0.0'
PRECAST CONCRETE SILL
BAY FLOOR EL -27.0'
SECTION 2-2
DIVERSION SILL ALTERNATIVE
1"=10'
0001-
0001680
FIGURE 3-6
STONE & WEBSTER ENGINEERING CORPORATION
S&W DWG NO.17283.03-DY-6
NORTHEAST UTILITIES SERVICE CO.
COOLING WATER SYSTEM ALTERNATIVES TO REDUCE LARVAL ENTRAINMENT
MILLSTONE NUCLEAR STATION-UNIT NO.3
SILL/CURTAIN WALL ALTERNATIVE

3.6.2 CURTAIN WALL WITH AIR BUBBLER

The barrier with air bubbler floatation system would be designed to float flounder larvae up to near the surface and then divert them away from the intake with an angled curtain wall. The curtain wall would consist of a barrier constructed of timber or nonmetallic synthetic material that would be supported by precast concrete piles as shown on **Figure 3-6**. The barrier would incorporate a float system (not shown) that would allow the barrier to slide up and down on the piles with the tide while maintaining a constant depth. The barrier would be serviceable by a walkway which would be connected to the Unit 3 intake structure at either end of the barrier.

The air bubbler system would consist of multiple (10 to 15) diffuser pipes that would be mounted on the sea floor on a concrete pad. Air blowers to provide air to the diffuser pipes would be located on the shore as shown on **Figure 3-6**. Two air bubbler systems would be provided, one for each leg of the angled barrier. The multiple pipe air bubble diffuser arrangement would be designed to create a wide curtain of bubbles that could effectively float the flounder larvae. This multiple air bubbler diffuser pipe arrangement has been used by the Swedes to float jellyfish. The air bubbler system would be located a distance in front of the floating barrier to allow complete floatation of the larvae in the approaching flow to the intake. The submerged position of the air bubbler system would be removable when not required for service.

Both laboratory and site testing would be required to develop reliable design criteria for this system and confirm effective performance at the MNPS intakes. This design concept, like the submerged barrier, may divert a portion of floating eelgrass and kelp away from the intake.

3.7 PLANT OPERATIONAL STRATEGIES

3.7.1 POWER AND FLOW REDUCTION

A reduction in the power output of the MNPS units does not have a corresponding reduction in the required cooling-water flow. Significant flow reduction can only be achieved by shutting down one or more of the circulating water pumps. Various scenarios of circulating water pump flows to achieve approximately 25 percent total flow reduction are shown in **Table 3-1**.

0001- 0001681

TABLE 3-1

MNPS UNITS CIRCULATING WATER PUMP vs FLOW REDUCTION

Option	Unit 1 (gpm)	Unit 2 (gpm)	Unit 3 (gpm)	Total (gpm)	% of Goal
1 Pump from each Unit	105,000	137,000	152,000	394,000	84
2 Unit 3 Pumps, 1 Unit 2 Pump	-	137,000	304,000	441,000	94
2 Unit 3 Pumps, 1 Unit 2 Pump, 1 Unit 1 Pump	105,000	137,000	304,000	546,000	116

NOTE: 25 percent of Total Flow = 0.25 (1,880,000) = 470,000 gpm = Goal

There are several negative aspects associated with operating one of the MNPS units during the spring season with one or more circulating water pumps isolated. The most important of these is vulnerability to an automatic plant trip if an operating pump were to trip. It also causes the condenser pressure to increase and the Institute of Nuclear Power Operation (INPO) thermal performance goals to degrade. Depending upon other plant factors it could also result in a significant loss of power output. Other issues which would require additional study are the NPDES permit restriction on differential temperature between the intake structure and discharge (which would be exceeded under some operating conditions) and the impact on backflushing capability, mussel cooks, and hypochlorite injection.

The challenge to safety posed by purposefully operating an MNPS unit at a state of readiness which is far less than optimum during the time of year when high energy storms have historically caused problems is not acceptable from an engineering or plant management perspective. It is, therefore, prudent to investigate variable/multispeed circulating water pumps.

3.7.2 VARIABLE-SPEED PUMPS

Variable-speed driver for the circulating water pumps would allow reduction in circulating water flow during periods of flounder larval activity. A two-speed drive which would operate the circulating water pumps either at rated flow or at ½-rated flow was evaluated in this section.

3.7.2.1 Hydraulic and Pumping Energy Requirements for ½ Speed Operation

Reduction in the pump speed to ½ would result in transposition of the pump performance curve to flows equal to ½ of the existing curve and total dynamic heads of ¼ of the existing curve according to pump affinity laws (15). The actual ½-speed pump flow rate was determined by superimposing the repositioned 6-pump curve for 6 pumps operating at ½ speed on to the circulating water resistance curve as shown on **Figure 3-7**. Reducing 6 circulating water pumps to ½-speed would result in each pump operating at a flow of 76,000 gpm at a total dynamic head of 6.5 feet. This would result in a reduced power requirement for each pump from the existing 1,500 to 170 horsepower. The 76,000 gpm was exactly ½ of the design pump flow of 152,000 gpm. This total reduction in pumping energy requirements for ½-speed operation would be 5,950 kW.

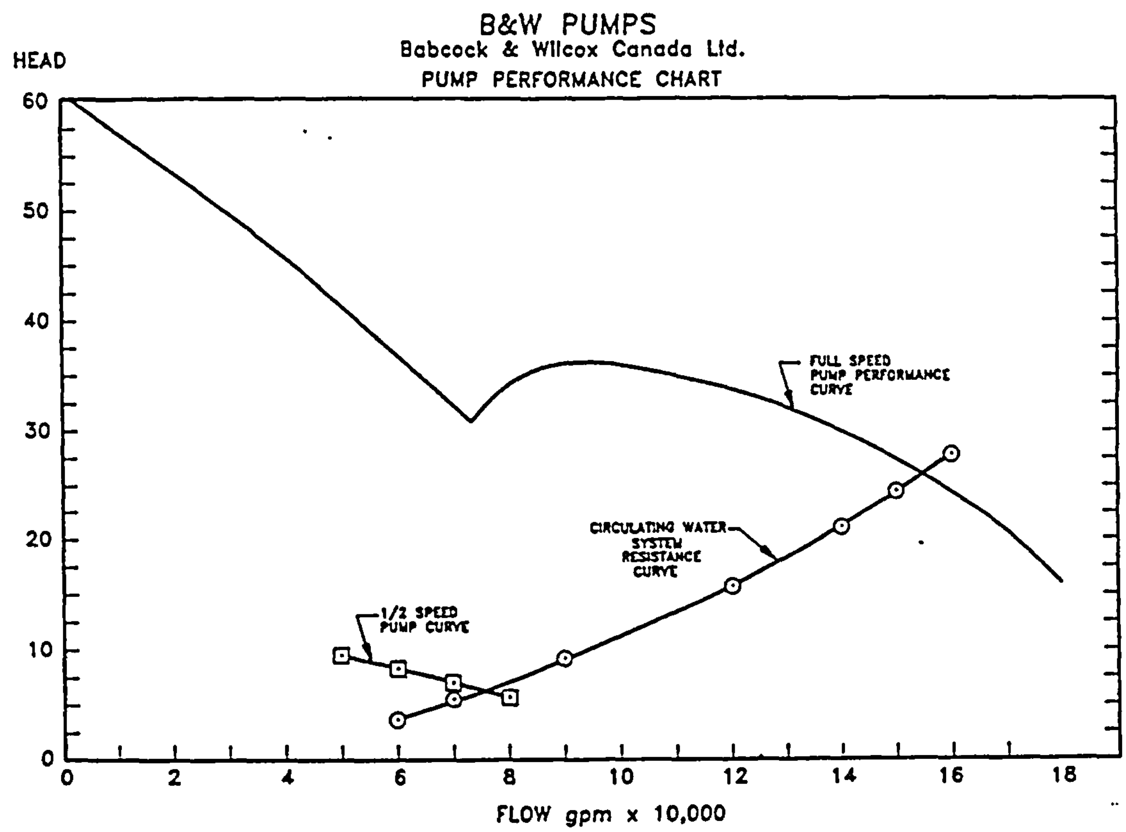


Figure 3-7 Pump Performance Curve

3.7.2.2 Two-Speed Electric Motors

A circulating water flow decrease to ½ could be achieved by decreasing the motor synchronous speed from 277 to 139. This could be accomplished either by a variable-speed drive or by a two-speed motor. It was decided to provide an estimate for only the two-speed motor option. The variable-speed drive was eliminated for the following reasons:

1. Only two speeds are required.
2. The cost of each system was approximately equal, $275,000.
3. The space requirements: For the system investigated, each drive system would occupy an indoor area 394 inches long x 48 inches deep x 90 inches high and an outdoor area 57 inches deep by 93 inches wide by 100 inches high. Other systems would require comparable area.

The six existing 4 kV, 1,500 horsepower, 277 rpm vertical circulating water pump motors would be replaced with 2-speed, 4 kV, 1,500 horsepower, 277 rpm motors. The motor would be based on the concept of pole amplitude modulation (PAM) and the license to this design is held exclusively by Westinghouse. An estimated price was also obtained for a conventional two-speed, double winding motor. The price of this motor was in excess of $200,000 more per motor than the PAM motor. Even the PAM motor would be a large motor, approximately 45,000 pounds, which is 20,000 pounds more than the existing motors.

Power would still be provided to the motors from the six breakers located on buses 34A and B. However, a two-speed motor starter would be required for each motor to reconnect the windings to change the motor speed. The motor starters would be controlled from control switches mounted on the main control board. The screenwell structure is neither a suitable environment nor does it have adequate space to locate this equipment. Therefore, the cost of a heated and ventilated building, 30 feet long x 25 feet wide x 12 feet high, was included to house the starters. It was assumed that the existing circulating and service water pumphouse would provide power for the new building heating and ventilating, and lighting. The building would be located in front of the circulating and service water pumphouse.

As part of the estimate, it was also assumed that existing motor feeder cables would be pulled back to the manhole nearest the circulating and service water pumphouse. This is approximately 300 feet from that structure. A new ductline from the existing manhole to the new starter building would be included. The existing cables would then be pulled and connected to the two-speed motor starters. Finally, new ducts from the motor starter building to the existing circulating and service water building with new motor feeder cables would be included.

A cursory check of the existing installation indicated that the foundations were adequate. However, if this alternative were pursued, an extensive investigation of the foundations would be required.

3.7.2.3 Impact on Unit Performance

Reduction in circulating water flow rate to ½ in each condenser tube bundle during the months of April and May would result in a reduction in unit performance of 32,840 kW for each month. This reduction to unit performance would be due to the reduced flow in the condenser tubes and reduction in the heat transfer efficiency of the condenser tubes due to reduced tube flow velocities. A 90 percent cleanliness factor could only be maintained with on-line ball cleaning at reduced tube flow velocities. Currently, Unit 3 does not have an on-line tube cleaning system. Capital cost of this cleaning system would be about one million dollars.

Without on-line tube cleaning, the condenser tubes would foul. Unit 3 load would have to be reduced to as much as ½ to avoid turbine trip. Because of the fouling buildup of slime in the tubes during ½-flow operation, condenser tube cleanup could be necessary following reduced flow operation before full flow and unit operation could be resumed.

This would lead to a vulnerability similar to that described earlier for operation with one or more circulating water pumps isolated. Therefore, this alternative would require additional study of condenser vacuum imbalance and associated issues to determine if the plant could continue safe operation with significant condenser fouling and less than maximum cooling-water flow.

3.7.3 SCHEDULED REFUELING OUTAGES

Refueling outages are generally targeted for periods of low electrical demand and, hence, most refueling outages are scheduled for the spring and fall. The outage schedule also takes into account factors such as fuel nucleonics (usable life), required upgrades to plant equipment, required inspections, regulatory commitments, safety, maintenance concerns, and available manpower. Factors that could influence the actual versus scheduled outage include safety, duration of a previous outage, equipment malfunction or failure, and inspection or surveillance failure.

The scheduled refueling outages for MNPS are shown in **Table 3-2**. As shown, the Unit 1 scheduled refueling outages occur in the even numbered years and coincide with a portion of the average winter flounder larval entrainment period of April through mid-June. Unit 2's

scheduled outages are also even-numbered, although the dates are subject to change based upon completion of the Steam Generator Replacement Project. Unit 3's scheduled outages occur in odd-numbered years and also coincide with a portion of the winter flounder larval entrainment period. If all plant operation and refueling outages went as scheduled, then planned outages at Unit 1 (even-numbered years) and Unit 3 (odd-numbered years) could coincide with the larval entrainment period each spring.

Several refueling outages have in fact taken place during all or portions of the larval entrainment period, and the refueling outage schedule indicates that this will probably continue. A review of past MNPS refueling outages indicated that four refueling outages occurred during the dates shown in **Table 3-3**. There were another three refueling outages that took place for portions of the time periods shown in **Table 3-3**. It should be noted that cooling-water flow is not terminated during refueling outages; however, the durations shown in **Table 3-3** compensate for continued flow and would result in MNPS flow reduction of approximately 25 percent, except for Unit 2 which achieves a maximum of about 13 percent. For further detail in understanding how these dates were established, refer to Section II, Part 4.

TABLE 3-2

**MILLSTONE STATION
REFUELING OUTAGE SCHEDULE
1993-2003**

Plant	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Unit 1		Feb. 19- May 2		Mar. 25- June 5		Apr. 29- July 1		May 25- Aug. 5		July 4- Sept. 14	
Unit 2		July 1- Sept. 11		June 23- Sept. 3		July 19- Sept. 29		Aug. 14- Oct. 25		Sept. 10- Nov. 21	
Unit 3	Aug. 8 Oct. 19		May 24- Aug. 4		May 20- July 31		May 18- July 29		May 14- July 25		May 11- July 22
CY*	May 22- Aug. 2	Dec. 9- Feb. 19		Aug. 10- Oct. 21		Aug. 11- Oct. 22		Aug. 9- Oct. 20		Aug. 18- Oct. 29	
Seabrook *		Mar. 26- June 6	Oct. 15- Dec. 26		May 6- July 17	Nov. 26- Feb. 6		June 17- Aug. 28		Jan. 14- Mar. 26	

* The outages for CY and Seabrook are shown to illustrate the potential impact in changes to the refueling schedule.

TABLE 3-3

APPROXIMATE OUTAGE DURATIONS
AT MNPS FOR 25 PERCENT ENTRAINMENT MITIGATION

PLANT(S)		CALENDAR DATE *		ELAPSED
Single	Combination	Start	Finish	Days
Unit 1	-	April 2	June 13	73
Unit 2**	-	April 2	June 13	73
Unit 3	-	April 2	June 6	66
-	Unit 1 & Unit 2	April 2	June 6	66
-	Unit 1, Unit 2, & Unit 3	April 22	May 12	21

NOTE:
* Rationale for date selection is described in Part II of this report.
** Maximum attainable mitigation for Unit 2 is 13 percent.

Unplanned outages are common and have a potentially significant impact on the scheduled refueling outages for a nuclear unit as well as the other nuclear units owned by NUSCO. This is due to the nuclear fuel burn-up cycle. Interruptions in plant operation during a particular fuel cycle essentially extend the life (or cycle) of the particular fuel. This could potentially postpone the required date for refueling. Changes to the refueling schedule for one nuclear unit potentially changes the schedule for the other units.

Because fuel purchases must be planned in advance, there are design costs and carrying charges to consider when deciding on a refueling outage schedule change. The costs associated with nuclear fuel procurement, fuel cycle redesign, and carrying charges are significant; up to $½ million could be expended in cycle redesign and carrying charges. Flexibility in the refueling outage schedule is obviously important.

Although a detailed cost estimate and engineering analysis of all the issues associated with rescheduling the Unit 1 and Unit 3 refueling outages to coincide more precisely with Table 3-3 was not performed, preliminary indications were that a one-time adjustment to the outage schedule would not be very difficult or costly. However, it would not be possible to maintain that schedule every year without exception, even with extraordinary and costly engineering and nuclear fuel procurement strategies, unless forced outages were to occur each spring.

3.7.4 FORCED OUTAGES EACH SPRING

A forced outage each spring to coincide with 25 percent mitigation of an average winter flounder larval entrainment year is shown in **Table 3-3**. While this option does not significantly affect fuel nucleonics (the next refuel outage can be extended to allow fuel burn-up), it would be a severe economic burden to NUSCO and the ratepayers as shown on Table 3-4.

TABLE 3-4

**FORCED OUTAGE COST ESTIMATE
FOR 25 PERCENT
ENTRAINMENT MITIGATION**

Scenario	Cumulative Replacement Power Costs in Millions of 1992 $
Unit 1 Offline 4/2 to 6/13	$214
Unit 2 Offline 4/2 to 6/13	$307
Unit 1 & Unit 2 Offline 4/2 to 6/6	$519
Unit 3 Offline 4/2 to 6/6	$310
Unit 1, Unit 2, & Unit 3 Offline 4/22 to 5/12	$318

NOTES:

1. Estimates are 1992 $ grossed up to full output for each scenario.
2. Some years had no replacement power cost because a scheduled refuel overlaps the time period..
3. Estimated costs starting in 1993 through year 2010.
4. Dates offline are approximate, Part II of this report discusses rationale for date selection.
5. Maximum mitigation for Unit 2 is 13 percent.
6. Explanation of how the cumulative replacement power costs were developed for power reduction cases using net fuel cost data included in Appendix C.
   - by year each case's (Case 1, Case 2, etc.) replacement costs were grossed up to full plant.
   - these full plant replacement power costs were then expressed in 1992 dollars by discounting at 11.78 percent per year.
   - these full plant replacement power costs in 1992 dollars were then summed.
   - this resulting value was then reported as the cumulative replacement power cost for the case.

3.8 REFERENCES

1. Millstone Nuclear Power Station Unit 3, Final Safety Analysis Report (FSAR), Docket No. 50-423.

2. Final Environmental Statement Related to the Proposed Construction of Millstone Nuclear Power Station - Unit 3. Millstone Point Co. et al, Docket No. 50-423, United States Atomic Energy Commission, Directorate of Licensing, February 1974.

3. Hydraulic Model Study - Phases I and II; Testing of the Circulating Water Pump Installation; Millstone Nuclear Power Station - Unit No. 3; Lasalle Hydraulic Laboratory Ltd; LHL-847; June 1982.

4. A.J. Hulchizer, J.C. Stuart, R.L. Obradovic, and A.J. Stuart. Land Shaft Construction and Initial Station Development for Seabrook Station Cooling Water Tunnels. RETC Proceedings, Vol. 2, 1979.

5. A.J. Hulchizer and J.P. Rossereau. Design and Installation of Large Diameter Sub Sea Connecting Shafts for the Seabrook Station Cooling System. RETC, San Francisco, CA, 1981.

6. R.T. Richards. Alternative Water Screening for Thermal Power Plants. J. Hydraulic Division, ASCE Vol. 114, No. 6, June 1988, pp 578-597.

7. Electric Power Research Institute. Guidelines on Macrofouling Control Technology. EPRI CS-5271, Project 1689-9, Final Report, June 1987.

8. Y.G. Mussalli, J. Williams, and J. Hockman. Engineering Biological Evaluation of a Fine-Mesh Traveling Screen for Protecting Organisms. Proceedings of the Workshop of Advanced Intake Technology, held at the Sheraton-Harbor Island Hotel, San Diego, CA, April 22-24, 1981.

9. M.R. Anderson, J.A. DiVito, and Y.G. Mussalli. Design and Operation of Angled-Screen Intake. J. Hydraulic Division, ASCE Vol. 114, No. 6, June 1988, pp 598-615.

10. S.J. Edwards, J. Dimbeck, T.E. Pease, M.J. Skelly, and D. Renpert. Effectiveness of Angled-Screen Intake Systems. J. Hydraulic Division, ASCE Vol. 114, No. 6, June 1988, pp 626-640.

11. J.A. Matousek, T.E. Pease, J.G. Holsapple, and R.C. Roberts. Biological Evaluation of Angled-Screen Test Facility. J. Hydraulic Division, ASCE Vol. 114, No. 6, June 1988, pp 641-650.

12. Stefan, H., A. Tu. Collector Well Study of the Cooling Water Intake System of James H. Campbell Electric Power Generating Plant Unit No. 3, St. Anthony Falls Hydraulic Laboratories, University of Minnesota, Project No. 176, November 1978.

13. Veneziale, E.J. Fish Protection with Wedgewire Screens at Eddystone Station. Proceedings of the American Power Conference 54(1):433-438.

14. J.A. Odgaard and Y. Wang. Sediment Management with Submerged Vanes. J. Hydraulic Division, ASCE Vol. 117, No. 3, March 1991, pp 267-283.

15. I.J. Karassik, W.C. Krutzsch, W.H. Fraser, and J.P. Messina. Pump Handbook. McGraw-Hill Book Co., 1976.

4

ESTIMATED COSTS AND CONSTRUCTION SCHEDULE

Order of magnitude costs and estimated construction schedules were developed for each of the proposed alternative intakes for Unit 3 discussed in Section 3.

4.1 ESTIMATED COSTS

The estimated costs for each of the seven alternatives are summarized in Tables 4-1 through 4-6. These summary tables are based on the detailed information in Appendices A, B, and C.

Appendix A provides detailed capital costs for each alternative.

Appendix B provides tabulated calculations of annual costs for added power consumption and performance degradation resulting from implementation of cooling-water system alternatives for Unit 3 for the years 1993 through 2010. Performance penalty costs appearing in Tables 4-1 through 4-6 are the sum of total increased system annual costs for the years 1993 through 2010.

Appendix C provides net fuel cost data for the various outage scenarios evaluated to determine outage costs.

Table 4-7 summarizes the direct, capital, and total costs of each alternative for comparison.

TABLE 4-1

NATURAL-DRAFT COOLING TOWERS
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	Full-Size Tower	⅔-Size Tower
Cooling Tower	$13,000,000	$11,700,000
Equipment	6,500,000	4,500,000
Piping		
Main C.W. Piping	12,500,000	9,600,000
Makeup and Blowdown	1,100,000	800,000
Excavation and Backfill	3,100,000	2,200,000
Cooling Tower Pump Station and Apron, and Access Road	1,700,000	1,100,000
Cooling Tower Basin	3,500,000	2,900,000
Electric and Control Equipment	2,600,000	2,200,000
Tie-ins to Operating Plant	100,000	100,000
TOTAL DIRECT COST	44,100,000	35,100,000
Engineering	4,400,000	3,500,000
Construction Management	3,100,000	2,500,000
Allowance for Indeterminates/Contingency	10,500,000	8,200,000
TOTAL CAPITAL COST	62,100,000	49,300,000
Outage Cost	12,000,000	12,000,000
Performance Penalty	14,700,000	9,800,000
TOTAL ESTIMATED COST	$88,800,000	$71,100,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may be considerably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-2

OFFSHORE INTAKE
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	
Pumps, equipment	$4,700,000
Tunnel	32,700,000
Shafts	11,400,000
Concrete & Dredging	4,700,000
Pumphouse, Forebay, Temp. Dock	6,200,000
Electrical	700,000
Tie-ins to Operating Plant	600,000
TOTAL DIRECT COSTS	61,000,000
Engineering	6,100,000
Construction Management	4,300,000
Allowance for Indeterminates/Contingency	17,700,000
TOTAL CAPITAL COST	89,100,000
Outage Cost	24,000,000
Performance Penalty	4,600,000
TOTAL ESTIMATED COST	$117,700,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may be considerably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-3

FINE-MESH SCREENS
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	
Equipment	$8,600,000
Piping & Sluicing System	500,000
Concrete & Dredging	4,400,000
Forebay, Cofferdam & Temp. Dock	5,400,000
Electrical	350,000
Tie-ins to Operating Plant	50,000
TOTAL DIRECT COSTS	19,300,000
Engineering	1,900,000
Construction Management	1,300,000
Allowance for Indeterminates/Contingency	5,700,000
TOTAL CAPITAL COST	28,200,000
Outage Cost	24,000,000
Performance Penalty	N/A
TOTAL ESTIMATED COST	$52,200,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may be considerably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-4

WEDGEWIRE SCREENS
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	
Equipment	$5,500,000
Piping	1,900,000
Concrete & Dredging	1,200,000
Cofferdam & Temp. Dock	3,300,000
Electrical	150,000
Tie-ins to Operating Plant	50,000
TOTAL DIRECT COSTS	12,100,000
Engineering	1,200,000
Construction Management	800,000
Allowance for Indeterminates/Contingency	3,500,000
TOTAL CAPITAL COST	17,600,000
Outage Cost	48,000,000
Performance Penalty	N/A
TOTAL ESTIMATED COST	$65,600,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may be considerably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-5

TWO-SPEED PUMPS
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	
Equipment	$1,500,000
Piping	-
Excavation/Concrete	100,000
Electrical	650,000
Tie-ins to Operating Plant	50,000
TOTAL DIRECT COSTS	2,300,000
Engineering	200,000
Construction Management	200,000
Allowance for Indeterminates/Contingency	500,000
TOTAL CAPITAL COST	3,200,000
Outage Cost	12,000,000
Performance Penalty	16,800,000
TOTAL ESTIMATED COST	$32,000,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may beconsiderably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-6

BARRIER SILLS
SUMMARY OF ORDER OF MAGNITUDE COST ESTIMATES

Item	
Sill Fabrication	$400,000
Sill Installation	600,000
Tremie Concrete	200,000
Temporary Dock	100,000
TOTAL DIRECT COSTS	1,300,000
Engineering	100,000
Construction Management	100,000
Allowance for Indeterminates/Contingency	300,000
TOTAL CAPITAL COST	1,800,000
Outage Cost	N/A
Performance Penalty	N/A
TOTAL ESTIMATED COST	$1,800,000

Note: Costs were developed for relative comparison purposes and due to their conceptual nature may be considerably lower than actual. Further limitations are described in the applicable text describing the design alternative.

TABLE 4-7

TOTAL COSTS ESTIMATE SUMMARY[1],[2]
(All Dollars in 000s Present Day)

Description	Cooling Tower 100%	Cooling Tower ⅔	Offshore Intake	Fine-Mesh Screens	Wedgewire Screens	Two-Speed Motor	Concrete Sills
Direct Costs	$44,100	$35,100	$61,000	$19,300	$12,100	$2,300	$1,300
Total Capital Costs	$62,100	$49,300	$89,100	$28,200	$17,600	$3,200	$1,800
Performance Penalty Costs	$14,700 [3]	$9,800 [3]	$4,600 [4]	N/A	N/A	$16,800 [3]	N/A
Lost Generation (Outage) Costs	$12,000 [5]	$12,000 [5]	$24,000 [5]	$24,000 [5]	$48,000 [5]	$12,000 [5]	N/A
TOTAL COST	$88,800	$71,100	$117,700	$52,200	$65,600	$32,000	$1,800

NOTES:

1. Operation and maintenance costs are not included although they could be considerable.
2. These estimates are for comparison of relative costs and due to their conceptual nature could be significantly less than actual costs.
3. 1992 cumulative net present value of replacement power costs, assuming 2 months of operation per year, over the years 1993-2010 for NUSCO's share of Unit 3 grossed up to full output.
4. Same as Note (1) except replacement power is needed for all months.
5. Based on the cost to replace NUSCO's share of Unit 3 output on average in 1993 grossed up to full output and discounted to 1992 dollars.

The estimated costs listed in Tables 4-1 through 4-7 were based on the following general assumptions:

- Present day prices and fully sub-contracted labor rates as of 11/1/92.
- 40-hour workweek, single-shift operation
- Dredged material can be disposed of locally; assumed to be not contaminated
- Required construction utilities will be supplied by Owner
- Land required for construction trailers, parking, and lay down provided by Owner
- Allowance for interferences along pipeline trench; electrical ductbank included within trench
- Construction management included at 7 percent of direct construction cost
- Detailed engineering/design included at 10 percent of direct construction cost

The cooling towers, the two-speed pump drives, and the concrete sills have a 20 percent AFI/contingency applied to total capital costs. The fine-mesh screens, the wedgewire screens, and the offshore intake each have a 25 percent AFI/contingency applied to total capital costs. These factors were recommended based on the level of detail of the preliminary designs and estimate pricing basis. These factors could also be referred to as budget protection factors for possible additional costs that might develop but cannot be determined at the time of preparation of the estimate. A higher factor has been applied to the more difficult marine alternatives.

Costs associated with the following were not included in the estimate:

- Escalation
- Abandonment
- Demolition/relocations
- Sales, use, service or other taxes
- Insurance (building all risk and other marine insurances)
- Severe contingency costs (e.g., those associated with adverse weather, craft strikes)
- Startup

- Permits (including environmental)
- Employee training, certifications, security work
- Operation and maintenance
- Category I structures
- Owner's cost

The total present-day capital costs consisted of the October 1992 direct, distributable, and engineering costs, and allowance for indeterminates/contingencies.

4.2 SPECIAL EXCAVATION COST CONSIDERATIONS

Relative order of magnitude cost estimates for excavation were based on preliminary excavation quantities, available site conditions and similar case histories.

4.2.1 NATURAL-DRAFT COOLING TOWER EXCAVATION COSTS

Typical rock excavation costs, utilizing pre-split blasting in rock range from $10.00 to $20.00 per cubic yard. This assumed that average haulage would be less than 5 miles, and easy site access would be available.

4.2.2 OFFSHORE INTAKE COSTS

4.2.2.1 Tunnel Excavation Assumptions/Costs

A relative order of magnitude of tunneling costs for a 24-foot I.D., 5,000-foot long intake tunnel has been made. The following assumptions were made:

1. The tunnel would be excavated through drill and blast methods along its entire 5,000-foot length.
2. A single intake structure would be built offshore, requiring an offshore shaft to be constructed from the tunnel up to the submerged structure elevation.
3. The tunnel liner would be cast in place, reinforced concrete, 2-foot average thickness.
4. Tunnel cross-sectional shape would be near circular/modified horseshoe.

5. The access shaft would also be located offshore, approximately 150 to 200 feet from the front of the current pumphouse structure.

6. One working face was assumed to be available starting from the access shaft, and that the tunnel would be driven towards the offshore intake structure.

7. The heading was assumed wet, yet with controllable water inflow rates; and the rock assumed competent. If the heading were to be driven under wet conditions with crushed rock or unconsolidated conditions, the tunnel excavation contingency could be as high as 50 percent.

Table 4-8 describes the breakdown of the tunnelling costs. In general, tunnel costs are approximately $ 6,500/lineal foot. Total cost of the tunnel excavation and construction is estimated at $ 32,700,000 for 5,000 feet of cast in place concrete lined tunnel.

TABLE 4-8

RELATIVE ORDER OF MAGNITUDE COSTS FOR TUNNELLING

DESCRIPTION	QUANTITY	UNIT COST	TOTAL COST
Mobilization	1	$5,000,000	$5,000,000
Shaft Station Development	2	$175,000	$350,000
Tunnel Excavation + Temp. Support (Rock Bolts)	5000 LF	$4376	$21,880,000
Concrete Lining (Slip Form)	5000 LF	$920	$4,600,000
Drilling in Advance of Face	5000 LF	$40	$200,000
Pressure Grouting at Tunnel Face	3000 LF	$100	$300,000
Muck Disposal	106,029 cu-yd	-	$120,000
Final Cleanup	5000 LF	$42	$210,000
GRAND TOTAL		$32,700,000 or $6500/LF of Tunnel	

4.2.2.2 Shaft Excavation Assumptions/Costs

1. The circular access shaft would be sunk through conventional drill and blast full face methods. A gallow stage would be used to advance, drill and muck the shaft. This platform would also allow grouting and placement of the shaft liner during construction.

2. The intake shaft would be drilled by raised bore/reaming methods to 26 feet in diameter.

3. Only conventional surface preparation costs and equipment were considered. Underwater preparation, offshore shaft servicing and operations were not considered and are likely to raise this estimate slightly.

4. Access shaft diameter would be 27 feet O.D. (outside diameter), 24 feet I.D. with cast in place concrete liner. It would be drilled entirely through rock.

5. The rock was assumed to be competent and groundwater inflows to be at a rate as only requiring standard grouting techniques during shaft sinking.

The costs for a full-faced excavated shaft were estimated based upon 1982 Army Corps of Engineers' estimates for a shaft of this diameter. The final costs were adjusted to 1992 prices through the Construction Cost Index published by the Engineering News Record. The price difference is 32 percent. The average cost per linear foot of shaft depth is $7645/foot. This includes both capital costs and operating costs.

These costs compare favorably with other proposed shafts in high strength granite of similar diameter in North New Jersey. The New Jersey project cost estimate for a 24-foot shaft was $6883/foot. The New Jersey costs reflect dryer conditions (little or no grouting), and little or no ground support prior to liner installation. Excavation techniques are similar. Collar development in rock for a 24-foot diameter shaft typically costs $1 to $1.5 million.

The north shaft for the outfall tunnel of the MWRA Deer Island Project was not entirely comparable to the proposed shaft of MNPS. Slurry wall construction was necessary, as was a larger diameter (35 feet) to accommodate a TBM.

Total cost for a single shaft at MNPS would be: 350 feet x $7645/foot + collar development ($1,500,000) = $4,175,750/shaft. This does not include underwater construction costs for sea floor prep and caisson installation. For preparation and caisson costs associated with the main access shaft and the velocity cap access shaft, the allowances were $2,000,000 and

$1,000,000, respectively. It should be noted that shafts costs can vary considerably with respect to the following factors: ground conditions, crew experience, quality of supervision, labor rates, and excavation techniques. The cost estimates for MNPS consider that the entire length of the shaft would be excavated in competent rock under wet conditions. Ground conditions any less favorable could significantly raise the shaft excavation costs. The contingency for the shaft excavation costs was 30 percent.

4.2.2.3 Schedule Assumptions and Considerations

The schedule was based upon onsite construction requirements. It does not include engineering design, site investigation work, or other prerequisite work. The schedule also does not include the Unit 3 intake structure modifications. Both the access shaft caisson structure and the intake shaft structures would be prefabricated and floated to final location. The schedule was based upon similar facility experience. Variations in rock types or ground conditions could significantly impact the schedule. Excavation techniques for the access shaft and the tunnel would utilize full face drill and blast methods. The offshore intake shaft would be excavated using raised boring techniques, which would reduce shaft excavation by 1 month and create a safer working environment. Excavation rates for the tunnel and access shaft were assumed at 30 feet/day and 8 feet/day, respectively. The excavation for the raised boring machine was assumed at 30 feet/day. It was assumed that the liner would be installed during excavation with the tunnel face at least 150 feet in front of the installed final liner. Final liner installation and sealing of the tunnel floor would be performed prior to raised boring of the intake shaft.

4.2.2.4 Total Offshore Intake Excavation Costs

Two offshore shafts would be necessary, one main access shaft and one intake shaft. The main access shaft would be close to shore, 350 feet deep. The offshore shaft would be 225 feet deep, yet constructed approximately 1 mile offshore in slightly deeper water by raise bore techniques. While the raised boring schedule would be shorter than conventional shaft construction techniques, capital equipment costs were assumed to be higher. For estimation purposes, both shafts have equivalent costs of $4,175,750. The total cost for this scheme would be:

Tunnel:	$ 32,500,000
Shafts (2) - $4,175,750 x 2:	$ 8,351,500
Access Costs for Shafts:	$ 3,000,000
Total:	$ 43,851,500

4.3 CONSTRUCTION PERIODS ESTIMATES

Construction periods and estimated outage periods for each of the alternatives are presented in Table 4-9. These periods do not account for time for engineering and design, equipment procurement, or permits.

The construction periods estimates were developed assuming standard construction methods and work weeks. Estimated outage periods are total durations. The periods could be scheduled to take advantage of scheduled refueling outages to minimize forced outage time.

TABLE 4-9

CONSTRUCTION AND OUTAGE PERIOD ESTIMATES

Alternative	Construction Period (Months)	Outage Period (Months)
Full-Size Cooling Tower System	24	1
Two-Thirds Size Cooling Tower System	24	1
Offshore Intake	36	2-6
Fine-Mesh Screens	18	2-6
Wedgewire Screens	12	4-6
Submerged Diversion Sill	2	0
Curtain Wall with Air Bubbler	2	0
Variable-Speed Pumps	2	1

5

ENGINEERING SUMMARY

The present seawater intakes for Millstone Power Station consists of three separate shoreline surface intakes, one per each of the three units. The intakes are similar in design having vertical wet pit type circulating water pumps (non-nuclear safety related) and service water pumps (nuclear safety related). Each intake incorporates traveling water screens, coarse-bar racks, and curtain walls extending below lowest water level. Each intake draws water directly from Niantic Bay. Total station withdrawal from Niantic Bay during normal full power operation of all three units is 4358 cfs. Unit 3 withdrawal (2097 cfs) is approximately ½ of the total with Unit 2 (1282 cfs) and Unit 1 (979 cfs) each withdrawing approximately ¼ of the total.

This engineering evaluation consisted of an initial overview of available mitigation measures which offered potential reduction to the entrainment of winter flounder larvae into the intakes. These technologies would achieve reduction to the entrainment into the intakes of fish and fish larvae through flow reduction, prevention of entrainment, and reduction of entrainment. From this overview the following alternative cooling system schemes were selected for detailed study:

- Natural-Draft Cooling Towers
- Offshore Intake
- Fine-Mesh Screens
- Wedgewire Screens
- Diversion Sills and Curtain Walls
- Infiltration Systems
- Operational Strategies
    - Reduced power/flow
    - Variable-speed pumps
    - Scheduled refueling outages
    - Forced outages

Preliminary designs for these selected alternatives were developed for Unit 3 only. A major reduction in fish and fish larvae entrainment for Unit 3, which draws ½ of the total station flow, would represent a major reduction to station entrainment.

Cooling towers would achieve reduction in fish entrainment by reducing intake flow to only that required for cooling tower makeup. Two salt water cooling tower alternatives were evaluated: a full-size natural-draft cooling tower and a ⅔-size natural-draft cooling tower. The existing condenser crossover valving and waterbox design pressure would allow conversion to a closed-loop system with the condenser operating in a two-pass configuration. Natural-draft cooling towers were selected based on the results of previous studies conducted for MNPS. The cooling towers would be located in the existing wooded area to the east of the switchyard. New pumping stations would be located at the cooling towers. Piping for the new closed-loop circulating water systems would be routed in a common cut and cover trench to the north and east of the station and would join the existing circulating inlet piping to the west of the turbine building. Valving would be provided to operate either the existing once-through system or the closed-loop system with the cooling towers. The nuclear safety-related service water system would remain unaltered with the cooling towers. New makeup water pumps would be installed in the existing Unit 3 intake structure. Cooling tower blowdown would be discharged to the quarry. A chlorination system would be required to control biofouling of the condenser tubes and tower fill. A dechlorination system would be required for the blowdown.

Construction cost would be very high for a cooling tower, and there would be considerable costs associated with the loss in performance. Maintenance costs would probably also be high but were not evaluated.

An offshore intake would place the intake outside of the confines of Niantic Bay. Entrained fish and larvae would be drawn from the entire Long Island Sound population in lieu of the confined Niantic Bay population. The offshore intake alternative would consist of extending the Unit 3 intake approximately 1 mile south into Long Island Sound. A rock tunnel was selected to develop cost estimates. The offshore end of the tunnel would terminate with a velocity cap structure located in the bottom of the sound. A booster pump station would be located at the shoreward end of the tunnel to provide added pumping head to compensate for hydraulic head losses in the tunnel. The offshore intake system would be joined to the existing Unit 3 pump structure by double sheet pile walls with tremie concrete filler. A nuclear safety-related flow bypass system would be provided for the service water pumps. Bypass gates for 50 percent of the circulating water flow would be provided. A chlorination system would be required to control biofouling in the inlet, shafts, and tunnel and a dechlorination system would be required for the circulating water discharge. Experience at

Seabrook Nuclear Station and the sewage outfall tunnel currently being constructed in Boston Harbor were utilized for design criteria and cost estimating.

The construction cost for an offshore intake would be extremely high, construction time would be lengthy, and the project would be difficult due to uncertainties in rock stability and permeability. Also, biofouling of the tunnel from mussels and other marine organisms could be severe and difficult to control. Chlorine (Cl_2) will kill larvae.

Fine-mesh screens prevent fish and larvae from entering the intake by intercepting them and returning them to Niantic Bay with a fish return system. The fine-mesh (1 to 2 mm) screens require an approach velocity of 0.5 fps to prevent overloading of the screens by debris. A through flow fine-mesh screening system for Unit 3 would consist of eighteen 10 foot wide traveling screens, housed in a screening structure 276 feet long by 40 feet wide that would be constructed directly in front of the existing Unit 3 intake. A forebay would be created, connecting the existing intake structure to the new fine-mesh screen structure by double sheet pile walls. A nuclear safety-related flow bypass system would be included for the service water pumps and bypass gates would be provided for circulating water flow. Fish and larvae collected on the fine-mesh screens would be returned to Niantic Bay to the east of Bay Point by a sluicing system. Alternate fine-mesh screen design utilizing angled through-flow screens and double entry drums screens were also evaluated.

Fine-mesh screen technology has been successful with certain species and sizes of fish and larvae; however, success with stage 3 winter flounder larvae was not found in the literature. There were also concerns with debris clogging of fine-mesh screens, which is prevalent at MNPS during the spring season.

Wedgewire screens reduce or eliminate entrainment of fish and larvae by taking advantage of natural cross currents to sweep fish and larvae past the submerged screen units and by utilizing small screen slot widths to block entry of small life forms and debris. A staggered array design for submerged wedgewire screen units with six collection conduits was developed for Unit 3. The staggered array design with alternate long and short collection conduits would promote better natural flushing of screen units. A plenum structure, constructed in front of the existing intake structure, would gather the flow from the collector pipes and distribute it to the existing intake bays. An automatic air burst system would be provided to backflush the screen units. A chlorination system may be required to control biofouling in the conduits. The plenum would be equipped with a nuclear safety-related flow bypass for the service water pumps and separate bypass gates for circulating water. An alternate bulkhead design is also presented but not costed.

Wedgewire screens are not in use at flow rates as high as the Unit 3 circulating and service water flows. There is also the strong potential for severe debris clogging, biofouling, and corrosion of the wedgewire screen units in the marine environment of Niantic Bay.

Diversion sills and curtain walls can divert a portion of the flounder larvae away from the intakes. Concrete sills constructed of Jersey type barriers placed on the bottom of Niantic Bay in front of the Unit 3 intake offer the potential for diverting a portion of the flounder larvae away from the intake. A design is presented consisting of a vee shaped barrier that would be constructed in front of the existing intake. The sill has an added potential benefit of diverting silt away from the intake. Additional angled vanes that would be placed upstream of the sill are included with the design to enhance silt diversion.

An alternative to the sill is a floating curtain wall with an air bubble floatation system. The floating curtain wall would also be angled to divert larvae to either side of the intake. The curtain wall would be supported by piles driven into the sea floor. The floatation system would consist of multiple diffuser pipes installed on the sea floor in front of the barrier and would be supplied by compressed air from blowers located on the shore.

There are no reported installations of diversion barriers or sills for the purpose of diverting fish larvae and therefore no quantitative data is available for determination of effectiveness.

Infiltration systems consist of arrays of perforated pipes installed in the bottom sediments. Water enters these pipes by percolating through the overlaying sediments into the pipes. These systems would prevent the entry of fish larvae. Existing systems in the United States have capacities an order of magnitude less than the Unit 3 operating flow. These systems have clogging and maintenance problems when high yields are attempted. A European design offers potential improved performance, however, a review of this design which incorporates a patented filter media design indicated it could be subject to clogging in the high detrital environment at MNPS. For these reasons, infiltration was eliminated as a nonviable technology for the high MNPS intake flows.

Power reductions do not result in corresponding cooling-water flow reductions; however, significant reductions in cooling-water flow could necessitate a reduction in station power production. Isolation of circulating water pumps during the spring season was not considered a viable option due to operational difficulties and a degradation of plant safety.

Variable-speed drives for the circulating water pumps allow reduction in circulating water flow during periods of flounder larvae activity. Reduced circulating water flows would result in increased condenser tube fouling and would likely require a reduction in unit output or an

outage. A two-speed drive system design was developed which would operate the circulating water system at either full-flow or ½ flow.

Refueling outages are scheduled for spring and fall seasons. Spring refueling outages will occasionally occur during some or all of the period of larval entrainment. However, it would be extremely expensive to guarantee the exact timing every year. Forced outages of one or more of the MNPS units would also be extremely expensive as shown in **Table 5-2.**

Cost estimates were developed for the selected alternatives. Costs are order of magnitude and include direct costs, engineering, construction management, AFI, contingency, outage costs, and performance penalty costs. **Table 5-1** provides a summary of cost estimates.

A tabulated evaluation of the selected alternatives in terms of constructibility, compatibility to Unit 3, operability, maintainability, plant safety, biological effectiveness, environment impact, and costs is presented on **Table 5-3.**

TABLE 5-1

TOTAL COST ESTIMATE SUMMARY(1),(2)
(All Dollars in 000s Present Day)

Description	Cooling Tower 100%	Cooling Tower ⅔	Offshore Intake	Fine-Mesh Screens	Wedgewire Screens	Two-Speed Motor	Concrete Sills
Direct Costs	$44,100	$35,100	$61,000	$19,300	$12,100	$2,300	$1,300
Total Capital Costs	$62,100	$49,300	$89,100	$28,200	$17,600	$3,200	$1,800
Performance Penalty Costs	$14,700 (3)	$9,800 (3)	$4,600 (4)	N/A	N/A	$16,800 (3)	N/A
Lost Generation (Outage) Costs	$12,000 (5)	$12,000 (5)	$24,000 (5)	$24,000 (5)	$48,000 (5)	$12,000 (5)	N/A
TOTAL COST	$88,800	$71,100	$117,700	$52,200	$65,600	$32,000	$1,800

NOTES:

1. Operation and maintenance costs are not included although they could be considerable.
2. These estimates are for comparison of relative costs and due to their conceptual nature could be significantly less than actual costs.
3. 1992 cumulative net present value of replacement power costs, assuming 2 months of operation per year, over the years 1993-2010 for NUSCO's share of Unit 3 grossed up to full output.
4. Same as Note (1) except replacement power is needed for all months.
5. Based on the cost to replace NUSCO's share of Unit 3 output on average in 1993 grossed up to full output and discounted to 1992 dollars.

TABLE 5-2

FORCED OUTAGE COST ESTIMATE FOR 25 PERCENT ENTRAINMENT MITIGATION

Scenario	Cumulative Replacement Power Costs in Millions of 1992 $
Unit 1 Offline 4/2 to 6/13	$214
Unit 2 Offline 4/2 to 6/13	$307
Unit 1 & Unit 2 Offline 4/2 to 6/6	$519
Unit 3 Offline 4/2 to 6/6	$310
Unit 1, Unit 2, & Unit 3 Offline 4/22 to 5/12	$318

NOTES:

1. Estimates are 1992 $ grossed up to full output for each scenario.
2. Some years had no replacement power cost because a scheduled refuel overlaps the time period.
3. Estimated costs starting in 1993 through year 2010.
4. Dates offline are approximate, Part II of this report discusses rationale for date selection.
5. Maximum mitigation for Unit 2 is 13 percent.
6. Explanation of how the cumulative replacement power costs were developed for power reduction cases using net fuel cost data included in Appendix C.
   - by year each case's (Case 1, Case 2, etc.) replacement costs were grossed up to full plant.
   - these full plant replacement power costs were then expressed in 1992 dollars by discounting at 11.78 percent per year.
   - these full plant replacement power costs in 1992 dollars were then summed.
   - this resulting value was then reported as the cumulative replacement power cost for the case.

TABLE 5-3

EVALUATION OF ENTRAINMENT MITIGATION ALTERNATIVES FOR MNPS

	Constructibility	Compatibility	Operability	Maintainability	Plant Safety - Regulatory Impact	Biological Effectiveness	Environmental Impact	Cost Effectiveness	Total Cost (Millions)
Cooling Tower	F	P	F	?	P	G	P	P	70-90
Tunnel	P	F	F	?	P	G-?	P	P	120-120
Fine-Mesh TWS	G	F	P	P	F	P	F	P	55
Wedgewire Screens	F	F	P	P	F	P	F	P	70
Sills/Barriers	G	G	G	G	G	P	G	P	2
Power/Flow Reduction	n/a	n/a	P	n/a	P	G	n/a	P	n/a
Variable-Speed Pumps	G	F	P	F	P	G	G	P	30
Scheduled Refuels	n/a	n/a	n/a	n/a	?	G	n/a	P	n/a
Forced Outages	n/a	n/a	n/a	n/a	n/a	G	n/a	P	200-520

NOTES:

P - Poor
F - Fair
G - Good
n/a - Not applicable
? - Evaluation incomplete due to uncertainties

APPENDICES

A. Cost Estimates of Design Alternatives

B. Cost Estimates of Performance Penalties

C. Cost Estimates of Forced Outages

A

COST ESTIMATES OF DESIGN ALTERNATIVES

SUMMARY REPORT STONE & WEBSTER ENGINEERING CORPORATION J.O. 1728303 - COOL TOWER-100% PAGE 1

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 10:33:56 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

STEM ACCOUNT	T I T L E	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	34,032,367	10,105,422	44,137,789	180,164
910	CONSTRUCTION MANAGEMENT	3,090,000		3,090,000	
920	ENGINEERING	4,414,000		4,414,000	
930	ESCALATION - PRESENT DAY				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	10,467,000		10,467,000	
	T O T A L E S T I M A T E	52,003,367	10,105,422	62,108,789	180,164

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally, assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work included.
18. Estimate allowance for interferences along circ. water pipeline trench included.
19. Electrical ductbank to be included within trench.

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST									
100.		NATURAL DRAFT COOLING TOWER FOR ENTIRE UNIT 3								
100.	TOTAL WORK PACKAGE									
100.1000		COOLING TOWER CIRCULATING WATER SYSTEM - EQUIPMENT								
100.1000	2490	COOLING TOWER, NATURAL DRAFT - COUNTERFLOW NATURAL DRAFT COOLING TOWER, MARLEY, FURNISH & INSTALL, 628,320 GPM, 116-91-77, 535 FT HIGH, 450 FT DIA AT BASIN, EVAP RATE=2.1%, WITHOUT BASIN, FULL SIZE TO ACCOMODATE 100% OF COOLING WATER REQUIREMENTS	1.0 EA	13000000.00			13,000,000		13,000,000	
100.1000	2500	CIRC WATER PUMPS & MOTORS - 105,000 GPM @ 100FT TDH, 3300 HP MOTORS	6.0 EA	750000.00	650.000	52.75	4,500,000	205,725	4,705,725	3,900
100.1000	2510	GANTRY CRANE, 30 TON	1.0 EA	200000.00	700.000	52.75	200,000	36,925	236,925	700
100.1000	2520	PUMP DISCHARGE VALVES, 72"H.O.	6.0 EA	47500.00	300.000	56.00	285,000	100,800	385,800	1,800
100.1000	2530	ISOLATION VALVES, 84",COOL TWR	3.0 EA	65000.00	350.000	56.00	195,000	58,800	253,800	1,050
100.1000	2540	RUBBER EXPANSION JOINTS, 72"	6.0 EA	5000.00	80.000	52.75	30,000	25,320	55,320	480
100.1000	2550	PANEL SCREENS, 16' X 20'	6.0 EA	10000.00	120.000	52.75	60,000	37,980	97,980	720
100.1000	2555	PUMP DISCHARGE VALVES, 48"H.O.	2.0 EA	22250.00	210.000	52.75	44,500	22,155	66,655	420
100.1000	2560	MAKEUP WATER PUMPS, 750 HP, 40,400 GPM @ 55FT, LOCATED IN EXISTING STRUCTURE	2.0 EA	200000.00	250.000	52.75	400,000	26,375	426,375	500
100.1000	2570	CONTROL SYSTEM	1.0 EA	60000.00	737.000	54.25	60,000	39,982	99,982	737
100.1000	2590	HVAC FOR PUMP HOUSE	1.0 LS	90000.00	1022.000	58.75	90,000	60,043	150,043	1,022
100.1000	TOTAL WORK PACKAGE						18,864,500	614,105	19,478,605	11,329
100.1100		PIPING-MAIN INLET & DISCHARGE								
100.1100	2610	14' DIA INLET & DISCH PIPE,FRP - FRP, SCHED 80 ??? WRAPPED & GLUED JOINTS	6000.0 LF	1325.00	1.380	56.00	7,950,000	463,680	8,413,680	8,280
100.1100	2620	3-WAY MANIFOLD, FRP, 14' DIA X 200LF LONG X 84" CONNECTIONS	2.0 EA	300000.00	840.000	56.00	600,000	94,080	694,080	1,680
100.1100	2630	ELBOW, FRP, 14' X 45DEG	10.0 EA	40000.00	19.300	56.00	400,000	10,808	410,808	193
100.1100	2640	ELBOW, FRP, 14' X 90DEG	2.0 EA	80000.00	19.300	56.00	160,000	2,162	162,162	39
100.1100	2650	110 LF SECTION W/6-72" CONNECT ,FRP	1.0 EA	200000.00	460.000	56.00	200,000	25,760	225,760	460
100.1100	2650	14' DIA FIELD WELD KITS	150.0 EA	4446.00	93.500	56.00	666,900	785,400	1,452,300	14,025

0001 - 0001119

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1100	2650	FREIGHT FOR 14' PIPE-150 LOADS	1.0 LS	1000000.00			1,000,000		1,000,000	
100.1100	TOTAL WORK PACKAGE						10,976,900	1,381,890	12,358,790	24,677
100.1200		PIPING-PUMP DISCHARGE								
100.1200	2710	72" DIA PIPE, FRP	180.0 LF	251.00	0.590	56.00	45,180	5,947	51,127	106
100.1200	2720	ELBOW, FRP, 72" X 90DEG	6.0 EA	10700.00	8.250	56.00	64,200	2,772	66,972	50
100.1200	2720	72" DIA FIELD WELD KITS	4.0 EA	1100.00	42.000	56.00	4,400	9,408	13,808	168
100.1200	2720	FREIGHT FOR 72" PIPE-	1.0 LS	20000.00			20,000		20,000	
100.1200	TOTAL WORK PACKAGE						133,780	18,127	151,907	324
100.1300		PIPE-MAKEUP & BLOWDOWN SYSTEM								
100.1300	2810	42"DIA PIPE,FRP (MAKEUP LINE)	550.0 LF	111.00	0.350	56.00	61,050	10,780	71,830	193
100.1300	2820	ELBOW, FRP, 42" x 90DEG	2.0 EA	2641.00	4.850	56.00	5,282	543	5,825	10
100.1300	2830	ELBOW, FRP, 42" X 45DEG	2.0 EA	1464.00	4.850	56.00	2,928	543	3,471	10
100.1300	2830	42" DIA FIELD WELD KITS	14.0 EA	620.00	24.200	56.00	8,680	18,973	27,653	339
100.1300	2830	FREIGHT FOR 42" PIPE-	1.0 LS	50000.00			50,000		50,000	
100.1300	2840	60"DIA PIPE,FRP(BLOWDOWN LINE)	2500.0 LF	196.00	0.500	56.00	490,000	70,000	560,000	1,250
100.1300	2850	ELBOW, FRP, 60" X 45DEG	6.0 EA	2951.00	6.880	56.00	17,706	2,312	20,018	41
100.1300	2850	60" DIA FIELD WELD KITS	42.0 EA	917.00	34.000	56.00	38,514	79,968	118,482	1,428
100.1300	2850	FREIGHT FOR 60" PIPE-	1.0 LS	230000.00			230,000		230,000	
100.1300	TOTAL WORK PACKAGE						904,160	183,119	1,087,279	3,271
100.1400		MAIN CIRC WATER LINES EXC/BKFL								
100.1400	1410	EXCAVATION, OPEN TRNCH (300')	17000.0 CY		0.120	60.50		123,420	123,420	2,040
100.1400	1410	BACKFILL, SELECT	800.0 CY	5.00	0.150	60.50	4,000	7,260	11,260	120
100.1400	1420	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	12600.0 CY		0.100	60.50		76,230	76,230	1,260
100.1400	1430	ROCK EXCAVATION, TRENCH (1500'	48000.0 CY	1.40	0.300	60.50	67,200	871,200	938,400	14,400
100.1400	1440	BACKFILL, SELECT	4800.0 CY	5.00	0.150	60.50	24,000	43,560	67,560	720
100.1400	1450	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	25200.0 CY		0.100	60.50		152,460	152,460	2,520
100.1400	1460	EXCAVATION, BRACED TRNCH(1000'	35000.0 CY		0.150	60.50		317,625	317,625	5,250
100.1400	1465	BRACING, FULL DEPTH X 2 SIDES	44000.0 SF	0.60	0.060	49.75	26,400	131,340	157,740	2,640
100.1400	1470	BACKFILL, SELECT	3500.0 CY	5.00	0.150	60.50	17,500	31,763	49,263	525
100.1400	1480	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	19400.0 CY		0.100	60.50		117,370	117,370	1,940
100.1400	1490	EXCAVATION,MANIFOLD TRNCH(200'	12000.0 CY		0.120	60.50		87,120	87,120	1,440
100.1400	1500	BACKFILL, SELECT	1000.0 CY	5.00	0.150	60.50	5,000	9,075	14,075	150
100.1400	1510	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	9700.0 CY		0.100	60.50		58,685	58,685	970
100.1400	TOTAL WORK PACKAGE						144,100	2,027,108	2,171,208	33,975
100.1450		ALLOWANCE FOR INTERFERENCES								

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1450	1400	ALLOWANCE FOR INTERFERENCES ALONG EXCAVATED TRENCH FOR MAIN CIRC WATER LINES-USE 40% X EXCV/BKFL COSTS FOR NORTH-SOUTH RUN & 20% X EXCV/BKFL COSTS FOR EAST-WEST RUN	1.0 LS	40300.00	9382.000	60.50	40,300	567,611	607,911	9,382
100.1450		TOTAL WORK PACKAGE					40,300	567,611	607,911	9,382
100.1500		MAKEUP&BLOWDOWN LINES EXC/BKFL								
100.1500	1520	EXCAVATION, OPEN TRENCH	10000.0 CY		0.120	60.50		72,600	72,600	1,200
100.1500	1530	BACKFILL, SELECT	550.0 CY	5.00	0.150	60.50	2,750	4,991	7,741	83
100.1500	1540	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	8881.0 CY		0.100	60.50		53,730	53,730	888
100.1500	1550	ROCK EXCAVATION, TRENCH	1700.0 CY	1.40	0.300	60.50	2,380	30,855	33,235	510
100.1500	1560	BACKFILL, SELECT	350.0 CY	5.00	0.150	60.50	1,750	3,176	4,926	53
100.1500	1570	BACKFILL, NORMAL	1000.0 CY		0.100	60.50		6,050	6,050	100
100.1500	1580	EXCAVATION, BRACED TRENCH	3500.0 CY		0.150	60.50		31,763	31,763	525
100.1500	1580	BRACING, FULL DEPTH X 2 SIDES	17200.0 SF	0.60	0.060	49.75	10,320	51,342	61,662	1,032
100.1500	1590	BACKFILL, SELECT	700.0 CY	5.00	0.150	60.50	3,500	6,353	9,853	105
100.1500	1600	BACKFILL, NORMAL	2100.0 CY		0.100	60.50		12,705	12,705	210
100.1500		TOTAL WORK PACKAGE					20,700	273,565	294,265	4,706
100.1600		COOLING TOWER PUMP STATION								
100.1600	1604	ROCK EXCAVATION	2500.0 CY	1.40	0.300	60.50	3,500	45,375	48,875	750
100.1600	1605	EXCAVATION, OVERBURDEN	3200.0 CY		0.120	60.50		23,232	23,232	384
100.1600	1606	BACKFILL	1500.0 CY		0.200	60.50		18,150	18,150	300
100.1600	1610	CONCRETE	1600.0 CY	65.00	2.200	50.75	104,000	178,640	282,640	3,520
100.1600	1620	FORMWORK	16000.0 SF	1.50	0.450	49.75	24,000	358,200	382,200	7,200
100.1600	1630	REINFORCING	120.0 TN	575.00	25.000	61.75	69,000	185,250	254,250	3,000
100.1600	1640	ENCLOSED STRUCT, BUTLER TYPE SUPERSTRUCTURE, DIMENSIONS OF 45'X110'X50' HIGH	4950.0 SF	20.00	0.250	60.00	99,000	74,250	173,250	1,238
100.1600		TOTAL WORK PACKAGE					299,500	883,097	1,182,597	16,392
100.1700		CONCRETE APRON								
100.1700	1704	ROCK EXCAVATION	1100.0 CY	1.40	0.300	60.60	1,540	19,998	21,538	330
100.1700	1705	EXCAVATION, OVERBURDEN	2200.0 CY		0.120	60.60		15,998	15,998	264
100.1700	1706	BACKFILL	500.0 CY		0.200	60.60		6,060	6,060	100
100.1700	1710	CONCRETE	510.0 CY	65.00	2.200	50.75	33,150	56,942	90,092	1,122
100.1700	1720	FORMWORK	10000.0 SF	1.50	0.450	49.75	15,000	223,875	238,875	4,500
100.1700	1730	REINFORCING	40.0 TN	575.00	25.000	61.75	23,000	61,750	84,750	1,000
100.1700		TOTAL WORK PACKAGE					72,690	384,623	457,313	7,316
100.1800		COOLING TOWER BASIN								

0001- 0001721

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ	SORT	ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1800		1800		EXCAVATION, OVERBURDEN	19000.0	CY		0.120	60.50		137,940	137,940	2,280
100.1800		1810		BACKFILL	1500.0	CY		0.200	60.50		18,150	18,150	300
100.1800		1820		CONCRETE (MASS)	9200.0	CY	65.00	1.750	50.75	598,000	817,075	1,415,075	16,100
100.1800		1830		FORMWORK	18000.0	SF	1.50	0.450	49.75	27,000	402,975	429,975	8,100
100.1800		1840		REINFORCING	700.0	TN	575.00	25.000	61.75	402,500	1,080,625	1,483,125	17,500
100.1800 TOTAL WORK PACKAGE										1,027,500	2,456,765	3,484,265	44,280
100.1900				ACCESS ROADWAY TO COOLING TOWE									
100.1900		1920		ASPHALT SURFACE,600' X 24'WIDE - INCL 6" SCRAPE, 4" AGGREGATE BASE, 1.5" BINDER, 2" WEARING COURSE	14400.0	SF	0.82	0.010	60.50	11,808	8,712	20,520	144
100.1900		1920		SHOULDER,8'WIDE X 600'X 2 SIDE - INCL 3" SELECT FILL, FINE GRADING, SEEDING, LIME, ETC.	1067.0	SY	0.68	0.053	60.50	726	3,421	4,147	57
100.1900		1930		DESC		CY							
100.1900 TOTAL WORK PACKAGE										12,534	12,133	24,667	201
100.1 TOTAL SUBACCOUNT										32,496,664	8,802,143	41,298,807	155,853
100.5010	--			ELECTRICAL EQUIPMENT									
100.5010	001	4700	AA	DOUBLE ENDED LOAD CENTER	1.0	EA	90000.00	120.000	53.75	90,000	6,450	96,450	120
100.5010	002	4700	AA	1000/1333 KVA TRANSFORMER FOR LOAD CENTER	2.0	EA	20000.00	80.000	53.75	40,000	8,600	48,600	160
100.5010	003	4700	AA	MOTOR CONTROL CENTER-4 SECTION	2.0	EA	14400.00	100.000	53.75	28,800	10,750	39,550	200
100.5010	004	4700	AA	480V/277 V PANEL	1.0	EA	800.00	16.000	53.75	800	860	1,660	16
100.5010	005	4700	AA	120V/208 V PANEL	1.0	EA	600.00	16.000	53.75	600	860	1,460	16
100.5010	006	4700	AA	45 KVA TRANSFORMER	1.0	EA	1400.00	24.000	53.75	1,400	1,290	2,690	24
100.5010	007	4700	AA	5 KV CIRCUIT BREAKERS	10.0	EA	21500.00	32.000	53.75	215,000	17,200	232,200	320
100.5010 TOTAL WORK PACKAGE										376,600	46,010	422,610	856
100.5020	--			CABLE\TERMINATIONS									
100.5020	001	4300	AA	3/C#500 5KV CABLE W/JACKET FOR CIRC PUMPS	36000.0	LF	18.00	0.120	53.75	648,000	232,200	880,200	4,320
100.5020	002	4300	AA	3/C#4/0 5KV CABLE W/JACKET FOR LOAD CENTER FEEDS	6000.0	LF	10.00	0.075	53.75	60,000	24,188	84,188	450
100.5020	002	4300	AA	3/C#4/0 5KV CABLE W/JACKET FOR MKUP PUMPS FEEDS	1600.0	LF	10.00	0.075	53.75	16,000	6,450	22,450	120
100.5020	003	4300	AA	MCC FEEDS-ASSUME 3C#500 600V	300.0	LF	10.00	0.120	53.75	3,000	1,935	4,935	36
100.5020	004	4300	AA	MISC PANEL FEEDS-3C#4/0 600V	100.0	LF	10.00	0.075	53.75	1,000	403	1,403	8
100.5020	005	4300	AA	3/C#8 600V -MISC MOTOR CONN	4000.0	LF	10.00	0.024	53.75	40,000	5,160	45,160	96
100.5020	005	4300	AA	#500 5KV TERMINATIONS	72.0	EA	90.00	5.000	53.75	6,480	19,350	25,830	360
100.5020	005	4300	AA	#4/0 5KV TERMINATIONS	24.0	EA	50.00	3.500	53.75	1,200	4,515	5,715	84
100.5020	005	4300	AA	#500 600V TERMINATIONS	24.0	EA	10.00	1.500	53.75	240	1,935	2,175	36
100.[illegible]	[illegible]05	[illegible]	[illegible]	#[illegible] [illegible]00V T[illegible]ATIC[illegible]	[illegible]	[illegible]	[illegible].00	1.00[illegible]	[illegible].75	[illegible]	[illegible]327	[illegible]71	6

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5020 005 4300 AA	#8 600V TERMINATIONS-MOTOR ASSUME 20 MOTORS-INCLUDES FLEX & CONNECTIONS	20.0 EA	15.00	3.000	53.75	300	3,225	3,525	60
100.5020	TOTAL WORK PACKAGE					776,268	299,684	1,075,952	5,576
100.5030 --	CONDUIT								
100.5030 000 4200 AA	24" CABLE TRAY	150.0 LF	15.00	0.600	53.75	2,250	4,838	7,088	90
100.5030 000 4200 AA	6" CABLE TRAY	100.0 LF	10.00	0.400	53.75	1,000	2,150	3,150	40
100.5030 000 4200 AA	1" RIGID ALUM.CONDUIT FOR MISC FEEDS	4000.0 LF	1.50	0.160	53.75	6,000	34,400	40,400	640
100.5030 000 4200 AA	4" RIGID ALUM.CONDUIT ASSEMBLY FOR CIRC PUMPS-CONDUIT,FLEX,TRAY ADAPTER	6.0 EA	400.00	24.000	53.75	2,400	7,740	10,140	144
100.5030 000 4200 AA	3" RIGID ALUM.CONDUIT ASSEMBLY FOR MAKEUP PUMPS	2.0 EA	350.00	20.000	53.75	700	2,150	2,850	40
100.5030 000 4200 AA	MISC TRANSISTION BOXES-DUCT	1.0 LS	800.00	60.000	53.75	800	3,225	4,025	60
100.5030 000 4200 AA	FEED ONLY TO COOLING TOWER	1.0 LS	500.00	40.000	53.75	500	2,150	2,650	40
100.5030	TOTAL WORK PACKAGE					13,650	56,653	70,303	1,054
100.5040 --	GROUNDING								
100.5040 000 4040 AA	4/0 BARE COPPER	800.0 LF	2.00	0.060	53.75	1,600	2,580	4,180	48
100.5040 000 4040 AA	GROUND RODS	10.0 EA	20.00	2.000	53.75	200	1,075	1,275	20
100.5040 000 4040 AA	MISC CADWELDS\CONN	1.0 LS	500.00	80.000	53.75	500	4,300	4,800	80
100.5040	TOTAL WORK PACKAGE					2,300	7,955	10,255	148
100.5050 --	LIGHTING								
100.5050 000 4110 AA	STRIP TYPE FIXTURES	40.0 EA	80.00	1.500	53.75	3,200	3,225	6,425	60
100.5050 000 4110 AA	EXIT FIXTURES	4.0 EA	80.00	2.500	53.75	320	538	858	10
100.5050 000 4110 AA	EMERGENCY BATTERY PACKS	4.0 EA	350.00	4.000	53.75	1,400	860	2,260	16
100.5050 000 4110 AA	OUTDOOR WALL PACKS	10.0 EA	250.00	4.000	53.75	2,500	2,150	4,650	40
100.5050 000 4110 AA	3/4" RIGID CONDUIT	800.0 LF	1.00	0.150	53.75	800	6,450	7,250	120
100.5050 000 4110 AA	#12 WIRE	2400.0 LF	0.10	0.020	53.75	240	2,580	2,820	48
100.5050	TOTAL WORK PACKAGE					8,460	15,803	24,263	294
100.5051 --	MISC POWER								
100.5051 000 4000 AA	MISC RECEPTACLES/OUTLETS-COMPL	1.0 LS	1500.00	120.000	53.75	1,500	6,450	7,950	120
100.5051	TOTAL WORK PACKAGE					1,500	6,450	7,950	120
100.5055 --	FIRE ALARM								
100.5055 000 4060 AA	PULL STATIONS	4.0 EA	80.00	2.000	53.75	320	430	750	8
100.5055 000 4060 AA	MISC DETECTORS	10.0 EA	80.00	2.000	53.75	800	1,075	1,875	20
100.5055 000 4810 AA	3/4" RIGID CONDUIT	400.0 LF	1.00	0.150	53.75	400	3,225	3,625	60

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5055 000 4810 AA	#16 WIRE	1600.0	LF	0.10	0.020	53.75	160	1,720	1,880	32
100.5055 000 4810 AA	NEW ZONE CARD IN PLANT	1.0	EA	800.00	40.000	53.75	800	2,150	2,950	40
	INCLUDES TESTING									
100.5055 TOTAL WORK PACKAGE							2,480	8,600	11,080	160
100.5060 --	COMMUNICATIONS/CONTROL									
100.5060 000 4810 AA	GAITRONICS STATIONS	2.0	EA	500.00	4.000	53.75	1,000	430	1,430	8
100.5060 000 4810 AA	3/4" RIGID CONDUIT	300.0	LF	1.00	0.150	53.75	300	2,419	2,719	45
100.5060 000 4810 AA	5/C#12 CONTROL CABLE	64000.0	LF	0.45	0.020	53.75	28,800	68,800	97,600	1,280
100.5060 TOTAL WORK PACKAGE							30,100	71,649	101,749	1,333
100.5061 --	DUCTBANK TO PUMPHOUSE									
	TOTAL DUCTBANK = 2800'									
100.5061 001 1410 AA	EXCAVATION-6'X 4'X 2800-X1.4		CY							
	MULTIPLIER OF 1.4 USED FOR V									
	SHAPED TRENCH - QUANTITY									
	INCLUDED WITH GENERAL PIPE									
	TRENCH EXCAVATION; DUCTBANK TO									
	SHARE SAME TRENCH									
100.5061 001 1410 AA	FORMWORK-2800'X4'X 2 SIDES	22400.0	SF	1.50	0.200	49.75	33,600	222,880	256,480	4,480
100.5061 002 1410 AA	CONCRETE-4' X 4'X 2800'-X .75	1245.0	CY	65.00	1.500	60.50	80,925	112,984	193,909	1,868
	.75 MULTIPLIER USED FOR									
	CONDUIT VOIDS									
100.5061 003 1410 AA	BACKFILL		CY							
	-INCL W/NORMAL BACKFILL FOR									
	PIPE TRENCH									
100.5061 004 1410 AA	REBAR	21.0	TN	575.00	25.000	61.75	12,075	32,419	44,494	525
100.5061 005 4000 AA	5" SCH 40 PVC	72800.0	LF	1.80	0.080	53.75	131,040	313,040	444,080	5,824
100.5061 TOTAL WORK PACKAGE							257,640	681,323	938,963	12,697
100.5062 --	DUCTBANK TO INTAKE STRUCTURE									
	800'									
100.5062 001 1410 AA	EXCAVATION-3'X 1.5X 800'-X1.4		CY		0.120	60.50				
	MULTIPLIER OF 1.4 USED FOR V									
	SHAPED TRENCH - QUANTITY									
	INCLUDED WITH GENERAL PIPE									
	TRENCH EXCAVATION; DUCTBANK TO									
	SHARE SAME TRENCH									
100.5062 001 1410 AA	FORMWORK-800'X2'X 2 SIDES	3200.0	SF	1.50	0.200	49.75	4,800	31,840	36,640	640
	MULTIPLIER OF 1.4 USED FOR V									
	SHAPED TRENCH									
100.5062 002 1410 AA	CONCRETE-1.50'X1.50'X 800'	68.0	CY	65.00	1.500	60.50	4,420	6,171	10,591	102
100.5062 003 1410 AA	BACKFILL		CY							
	- INCL W/NORMAL BACKFILL FOR									
	PIPE TRENCH									
100.[illegible] 004 [illegible] AA	R[illegible]	[illegible]	[illegible]	[illegible]5.00	[illegible]5.00[illegible]	[illegible].75	[illegible]	4,67[illegible]	[illegible]56	75

0001- 0001724

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5062 005 4000 AA	5" SCH 40 PVC	3200.0 LF	1.80	0.080	53.75	5,760	13,760	19,520	256
100.5062	TOTAL WORK PACKAGE					16,705	56,402	73,107	1,073
100.5	TOTAL SUBACCOUNT					1,485,703	1,250,529	2,736,232	23,311
100.7000	TIE-IN TO OPERATING PLANT								
100.7000 7000	TIE-IN TO OPERATING PLANT	1.0 LS	50000.00	1000.000	52.75	50,000	52,750	102,750	1,000
100.7000	TOTAL WORK PACKAGE					50,000	52,750	102,750	1,000
100.7	TOTAL SUBACCOUNT					50,000	52,750	102,750	1,000
100	TOTAL - DIRECT COST					34,032,367	10,105,422	44,137,789	180,164
910	CONSTRUCTION MANAGEMENT								
910.9100	CONSTRUCTION MANAGEMENT								
910.9100 9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	3090000.00			3,090,000		3,090,000	
910.9100	TOTAL WORK PACKAGE					3,090,000		3,090,000	
910.9	TOTAL SUBACCOUNT					3,090,000		3,090,000	
910	TOTAL - CONSTRUCTION MANAGEMENT					3,090,000		3,090,000	
920	ENGINEERING								
920.9200	ENGINEERING								
920.9200 9000	ENGINEERING @ 10%	1.0 LS	4414000.00			4,414,000		4,414,000	
920.9200	TOTAL WORK PACKAGE					4,414,000		4,414,000	
920.9	TOTAL SUBACCOUNT					4,414,000		4,414,000	
920	TOTAL - ENGINEERING					4,414,000		4,414,000	

0001-0001725

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 10:34:18 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 100% SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
930		ESCALATION - PRESENT DAY								
930.9300		ESCALATION								
930.9300	9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300		TOTAL WORK PACKAGE								
930.9		TOTAL SUBACCOUNT								
930		TOTAL - ESCALATION - PRESENT DAY								
940		ALLOWANCE FOR INDETERMINATES/CONTINGENCY								
940.9400		ALLOW FOR INDTRMNTS/CONTINGNCY								
940.9400	9000	ALLOW FOR INDTRMNTS/CONTINGNCY	1.0 LS	10467000.00			10,467,000		10,467,000	
940.9400		TOTAL WORK PACKAGE					10,467,000		10,467,000	
940.9		TOTAL SUBACCOUNT					10,467,000		10,467,000	
940		TOTAL - ALLOWANCE FOR INDETERMINATES/CONTINGENCY					10,467,000		10,467,000	
		TOTAL ESTIMATE					52,003,367	10,105,422	62,108,789	180,164

0001- 0001726

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 12:36:28 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	27,274,015	7,840,496	35,114,511	140,487
910	CONSTRUCTION MANAGEMENT	2,458,000		2,458,000	
920	ENGINEERING	3,512,000		3,512,000	
930	ESCALATION - PRESENT DAY				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	8,200,000		8,200,000	
	TOTAL ESTIMATE	41,444,015	7,840,496	49,284,511	140,487

0001- 0001727

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY

REPORT DATE: 11/25/92

ESTIMATE DATE: 11/25/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally, assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work included.
18. Estimate allowance for interferences along circ. water pipeline trench included.
19. Electrical ductbank to be included within trench.

0001- 0001728

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ	SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST									
100.		NATURAL DRAFT COOLING TOWER FOR 2/3 COOLING WATER REQUIREMENTS OF UNIT 3								
100.	TOTAL WORK PACKAGE									
100.1000		COOLING TOWER CIRCULATING WATER SYSTEM - EQUIPMENT								
100.1000	2490	COOLING TOWER, NATURAL DRAFT - COUNTERFLOW NATURAL DRAFT COOLING TOWER, MARLEY, FURNISH & INSTALL, 422,000 GPM, 116-91-77, 460 FT HIGH APPROX, 375 FT DIAM AT BASIN APPROX, EVAP RATE=2.1%, WITHOUT BASIN, 2/3 SIZE TO ACCOMODATE 2/3 UNIT NO. 3 COOLING REQUIREMENTS	1.0 EA	11700000.00			11,700,000		11,700,000	
100.1000	2500	CIRC WATER PUMPS & MOTORS - 105,000 GPM @ 100FT TDH, 3300 HP	4.0 EA	750000.00	580.000	52.75	3,000,000	122,380	3,122,380	2,320
100.1000	2510	GANTRY CRANE, 30 TON CAP	1.0 EA	200000.00	700.000	52.75	200,000	36,925	236,925	700
100.1000	2520	PUMP DISCHARGE VALVES, 72"M.O.	4.0 EA	47500.00	300.000	56.00	190,000	67,200	257,200	1,200
100.1000	2530	ISOLATION VALVES, 84",COOL TWR	2.0 EA	65000.00	350.000	56.00	130,000	39,200	169,200	700
100.1000	2540	RUBBER EXPANSION JOINTS, 72"	4.0 EA	5000.00	80.000	52.75	20,000	16,880	36,880	320
100.1000	2550	PANEL SCREENS, 16' X 20'	4.0 EA	10000.00	120.000	52.75	40,000	25,320	65,320	480
100.1000	2560	MAKEUP WATER PUMPS, 475HP, 27,000 GPM @ 50FT, LOCATED IN EXISTING STRUCTURE	2.0 EA	175000.00	210.000	52.75	350,000	22,155	372,155	420
100.1000	2560	PUMP DISCHARGE VALVES, 36"M.O. 27,000 GPM @ 50FT, LOCATED IN EXISTING STRUCTURE	2.0 EA	19000.00	180.000	52.75	38,000	18,990	56,990	360
100.1000	2570	CONTROL SYSTEM	1.0 EA	45000.00	553.000	54.25	45,000	30,000	75,000	553
100.1000	2590	HVAC FOR PUMP HOUSE	1.0 LS	60000.00	681.000	58.75	60,000	40,009	100,009	681
100.1000	TOTAL WORK PACKAGE						15,773,000	419,059	16,192,059	7,734
100.1100		PIPING-MAIN INLET & DISCHARGE								
100.1100	2610	12' DIA INLET & DISCH PIPE,FRP - FRP, SCHED 80 ??? WRAPPED & GLUED JOINTS	6000.0 LF	955.00	1.180	56.00	5,730,000	396,480	6,126,480	7,080
100.1100	2620	2-WAY MANIFOLD,FRP, 12'X 200LF LONG X 84" DIA CONNECTIONS	2.0 EA	300000.00	700.000	56.00	600,000	78,400	678,400	1,400
100.1100	2630	ELBOW, FRP, 12' X 45DEG	10.0 EA	30000.00	16.500	56.00	300,000	9,240	309,240	165
100.1100	2640	ELBOW, FRP, 12' X 90DEG	2.0 EA	60000.00	16.500	56.00	120,000	1,848	121,848	33
100.1100	2650	90 LF SECTION W/4-72" CONNECT ,FRP	1.0 EA	200000.00	312.000	56.00	200,000	17,472	217,472	312

0001729 - 0001

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1100	2650	12' DIA FIELD WELD KITS ,FRP	150.0 EA	4000.00	80.000	56.00	600,000	672,000	1,272,000	12,000
100.1100	2650	FREIGHT FOR 12' PIPE-150 LOADS ,FRP	1.0 LS	750000.00			750,000		750,000	
100.1100	TOTAL WORK PACKAGE						8,300,000	1,175,440	9,475,440	20,990
100.1200		PIPING-PUMP DISCHARGE								
100.1200	2710	72" DIA PIPE, FRP	120.0 LF	251.00	0.590	56.00	30,120	3,965	34,085	71
100.1200	2720	ELBOW, FRP, 72" X 90DEG	4.0 EA	10689.00	8.250	56.00	42,756	1,848	44,604	33
100.1200	2720	72" DIA FIELD WELD KITS	3.0 EA	1100.00	42.000	56.00	3,300	7,056	10,356	126
100.1200	2720	FREIGHT FOR 72" DIA PIPE-	1.0 LS	10000.00			10,000		10,000	
100.1200	TOTAL WORK PACKAGE						86,176	12,869	99,045	230
100.1300		PIPE-MAKEUP & BLOWDOWN SYSTEM								
100.1300	2810	38"DIA PIPE,FRP (MAKEUP LINE)	550.0 LF	105.00	0.320	56.00	57,750	9,856	67,606	176
100.1300	2820	ELBOW, FRP, 38" x 90DEG	2.0 EA	2500.00	4.400	56.00	5,000	493	5,493	9
100.1300	2830	ELBOW, FRP, 38" X 45DEG	2.0 EA	1400.00	4.400	56.00	2,800	493	3,293	9
100.1300	2830	38" DIA FIELD WELD KITS	14.0 EA	600.00	22.000	56.00	8,400	17,248	25,648	308
100.1300	2830	FREIGHT FOR 38" DIA PIPE	1.0 LS	42000.00			42,000		42,000	
100.1300	2840	48"DIA PIPE,FRP(BLOWDOWN LINE)	2500.0 LF	137.00	0.400	56.00	342,500	56,000	398,500	1,000
100.1300	2850	ELBOW, FRP, 48" X 45DEG	6.0 EA	2007.00	5.500	56.00	12,042	1,848	13,890	33
100.1300	2850	48" DIA FIELD WELD KITS	42.0 EA	715.00	26.500	56.00	30,030	62,328	92,358	1,113
100.1300	2850	FREIGHT FOR 48" DIA PIPE	1.0 LS	190000.00			190,000		190,000	
100.1300	TOTAL WORK PACKAGE						690,522	148,266	838,788	2,648
100.1400		MAIN CIRC WATER LINES EXC/BKFL								
100.1400	1410	EXCAVATION, OPEN TRNCH (300')	13000.0 CY		0.120	60.50		94,380	94,380	1,560
100.1400	1410	BACKFILL, SELECT	700.0 CY	5.00	0.150	60.50	3,500	6,353	9,853	105
100.1400	1420	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	9510.0 CY		0.100	60.50		57,536	57,536	951
100.1400	1430	ROCK EXCAVATION, TRENCH (1500'	34000.0 CY	1.40	0.300	60.50	47,600	617,100	664,700	10,200
100.1400	1440	BACKFILL, SELECT	4000.0 CY	5.00	0.150	60.50	20,000	36,300	56,300	600
100.1400	1450	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	17100.0 CY		0.100	60.50		103,455	103,455	1,710
100.1400	1460	EXCAVATION, BRACED TRNCH(1000'	23000.0 CY		0.150	60.50		208,725	208,725	3,450
100.1400	1460	BRACING, FULL DEPTH X 2 SIDES	36000.0 SF	0.60	0.060	49.75	21,600	107,460	129,060	2,160
100.1400	1470	BACKFILL, SELECT	3000.0 CY	5.00	0.150	60.50	15,000	27,225	42,225	450
100.1400	1480	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	11420.0 CY		0.100	60.50		69,091	69,091	1,142
100.1400	1490	EXCAVATION,MANIFOLD TRNCH(200'	6500.0 CY		0.120	60.50		47,190	47,190	780
100.1400	1500	BACKFILL, SELECT	400.0 CY	5.00	0.150	60.50	2,000	3,630	5,630	60

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1400	1510	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	5230.0	CY		0.100	60.50		31,642	31,642	523
100.1400	TOTAL WORK PACKAGE							109,700	1,410,087	1,519,787	23,691
100.1450		ALLOWANCE FOR INTERFERENCES									
100.1450	1400	ALLOWANCE FOR INTERFERENCES ALONG EXCAVATED TRENCH FOR MAIN CIRC WATER LINES-USE 40% X EXCV/BKFL COSTS FOR NORTH-SOUTH RUN & 20% X EXCV/BKFL COSTS FOR EAST-WEST RUN	1.0	LS	30700.00	6526.000	60.50	30,700	394,823	425,523	6,526
100.1450	TOTAL WORK PACKAGE							30,700	394,823	425,523	6,526
100.1500		MAKEUP&BLOWDOWN LINES EXC/BKFL									
100.1500	1520	EXCAVATION, OPEN TRENCH	10000.0	CY		0.120	60.50		72,600	72,600	1,200
100.1500	1530	BACKFILL, SELECT	550.0	CY	5.00	0.150	60.50	2,750	4,991	7,741	83
100.1500	1540	BACKFILL, NORMAL - QTY ADJ FOR ELEC DUCTBANK	8881.0	CY		0.100	60.50		53,730	53,730	888
100.1500	1550	ROCK EXCAVATION, TRENCH	1700.0	CY	1.40	0.300	60.50	2,380	30,855	33,235	510
100.1500	1560	BACKFILL, SELECT	350.0	CY	5.00	0.150	60.50	1,750	3,176	4,926	53
100.1500	1570	BACKFILL, NORMAL	1000.0	CY		0.100	60.50		6,050	6,050	100
100.1500	1580	EXCAVATION, BRACED TRENCH	3500.0	CY		0.150	60.50		31,763	31,763	525
100.1500	1580	BRACING, FULL DEPTH X 2 SIDES	17200.0	SF	0.60	0.060	49.75	10,320	51,342	61,662	1,032
100.1500	1590	BACKFILL, SELECT	700.0	CY	5.00	0.150	60.50	3,500	6,353	9,853	105
100.1500	1600	BACKFILL, NORMAL	2100.0	CY		0.100	60.50		12,705	12,705	210
100.1500	TOTAL WORK PACKAGE							20,700	273,565	294,265	4,706
100.1600		COOLING TOWER PUMP STATION									
100.1600	1604	ROCK EXCAVATION	1700.0	CY	1.40	0.300	60.50	2,380	30,855	33,235	510
100.1600	1605	EXCAVATION, OVERBURDEN	2200.0	CY		0.120	60.50		15,972	15,972	264
100.1600	1606	BACKFILL	100.0	CY		0.200	60.50		1,210	1,210	20
100.1600	1610	CONCRETE	1100.0	CY	65.00	2.200	50.75	71,500	122,815	194,315	2,420
100.1600	1620	FORMWORK	11000.0	SF	1.50	0.450	49.75	16,500	246,263	262,763	4,950
100.1600	1630	REINFORCING	80.0	TN	575.00	25.000	61.75	46,000	123,500	169,500	2,000
100.1600	1640	ENCLOSED STRUCT, BUTLER TYPE SUPERSTRUCTURE, DIMENSIONS OF 45'X75'X50' HIGH	3375.0	SF	20.00	0.250	60.00	67,500	50,625	118,125	844
100.1600	TOTAL WORK PACKAGE							203,880	591,240	795,120	11,008
100.1700		CONCRETE APRON									
100.1700	1704	ROCK EXCAVATION	800.0	CY	1.40	0.300	60.50	1,120	14,520	15,640	240
100.1700	1705	EXCAVATION, OVERBURDEN	1500.0	CY		0.120	60.50		10,890	10,890	180
100.1700	1706	BACKFILL	400.0	CY		0.200	60.50		4,840	4,840	80
100.1700	1710	CONCRETE	340.0	CY	65.00	2.200	50.75	22,100	37,961	60,061	748

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ	SORT	ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1700		1720		FORMWORK	7000.0 SF	1.50	0.450	49.75	10,500	156,713	167,213	3,150
100.1700		1730		REINFORCING	27.0 TN	575.00	25.000	61.75	15,525	41,681	57,206	675
100.1700				TOTAL WORK PACKAGE					49,245	266,605	315,850	5,073
100.1800				COOLING TOWER BASIN								
100.1800		1800		EXCAVATION, OVERBURDEN	11000.0 CY		0.120	60.50		79,860	79,860	1,320
100.1800		1810		BACKFILL	1000.0 CY		0.200	60.50		12,100	12,100	200
100.1800		1820		CONCRETE	7100.0 CY	65.00	2.200	50.75	461,500	792,715	1,254,215	15,620
100.1800		1830		FORMWORK	16000.0 SF	1.50	0.450	49.75	24,000	358,200	382,200	7,200
100.1800		1840		REINFORCING	540.0 TN	575.00	25.000	61.75	310,500	833,625	1,144,125	13,500
100.1800				TOTAL WORK PACKAGE					796,000	2,076,500	2,872,500	37,840
100.1900				COOLING TOWER ROADWAY								
100.1900		1920		ASPHALT SURFACE,600' X 24'WIDE - INCL 6" SCRAPE, 4" AGGREGATE BASE, 1.5" BINDER, 2" WEARING COURSE	14400.0 SF	0.82	0.010	60.50	11,808	8,712	20,520	144
100.1900		1920		SHOULDER,8'WIDE X 600'X 2 SIDE - INCL 3" SELECT FILL, FINE GRADING, SEEDING, LIME, ETC.	1067.0 SY	0.68	0.053	60.50	726	3,421	4,147	57
100.1900		1930		DESC								
100.1900				TOTAL WORK PACKAGE					12,534	12,133	24,667	201
100.1				TOTAL SUBACCOUNT					26,072,457	6,780,587	32,853,044	120,647
100.5010			--	ELECTRICAL EQUIPMENT								
100.5010	001	4700	AA	DOUBLE ENDED LOAD CENTER	1.0 EA	90000.00	120.000	53.75	90,000	6,450	96,450	120
100.5010	002	4700	AA	1000/1333 KVA TRANSFORMER FOR LOAD CENTER	2.0 EA	20000.00	80.000	53.75	40,000	8,600	48,600	160
100.5010	003	4700	AA	MOTOR CONTROL CENTER-4 SECTION	2.0 EA	14400.00	100.000	53.75	28,800	10,750	39,550	200
100.5010	004	4700	AA	480V/277 V PANEL	1.0 EA	800.00	16.000	53.75	800	860	1,660	16
100.5010	005	4700	AA	120V/208 V PANEL	1.0 EA	600.00	16.000	53.75	600	860	1,460	16
100.5010	006	4700	AA	45 KVA TRANSFORMER	1.0 EA	1400.00	24.000	53.75	1,400	1,290	2,690	24
100.5010	007	4700	AA	5 KV CIRCUIT BREAKERS	8.0 EA	21500.00	32.000	53.75	172,000	13,760	185,760	256
100.5010				TOTAL WORK PACKAGE					333,600	42,570	376,170	792
100.5020			--	CABLE\TERMINATIONS								
100.5020	001	4300	AA	3/C#500 5KV CABLE W/JACKET FOR CIRC PUMPS	24000.0 LF	18.00	0.120	53.75	432,000	154,800	586,800	2,880
100.5020	002	4300	AA	3/C#4/0 5KV CABLE W/JACKET FOR LOAD CENTER FEEDS	6000.0 LF	10.00	0.075	53.75	60,000	24,188	84,188	450
100.5020	002	4300	AA	3/C#4/0 5KV CABLE W/JACKET FC[illegible]IP PU[illegible]EEDS	1600.0 LF	10.00	0.075	53.75	16,000	6,450	22,450	120

0001- 0001732

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5020 003 4300 AA	MCC FEEDS-ASSUME 3C#500 600V	300.0 LF	10.00	0.120	53.75	3,000	1,935	4,935	36
100.5020 004 4300 AA	MISC PANEL FEEDS-3C#4/0 600V	100.0 LF	10.00	0.075	53.75	1,000	403	1,403	8
100.5020 005 4300 AA	3/C#8 600V -MISC MOTOR CONN	4000.0 LF	10.00	0.024	53.75	40,000	5,160	45,160	96
100.5020 005 4300 AA	#500 5KV TERMINATIONS	48.0 EA	90.00	5.000	53.75	4,320	12,900	17,220	240
100.5020 005 4300 AA	#4/0 5KV TERMINATIONS	24.0 EA	50.00	3.500	53.75	1,200	4,515	5,715	84
100.5020 005 4300 AA	#500 600V TERMINATIONS	24.0 EA	10.00	1.500	53.75	240	1,935	2,175	36
100.5020 005 4300 AA	#4/0 600V TERMINATIONS	6.0 EA	8.00	1.000	53.75	48	323	371	6
100.5020 005 4300 AA	#8 600V TERMINATIONS-MOTOR ASSUME 20 MOTORS-INCLUDES FLEX & CONNECTIONS	20.0 EA	15.00	3.000	53.75	300	3,225	3,525	60
100.5020 TOTAL WORK PACKAGE						558,108	215,834	773,942	4,016
100.5030 --	CONDUIT								
100.5030 000 4200 AA	24" CABLE TRAY	100.0 LF	15.00	0.600	53.75	1,500	3,225	4,725	60
100.5030 000 4200 AA	6" CABLE TRAY	70.0 LF	10.00	0.400	53.75	700	1,505	2,205	28
100.5030 000 4200 AA	1" RIGID ALUM.CONDUIT FOR MISC FEEDS	4000.0 LF	1.50	0.160	53.75	6,000	34,400	40,400	640
100.5030 000 4200 AA	4" RIGID ALUM.CONDUIT ASSEMBLY FOR CIRC PUMPS- CONDUIT,FLEX,TRAY ADAPTER	4.0 EA	400.00	24.000	53.75	1,600	5,160	6,760	96
100.5030 000 4200 AA	3" RIGID ALUM.CONDUIT ASSEMBLY FOR MAKEUP PUMPS	2.0 EA	350.00	20.000	53.75	700	2,150	2,850	40
100.5030 000 4200 AA	MISC TRANSISTION BOXES-DUCT	1.0 LS	800.00	60.000	53.75	800	3,225	4,025	60
100.5030 000 4200 AA	FEED ONLY TO COOLING TOWER	1.0 LS	500.00	40.000	53.75	500	2,150	2,650	40
100.5030 TOTAL WORK PACKAGE						11,800	51,815	63,615	964
100.5040 --	GROUNDING								
100.5040 000 4040 AA	4/0 BARE COPPER	800.0 LF	2.00	0.060	53.75	1,600	2,580	4,180	48
100.5040 000 4040 AA	GROUND RODS	10.0 EA	20.00	2.000	53.75	200	1,075	1,275	20
100.5040 000 4040 AA	MISC CADWELDS\CONN	1.0 LS	500.00	80.000	53.75	500	4,300	4,800	80
100.5040 TOTAL WORK PACKAGE						2,300	7,955	10,255	148
100.5050 --	LIGHTING								
100.5050 000 4110 AA	STRIP TYPE FIXTURES	40.0 EA	80.00	1.500	53.75	3,200	3,225	6,425	60
100.5050 000 4110 AA	EXIT FIXTURES	4.0 EA	80.00	2.500	53.75	320	538	858	10
100.5050 000 4110 AA	EMERGENCY BATTERY PACKS	4.0 EA	350.00	4.000	53.75	1,400	860	2,260	16
100.5050 000 4110 AA	OUTDOOR WALL PACKS	10.0 EA	250.00	4.000	53.75	2,500	2,150	4,650	40
100.5050 000 4110 AA	3/4" RIGID CONDUIT	800.0 LF	1.00	0.150	53.75	800	6,450	7,250	120
100.5050 000 4110 AA	#12 WIRE	2400.0 LF	0.10	0.020	53.75	240	2,580	2,820	48
100.5050 TOTAL WORK PACKAGE						8,460	15,803	24,263	294
100.5051 --	MISC POWER								

0001- 0001733

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5051 000 4000 AA	MISC RECEPTACLES/OUTLETS-COMPL	1.0	LS	1500.00	120.000	53.75	1,500	6,450	7,950	120
100.5051	TOTAL WORK PACKAGE						1,500	6,450	7,950	120
100.5055 --	FIRE ALARM									
100.5055 000 4060 AA	PULL STATIONS	4.0	EA	80.00	2.000	53.75	320	430	750	8
100.5055 000 4060 AA	MISC DETECTORS	10.0	EA	80.00	2.000	53.75	800	1,075	1,875	20
100.5055 000 4810 AA	3/4" RIGID CONDUIT	400.0	LF	1.00	0.150	53.75	400	3,225	3,625	60
100.5055 000 4810 AA	#16 WIRE	1600.0	LF	0.10	0.020	53.75	160	1,720	1,880	32
100.5055 000 4810 AA	NEW ZONE CARD IN PLANT INCLUDES TESTING	1.0	EA	800.00	40.000	53.75	800	2,150	2,950	40
100.5055	TOTAL WORK PACKAGE						2,480	8,600	11,080	160
100.5060 --	COMMUNICATIONS/CONTROL									
100.5060 000 4810 AA	3/4" RIGID CONDUIT	300.0	LF	1.00	0.150	53.75	300	2,419	2,719	45
100.5060 000 4810 AA	5/C#12 CONTROL CABLE	48000.0	LF	0.45	0.020	53.75	21,600	51,600	73,200	960
100.5060 000 4810 AA	#12 TERMINATIONS	150.0	EA	0.50	0.200	53.75	75	1,613	1,688	30
100.5060	TOTAL WORK PACKAGE						21,975	55,632	77,607	1,035
100.5061 --	DUCTBANK TO PUMPHOUSE TOTAL DUCTBANK = 2800'									
100.5061 001 1410 AA	EXCAVATION-6'X 4'X 2800-X1.4 MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH - QUANTITY INCLUDED WITH GENERAL PIPE TRENCH EXCAVATION; DUCTBANK TO SHARE SAME TRENCH		CY							
100.5061 001 1410 AA	FORMWORK-2800'X4'X 2 SIDES	22400.0	SF	1.50	0.200	49.75	33,600	222,880	256,480	4,480
100.5061 002 1410 AA	CONCRETE-4' X 4'X 2800'-X .75 .75 MULTIPLIER USED FOR CONDUIT VOIDS	1000.0	CY	65.00	1.500	60.50	65,000	90,750	155,750	1,500
100.5061 003 1410 AA	BACKFILL - INCL W/NORMAL BACKFILL FOR PIPE TRENCH		CY							
100.5061 004 1410 AA	REBAR	18.0	TN	575.00	25.000	61.75	10,350	27,788	38,138	450
100.5061 005 4000 AA	5" SCH 40 PVC	47600.0	LF	1.80	0.080	53.75	85,680	204,680	290,360	3,808
100.5061	TOTAL WORK PACKAGE						194,630	546,098	740,728	10,238
100.5062 --	DUCTBANK TO INTAKE STRUCTURE 800'									

0001 - 0001734

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ	SORT	ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5062	001	1410	AA	EXCAVATION-3'X 1.5X 800'-X1.4 MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH - QUANTITY INCLUDED WITH GENERAL PIPE TRENCH EXCAVATION; DUCTBANK TO SHARE SAME TRENCH		CY							
100.5062	001	1410	AA	FORMWORK-800'X2'X 2 SIDES MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH	3200.0	SF	1.50	0.200	49.75	4,800	31,840	36,640	640
100.5062	002	1410	AA	CONCRETE-1.50'X1.50'X 800'	68.0	CY	65.00	1.500	60.50	4,420	6,171	10,591	102
100.5062	003	1410	AA	BACKFILL - INCL W/NORMAL BACKFILL FOR PIPE TRENCH		CY							
100.5062	004	1410	AA	REBAR	3.0	TN	575.00	25.000	61.75	1,725	4,631	6,356	75
100.5062	005	4000	AA	5" SCH 40 PVC	3200.0	LF	1.80	0.080	53.75	5,760	13,760	19,520	256
100.5062				TOTAL WORK PACKAGE						16,705	56,402	73,107	1,073
100.5				TOTAL SUBACCOUNT						1,151,558	1,007,159	2,158,717	18,840
100.7000				TIE-IN TO OPERATING PLANT									
100.7000		7000		TIE-IN TO OPERATING PLANT	1.0	LS	50000.00	1000.000	52.75	50,000	52,750	102,750	1,000
100.7000				TOTAL WORK PACKAGE						50,000	52,750	102,750	1,000
100.7				TOTAL SUBACCOUNT						50,000	52,750	102,750	1,000
100				TOTAL - DIRECT COST						27,274,015	7,840,496	35,114,511	140,487
910				CONSTRUCTION MANAGEMENT									
910.9100				CONSTRUCTION MANAGEMENT									
910.9100		9000		CONSTRUCTION MANAGEMENT @ 7%	1.0	LS	2458000.00			2,458,000		2,458,000	
910.9100				TOTAL WORK PACKAGE						2,458,000		2,458,000	
910.9				TOTAL SUBACCOUNT						2,458,000		2,458,000	
910				TOTAL - CONSTRUCTION MANAGEMENT						2,458,000		2,458,000	

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY   WORK PACKAGE DETAIL REPORT   REPORT TIME: 12:37:10 REPORT DATE: 11/25/92
**** NATURAL DRAFT COOLING TOWER - 2/3 SIZE *****
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY   ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
920		ENGINEERING								
920.9200		ENGINEERING								
920.9200	9000	ENGINEERING @ 10%	1.0 LS	3512000.00			3,512,000		3,512,000	
920.9200		TOTAL WORK PACKAGE					3,512,000		3,512,000	
920.9		TOTAL SUBACCOUNT					3,512,000		3,512,000	
920		TOTAL - ENGINEERING					3,512,000		3,512,000	
930		ESCALATION - PRESENT DAY								
930.9300		ESCALATION								
930.9300	9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300		TOTAL WORK PACKAGE								
930.9		TOTAL SUBACCOUNT								
930		TOTAL - ESCALATION - PRESENT DAY								
940		ALLOWANCE FOR INDETERMINATES/CONTINGENCY								
940.9400		ALLOW FOR INDTRMNTS/CONTINGNCY								
940.9400	9000	ALLOW FOR INDTRMNTS/CONTINGNCY	1.0 LS	8200000.00			8,200,000		8,200,000	
940.9400		TOTAL WORK PACKAGE					8,200,000		8,200,000	
940.9		TOTAL SUBACCOUNT					8,200,000		8,200,000	
940		TOTAL - ALLOWANCE FOR INDETERMINATES/CONTINGENCY					8,200,000		8,200,000	
		TOTAL ESTIMATE					41,444,015	7,840,496	49,284,511	140,487

0001- 0001736

SUMMARY REPORT | STONE & WEBSTER ENGINEERING CORPORATION | J.O. 1728303 - OFFSHORE INTAKE | PAGE 1

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY | STEM SUMMARY | REPORT TIME: 08:40:07 REPORT DATE: 12/02/92

########## OFFSHORE INTAKE ##########

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY | ESTIMATE DATE: 12/02/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	53,359,086	7,616,767	60,975,853	136,185
910	CONSTRUCTION MANAGEMENT	4,268,000		4,268,000	
920	ENGINEERING	6,098,000		6,098,000	
930	ESCALATION				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	17,747,000		17,747,000	
	TOTAL ESTIMATE	81,472,086	7,616,767	89,088,853	136,185

0001- 0001737

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY

REPORT DATE: 12/02/92
ESTIMATE DATE: 12/02/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally; assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work included.
18. All surface offshore work to be scheduled other than during winter months.

DETAIL REPORT　　STONE & WEBSTER ENGINEERING CORPORATION　　J.O. 1728303 - OFFSHORE INTAKE　　

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY　　WORK PACKAGE DETAIL REPORT　　REPORT TIME: 08:40:49　REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY　　ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST									
100.		OFFSHORE INTAKE								
100.	TOTAL WORK PACKAGE									
100.1010		EQUIPMENT								
100.1010	1010	BOOSTER PUMP & MOTOR - 240,000 GPM @ 7FT. TDH, 525 HP	4.0 EA	1000000.00	560.000	54.75	4,000,000	122,640	4,122,640	2,240
100.1010	1011	GANTRY CRANE - 30 TON - 240,000 GPM @ 7FT. TDH, 525 HP	1.0 EA	200000.00	700.000	54.75	200,000	38,325	238,325	700
100.1010	1012	GATES-FOREBAY AREA, SOLENOID OPERATED, W/ELECTRICAL ALLOWANCE	2.0 EA	110000.00	400.000	54.75	220,000	43,800	263,800	800
100.1010	1013	COLLAPSIBLE PANEL W/SHEAR PINS	2.0 EA	12500.00	160.000	70.25	25,000	22,480	47,480	320
100.1010	1014	DISCHARGE ELBOW	2.0 EA	12500.00	200.000	54.75	25,000	21,900	46,900	400
100.1010	TOTAL WORK PACKAGE						4,470,000	249,145	4,719,145	4,460
100.1020		TUNNEL DETAIL								
100.1020	1110	MOBILIZATION	1.0 LS	5000000.00			5,000,000		5,000,000	
100.1020	1111	SHAFT STATION DEVELOPMENT	2.0 EA	175000.00			350,000		350,000	
100.1020	1112	TUNNEL EXCAV & TEMP SUPPORT - ROCK BOLTS	5000.0 LF	4376.00			21,880,000		21,880,000	
100.1020	1113	CONCRETE LINING (SLIP FORM)	5000.0 LF	920.00			4,600,000		4,600,000	
100.1020	1114	DRILLING IN ADVANCE OF FACE	5000.0 LF	40.00			200,000		200,000	
100.1020	1115	PRESSURE GROUTING @TUNNEL FACE	3000.0 LF	100.00			300,000		300,000	
100.1020	1116	MUCK DISPOSAL	106029.0 CY	1.13			119,813		119,813	
100.1020	1117	FINAL CLEANUP	5000.0 LF	42.00			210,000		210,000	
100.1020	TOTAL WORK PACKAGE						32,659,813		32,659,813	
100.1025		SHAFT DETAIL								
100.1025	1125	SINGLE SHAFT EXCAV/TEMP SUPPRT	350.0 LF	7645.00			2,675,750		2,675,750	
100.1025	1126	COLLAR DEVELOPMENT	1.0 EA	1500000.00			1,500,000		1,500,000	
100.1025	1127	SINGLE SHAFT EXCAV/TEMP SUPPRT	350.0 LF	7645.00			2,675,750		2,675,750	
100.1025	1128	COLLAR DEVELOPMENT	1.0 EA	1500000.00			1,500,000		1,500,000	
100.1025	1130	OFFSHORE INTAKE SHAFT MARINE WORK, INCL JACK-UP BARGE, SINK CAISSON, PREP SURFACE, FLOOR BOTTOM, MUCK OUT, GROUT AND BACKFILL AROUND BASE OF CAISSON, ROCK BOLTS @ 45 DEG, DEWATER, TEMP CAP AND BULKHEAD ALLOWANCE	1.0 LS	1000000.00			1,000,000		1,000,000	

0001- 0001739

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1025	1131	ONSHORE MAIN ACCESS SHAFT MARINE WORK, PREP SURFACE, FLOOR BOTTOM, MUCK OUT, INSTALL SHEETING, GROUT AND BACKFILL AROUND BASE OF SHEETING, ROCK BOLTS @ 45 DEG, DEWATER, ETC. USE ALLOWANCE OF 3.75% X $40MIL	1.0 LS	2000000.00			2,000,000		2,000,000	
100.1025	TOTAL WORK PACKAGE						11,351,500		11,351,500	
100.1439		TEMPORARY COFFERDAM AREA - SURROUNDING PUMPHOUSE & TRANSITION AREA - 3.0 MOS DRIVING & 1.5 MOS REMOVE								
100.1439	1440	WORK BARGE W/4 MAN CREW	4.5 MO	42000.00			189,000		189,000	
100.1439	1442	DECK CARGO BARGE-120'X45'	4.5 MO	6000.00			27,000		27,000	
100.1439	1444	TUG BOAT W/3 MAN CREW	4.5 MO	29000.00			130,500		130,500	
100.1439	1551	TEMP. COFFERDAM DRIVEN W/RIG	770.0 TN		9.100	70.00		490,490	490,490	7,007
100.1439	1552	TEMP. STEEL BRACING INST W/RIG	230.0 TN		15.000	70.00		241,500	241,500	3,450
100.1439	1553	REMOVAL OF COFFERDAM,BRACING	1.0 LS		5229.000	70.00		366,030	366,030	5,229
100.1439	1555	RENTAL OF COFFERDAM,BRACING	1.0 LS	250000.00			250,000		250,000	
100.1439	1560	DEWATERING (TEST) @ 24HR/DAY	0.5 MO	2500.00	720.000	50.75	1,250	18,270	19,520	360
100.1439	1570	DIVERS - 2 DIVERS/2 TENDERS	2.0 MO	88000.00			176,000		176,000	
100.1439	TOTAL WORK PACKAGE						773,750	1,116,290	1,890,040	16,046
100.1440		TRANSITION STRUCTURE								
100.1440	1410	CONCRETE	900.0 CY	65.00	2.200	53.00	58,500	104,940	163,440	1,980
100.1440	1420	FORMWORK	16000.0 SF	1.50	0.450	52.00	24,000	374,400	398,400	7,200
100.1440	1430	REINFORCING	70.0 TN	575.00	25.000	64.75	40,250	113,313	153,563	1,750
100.1440	TOTAL WORK PACKAGE						122,750	592,653	715,403	10,930
100.1441		MARINE EQUIPMENT								
100.1441	1440	WORK BARGE(HVY DTY) W/3 MAN CR - HIGH CAPACITY FOR 4100 RINGER	5.0 MO	37300.00			186,500		186,500	
100.1441	1441	CRANE - 4100 W/2 MAN CREW	5.0 MO	43800.00			219,000		219,000	
100.1441	1442	DECK CARGO BARGE-120'X45'	5.0 MO	6000.00			30,000		30,000	
100.1441	1444	TUG BOAT W/3 MAN CREW	5.0 MO	29000.00			145,000		145,000	
100.1441	1560	DEWATERING @ 24 HRS/DAY - 2 PUMPS	5.0 MO	5000.00	720.000	50.75	25,000	182,700	207,700	3,600
100.1441	1700	DIVERS - 2 DIVERS/2 TENDERS -CK AFTER FLOODING	0.5 MO	88000.00			44,000		44,000	

0001- 0001740

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1441	1710	SURVEY & CONTROL - 2 EMP -CK AFTER FLOODING	5.0 MO	15600.00			78,000		78,000	
100.1441	TOTAL WORK PACKAGE						727,500	182,700	910,200	3,600
100.1442		PUMP STRUCTURE								
100.1442	1110	CONCRETE	2300.0 CY	65.00	2.200	53.00	149,500	268,180	417,680	5,060
100.1442	1120	FORMWORK	37000.0 SF	1.50	0.450	52.00	55,500	865,800	921,300	16,650
100.1442	1130	REINFORCING	175.0 TN	575.00	25.000	64.75	100,625	283,281	383,906	4,375
100.1442	1140	SUPERSTRUCTURE - FOR PUMP AND CRANE, HVAC, LIGHTING - 110'LONG X 50' WIDE X 20' HIGH; USE $40/SF	5500.0 SF	24.00	0.290	55.00	132,000	87,725	219,725	1,595
100.1442	TOTAL WORK PACKAGE						437,625	1,504,986	1,942,611	27,680
100.1443		MARINE EQUIPMENT								
100.1443	1141	WORK BARGE-(W/TRANSITION STRUC								
100.1443	1142	CRANE-(W/TRANSITION STRUCT)								
100.1443	1143	DECK CARGO BARGE-(W/TRANS STRU								
100.1443	1144	TUG BOAT-(W/TRANSITION STRUCT)								
100.1443	1145	DEWATERING-(W/TRANSITION STRUC								
100.1443	1170	DIVERS - 2 DIVERS/2 TENDERS	0.5 MO	88000.00			44,000		44,000	
100.1443	TOTAL WORK PACKAGE						44,000		44,000	
100.1445		FOREBAY AREA - SHEETPILE PERMANENT								
100.1445	1551	FOREBAY SHEETPILE WALLS W/RIG	145.0 TN	750.00	9.100	70.00	108,750	92,365	201,115	1,320
100.1445	1552	STEEL BRACING W/RIG	40.0 TN	900.00	15.000	70.00	36,000	42,000	78,000	600
100.1445	TOTAL WORK PACKAGE						144,750	134,365	279,115	1,920
100.1446		MARINE EQUIPMENT @ FOREBAY								
100.1446	1553	WORK BARGE W/4 MAN CREW	0.8 MO	42000.00			33,600		33,600	
100.1446	1555	DECK CARGO BARGE-120'X45'	0.8 MO	6000.00			4,800		4,800	
100.1446	1558	TUG BOAT W/3 MAN CREW	0.5 MO	29000.00			14,500		14,500	
100.1446	1650	TREMIE CONCRETE	250.0 CY	75.00	1.500	53.00	18,750	19,875	38,625	375
100.1446	1700	DIVERS - 2 DIVERS/2 TENDERS	0.8 MO	88000.00			70,400		70,400	

0001- 0001741

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY | WORK PACKAGE DETAIL REPORT | REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY | ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT	DESCRIPTION	ML	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1446	1710	SURVEY & CONTROL - 2 EMP		0.5	MO	15600.00			7,800		7,800	
100.1446		TOTAL WORK PACKAGE							149,850	19,875	169,725	375
100.1550		DREDGING AND FOUNDATION PREP QUANTITIES FOR BOOSTER PUMP STATION AND TRANSITION STRUCTURE										
100.1550	1510	DREDGING		900.0	CY		0.200	100.00		18,000	18,000	180
100.1550	1520	TREMIE CONCRETE		1800.0	CY	75.00	1.500	53.00	135,000	143,100	278,100	2,700
100.1550	1521	DISPOSAL (SPOILS)		900.0	CY	10.00	0.050	100.00	9,000	4,500	13,500	45
100.1550		TOTAL WORK PACKAGE							144,000	165,600	309,600	2,925
100.1555		OFFSHORE VELOCITY CAP INLET STRUCTURE - ONSHORE FABRICATION IN PIECES PORTION										
100.1555	1610	CONCRETE	MHX1.3	1100.0	CY	65.00	2.900	53.00	71,500	169,070	240,570	3,190
100.1555	1620	FORMWORK	MHX1.3	18000.0	SF	1.50	0.590	52.00	27,000	552,240	579,240	10,620
100.1555	1630	REINFORCING	MHX1.3	85.0	TN	575.00	33.000	64.75	48,875	181,624	230,499	2,805
100.1555	1640	STEEL BAR		6.0	TN	800.00	35.000	64.75	4,800	13,598	18,398	210
100.1555		TOTAL WORK PACKAGE							152,175	916,532	1,068,707	16,825
100.1660		MARINE EQUIPMENT FOR OFFSHORE VELOCITY CAP STRUCTURE INSTALLATION										
100.1660	1730	JACK BARGE W/4 MAN CREW		3.0	MO	47200.00			141,600		141,600	
100.1660	1740	DECK CARGO BARGE-120'X45'X 2EA		6.0	MO	6000.00			36,000		36,000	
100.1660	1750	TUG BOAT W/3 MAN CREW		3.0	MO	29000.00			87,000		87,000	
100.1660	1760	CONCRETE MIXING EQUIPMENT		3.0	MO	3500.00			10,500		10,500	
100.1660	1761	CRANE-100TN X 100' REACH		3.0	MO	19600.00	346.000	61.75	58,800	64,097	122,897	1,038
100.1660	1770	DIVERS- 4 DIVERS/4 TENDERS		3.0	MO	176000.00			528,000		528,000	
100.1660	1780	SURVEY & CONTROL-2 EMP		3.0	MO	15600.00			46,800		46,800	
100.1660	1785	BALLAST TANKS 20'DIA X 30'X2 - TO BE USED FOR FLOTATION		2.0	EA	40000.00			80,000		80,000	
100.1660	1790	TRAVEL TIME LOST - 2 HR/DY/EMP - AVG OF 20 EMP		1.0	LS		2640.000	50.00		132,000	132,000	2,640
100.1660		TOTAL WORK PACKAGE							988,700	196,097	1,184,797	3,678
100.1663		OFFSHORE VELOCITY CAP INSTALL										
100.1663	1610	ONSHORE SUPPORT-BALLAST,LOAD		2.0	MO		1038.000	60.00		124,560	124,560	2,076
100.1663	1620	OFFSHORE SUPPORT-ASSIST IN SET		3.0	MO		1038.000	60.00		186,840	186,840	3,114

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1663 1630	ALLOW FOR INTERCONNECT W/SHAFT	1.0 LS	100000.00			100,000		100,000	
100.1663	TOTAL WORK PACKAGE					100,000	311,400	411,400	5,190
100.1665	DREDGING @ OFFFSHORE VEL CAP								
100.1665 1650	DREDGING	1500.0 CY		0.200	100.00		30,000	30,000	300
100.1665 1660	TREMIE CONCRETE	1100.0 CY	75.00	1.500	53.00	82,500	87,450	169,950	1,650
100.1665 1670	DISPOSAL OF SPOILS	1500.0 CY	10.00	0.050	70.00	15,000	5,250	20,250	75
100.1665 1680	DREDGING MOB/DEMOB	1.0 LS	20000.00			20,000		20,000	
100.1665	TOTAL WORK PACKAGE					117,500	122,700	240,200	2,025
100.1	TOTAL SUBACCOUNT					52,383,913	5,512,343	57,896,256	95,654
100.5010 --	ELECTRICAL EQUIPMENT								
100.5010 003 4700 AA	MOTOR CONTROL CENTER-3 SECTION	2.0 EA	10800.00	80.000	54.75	21,600	8,760	30,360	160
100.5010 004 4700 AA	480V/277 V PANEL	1.0 EA	800.00	16.000	54.75	800	876	1,676	16
100.5010 005 4700 AA	120V/208 V PANEL	1.0 EA	600.00	16.000	54.75	600	876	1,476	16
100.5010 006 4700 AA	45 KVA TRANSFORMER	1.0 EA	1400.00	24.000	54.75	1,400	1,314	2,714	24
100.5010 007 4700 AA	5 KV CIRCUIT BREAKERS	4.0 EA	21500.00	32.000	54.75	86,000	7,008	93,008	128
100.5010 007 4700 AA	600V CIRCUIT BREAKERS	2.0 EA	7000.00	12.000	54.75	14,000	1,314	15,314	24
100.5010	TOTAL WORK PACKAGE					124,400	20,148	144,548	368
100.5020 --	CABLE\TERMINATIONS								
100.5020 001 4300 AA	3/C#350 5KV CABLE W/JACKET FOR CIRC PUMPS	4000.0 LF	15.00	0.100	54.75	60,000	21,900	81,900	400
100.5020 002 4300 AA	1/C##500 600V CABLE	6000.0 LF	5.00	0.075	54.75	30,000	24,638	54,638	450
100.5020 003 4300 AA	MCC FEEDS-ASSUME 3C#500 600V	300.0 LF	10.00	0.120	54.75	3,000	1,971	4,971	36
100.5020 004 4300 AA	MISC PANEL FEEDS-3C#4/0 600V	100.0 LF	10.00	0.075	54.75	1,000	411	1,411	8
100.5020 005 4300 AA	3/C#8 600V -MISC MOTOR CONN	4000.0 LF	10.00	0.024	54.75	40,000	5,256	45,256	96
100.5020 005 4300 AA	#350 5KV TERMINATIONS	24.0 EA	75.00	4.000	54.75	1,800	5,256	7,056	96
100.5020 005 4300 AA	#4/0 5KV TERMINATIONS	24.0 EA	50.00	3.500	54.75	1,200	4,599	5,799	84
100.5020 005 4300 AA	#500 600V TERMINATIONS	24.0 EA	10.00	1.500	54.75	240	1,971	2,211	36
100.5020 005 4300 AA	#4/0 600V TERMINATIONS	6.0 EA	8.00	1.000	54.75	48	329	377	6
100.5020 005 4300 AA	#8 600V TERMINATIONS-MOTOR ASSUME 20 MOTORS-INCLUDES FLEX & CONNECTIONS	20.0 EA	15.00	3.000	54.75	300	3,285	3,585	60
100.5020 005 4300 AA	ALLOW FOR GATE OPERATOR WIRING ASSUME 20 MOTORS-INCLUDES FLEX & CONNECTIONS	2.0 EA	7500.00	100.000	54.75	15,000	10,950	25,950	200
100.5020	TOTAL WORK PACKAGE					152,588	80,566	233,154	1,472
100.5030 --	CONDUIT								
100.5030 000 4200 AA	24" CABLE TRAY	150.0 LF	15.00	0.600	54.75	2,250	4,928	7,178	90
100.5030 000 4200 AA	6" CABLE TRAY	50.0 LF	10.00	0.400	54.75	500	1,095	1,595	20

0001- 0001743

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5030 000 4200 AA	1" RIGID ALUM.CONDUIT FOR MISC FEEDS	4000.0 LF	1.50	0.160	54.75	6,000	35,040	41,040	640
100.5030 000 4200 AA	4" RIGID ALUM.CONDUIT ASSEMBLY FOR BOOSTER PUMPS-CONDUIT,FLEX,TRAY ADAPTER	4.0 EA	400.00	24.000	54.75	1,600	5,256	6,856	96
100.5030 000 4200 AA	MISC TRANSITION BOXES-DUCT FOR BOOSTER PUMPS-CONDUIT,FLEX,TRAY ADAPTER	1.0 LS	500.00	40.000	54.75	500	2,190	2,690	40
100.5030	TOTAL WORK PACKAGE					10,850	48,509	59,359	886
100.5040	-- GROUNDING								
100.5040 000 4040 AA	4/0 BARE COPPER	600.0 LF	2.00	0.060	54.75	1,200	1,971	3,171	36
100.5040 000 4040 AA	GROUND RODS	10.0 EA	20.00	2.000	54.75	200	1,095	1,295	20
100.5040 000 4040 AA	MISC CADWELDS\CONN	1.0 LS	500.00	80.000	54.75	500	4,380	4,880	80
100.5040	TOTAL WORK PACKAGE					1,900	7,446	9,346	136
100.5050	-- LIGHTING								
100.5050 000 4110 AA	STRIP TYPE FIXTURES	48.0 EA	80.00	1.500	54.75	3,840	3,942	7,782	72
100.5050 000 4110 AA	EXIT FIXTURES	4.0 EA	80.00	2.500	54.75	320	548	868	10
100.5050 000 4110 AA	EMERGENCY BATTERY PACKS	6.0 EA	350.00	4.000	54.75	2,100	1,314	3,414	24
100.5050 000 4110 AA	OUTDOOR WALL PACKS	10.0 EA	250.00	4.000	54.75	2,500	2,190	4,690	40
100.5050 000 4110 AA	3/4" RIGID CONDUIT	1000.0 LF	1.00	0.150	54.75	1,000	8,213	9,213	150
100.5050 000 4110 AA	#12 WIRE	3000.0 LF	0.10	0.020	54.75	300	3,285	3,585	60
100.5050	TOTAL WORK PACKAGE					10,060	19,492	29,552	356
100.5051	-- MISC POWER								
100.5051 000 4000 AA	MISC RECEPTACLES/OUTLETS-COMPL	1.0 LS	1500.00	120.000	54.75	1,500	6,570	8,070	120
100.5051	TOTAL WORK PACKAGE					1,500	6,570	8,070	120
100.5055	-- FIRE ALARM								
100.5055 000 4060 AA	PULL STATIONS	4.0 EA	80.00	2.000	54.75	320	438	758	8
100.5055 000 4060 AA	MISC DETECTORS	10.0 EA	80.00	2.000	54.75	800	1,095	1,895	20
100.5055 000 4810 AA	3/4" RIGID CONDUIT	400.0 LF	1.00	0.150	54.75	400	3,285	3,685	60
100.5055 000 4810 AA	#16 WIRE	1600.0 LF	0.10	0.020	54.75	160	1,752	1,912	32
100.5055 000 4810 AA	NEW ZONE CARD IN PLANT INCLUDES TESTING	1.0 EA	800.00	40.000	54.75	800	2,190	2,990	40
100.5055	TOTAL WORK PACKAGE					2,480	8,760	11,240	160
100.5060	-- COMMUNICATIONS/CONTROL								
100.5060 000 4810 AA	GAITRONICS STATIONS	2.0 EA	500.00	4.000	54.75	1,000	438	1,438	8
100.5060 000 4810 AA	3/4" RIGID CONDUIT	300.0 LF	1.00	0.150	54.75	300	2,464	2,764	45

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5060 000 4810 AA	5/C#12 CONTROL CABLE	64000.0 LF	0.45	0.020	54.75	28,800	70,080	98,880	1,280
100.5060	TOTAL WORK PACKAGE					30,100	72,982	103,082	1,333
100.5062 --	DUCTBANK TO INTAKE STRUCTURE 800'								
100.5062 001 1410 AA	EXCAVATION-3.5'X 3'X 800'-X1.4 MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH	435.0 CY		0.120	60.50		3,158	3,158	52
100.5062 001 1410 AA	FORMWORK-800'X2'X 2 SIDES MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH	3200.0 SF	1.50	0.200	49.75	4,800	31,840	36,640	640
100.5062 002 1410 AA	CONCRETE-1.50'X3'X 800'	133.0 CY	65.00	1.500	60.50	8,645	12,070	20,715	200
100.5062 003 1410 AA	BACKFILL	119.0 CY		0.150	60.50		1,080	1,080	18
100.5062 004 1410 AA	REBAR	6.0 TN	575.00	25.000	61.75	3,450	9,263	12,713	150
100.5062 005 4000 AA	5" SCH 40 PVC	8000.0 LF	1.80	0.080	54.75	14,400	35,040	49,440	640
100.5062	TOTAL WORK PACKAGE					31,295	92,451	123,746	1,700
100.5	TOTAL SUBACCOUNT					365,173	356,924	722,097	6,531
100.6000	TEMPORARY DOCK FACILITIES								
100.6000 1700	TEMPORARY DOCK FACILITIES - OPERATE FOR THREE YEARS	1.0 LS	500000.00	24000.000	50.00	500,000	1,200,000	1,700,000	24,000
100.6000 1710	TEMPORARY LAYDOWN/FABRCTN AREA FOR OFFSHORE VELOCITY CAP STRUCTURE	1.0 LS	10000.00			10,000		10,000	
100.6000	TOTAL WORK PACKAGE					510,000	1,200,000	1,710,000	24,000
100.6	TOTAL SUBACCOUNT					510,000	1,200,000	1,710,000	24,000
100.7000	TIE-IN TO OPERATING PLANT								
100.7000 1800	TIE-IN TO OPERATING PLANT - TIE-IN PERIOD APPROX 6 MONTHS; ASSUME 6 EMP FOR 6 MOS	1.0 LS	100000.00	10000.000	54.75	100,000	547,500	647,500	10,000
100.7000	TOTAL WORK PACKAGE					100,000	547,500	647,500	10,000
100.7	TOTAL SUBACCOUNT					100,000	547,500	647,500	10,000
100	TOTAL - DIRECT COST					53,359,086	7,616,767	60,975,853	136,185

0001- 0001745

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92
########## OFFSHORE INTAKE ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
910		CONSTRUCTION MANAGEMENT								
910.9100		CONSTRUCTION MANAGEMENT								
910.9100	9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	4268000.00			4,268,000		4,268,000	
910.9100		TOTAL WORK PACKAGE					4,268,000		4,268,000	
910.9		TOTAL SUBACCOUNT					4,268,000		4,268,000	
910		TOTAL - CONSTRUCTION MANAGEMENT					4,268,000		4,268,000	
920		ENGINEERING								
920.9200		ENGINEERING								
920.9200	9000	ENGINEERING @ 10%	1.0 LS	6098000.00			6,098,000		6,098,000	
920.9200		TOTAL WORK PACKAGE					6,098,000		6,098,000	
920.9		TOTAL SUBACCOUNT					6,098,000		6,098,000	
920		TOTAL - ENGINEERING					6,098,000		6,098,000	
930		ESCALATION								
930.9300		ESCALATION								
930.9300	9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300		TOTAL WORK PACKAGE								
930.9		TOTAL SUBACCOUNT								
930		TOTAL - ESCALATION								
940		ALLOWANCE FOR INDETERMINATES/CONTINGENCY								
940.9400		ALLOW FOR INDETRMNTS/CONTNGNCY								

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:40:49 REPORT DATE: 12/02/92

########## OFFSHORE INTAKE ##########

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 12/02/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
940.9400	9000	ALLOW FOR INDETRMNTS/CONTNGNCY	1.0 LS	17747000.00			17,747,000		17,747,000	
940.9400		TOTAL WORK PACKAGE					17,747,000		17,747,000	
940.9		TOTAL SUBACCOUNT					17,747,000		17,747,000	
940		TOTAL - ALLOWANCE FOR INDETERMINATES/CONTINGENCY					17,747,000		17,747,000	
		TOTAL ESTIMATE					81,472,086	7,616,767	89,088,853	136,185

0001- 0001747

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 15:05:28 REPORT DATE: 11/25/92
<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	12,205,975	7,056,521	19,262,496	119,661
910	CONSTRUCTION MANAGEMENT	1,349,000		1,349,000	
920	ENGINEERING	1,926,000		1,926,000	
930	ESCALATION				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	5,691,000		5,691,000	
	TOTAL ESTIMATE	21,171,975	7,056,521	28,228,496	119,661

0001- 0001748

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY REPORT DATE: 11/25/92
<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally; assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work included.
18. All offshore work to be scheduled other than during winter months.

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 15:06:08 REPORT DATE: 11/25/92

<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100		DIRECT COST								
100.		FINE MESH SCREENS								
100.		TOTAL WORK PACKAGE								
100.1010		EQUIPMENT								
100.1010	1010	FINE MESH TRAVELLING SCREENS - 10' BASKETS, 42.5' SETTING, FISH HANDLING	18.0 EA	400000.00	480.000	54.75	7,200,000	473,040	7,673,040	8,640
100.1010	1020	MECHANICAL TRASH RAKE	1.0 EA	20000.00	336.000	54.75	20,000	18,396	38,396	336
100.1010	1030	GANTRY CRANE 30' SPAN	1.0 EA	200000.00	700.000	52.75	200,000	36,925	236,925	700
100.1010	1040	SCREEN WASH PUMPS - 500 GPM @ 200' HEAD, 35 HP	3.0 EA	10000.00	152.000	54.75	30,000	24,966	54,966	456
100.1010	1050	STRAINER, SELF CLEANING, 500 GPM	3.0 EA	5000.00	80.000	54.75	15,000	13,140	28,140	240
100.1010	1060	BY-PASS GATES WITH HOISTS 12' X 30' STEEL W/ELECTRICAL ALLOWANCE	4.0 EA	65000.00	400.000	70.25	260,000	112,400	372,400	1,600
100.1010	1065	COLLAPSIBLE PANEL W/SHEAR PINS	2.0 EA	12500.00	160.000	70.25	25,000	22,480	47,480	320
100.1010	1070	CONTROLS EQUIPMENT	1.0 LS	60000.00	737.000	54.25	60,000	39,982	99,982	737
100.1010		TOTAL WORK PACKAGE					7,810,000	741,329	8,551,329	13,029
100.1020		PIPE & FITTINGS (FOR SCREENWASH SYSTEM)								
100.1020	1110	4" DIA PIPE, FRP, HIGH STRNGTH	500.0 LF	18.50	0.410	57.75	9,250	11,839	21,089	205
100.1020	1110	4" DIA COUPLING, FRP	25.0 EA	5.00	2.000	57.75	125	2,888	3,013	50
100.1020	1120	4" DIA BUTTERFLY VALVES, FRP, OPERATED	25.0 EA	2500.00	6.000	57.75	62,500	8,663	71,163	150
100.1020	1130	4" DIA VALVES, MANUAL	25.0 EA	600.00	4.000	57.75	15,000	5,775	20,775	100
100.1020	1140	4" DIA TEES, FRP	25.0 EA	50.00	3.800	57.75	1,250	5,486	6,736	95
100.1020	1150	4" DIA ELBOWS, FRP	45.0 EA	45.00	2.400	57.75	2,025	6,237	8,262	108
100.1020		TOTAL WORK PACKAGE					90,150	40,888	131,038	708
100.1030		FISH SLUICING SYSTEM								
100.1030	1210	CHANNEL, FRP 2' X 2' WITH SUPPORTING STRUCTURES, 100' IN WATER, 900' ON LAND	1000.0 LF	120.00	2.750	70.25	120,000	193,188	313,188	2,750
100.1030	1210	CHANNEL, FRP 2' X 2'INSIDE STR	275.0 LF	70.00	1.750	57.75	19,250	27,792	47,042	481
100.1030		TOTAL WORK PACKAGE					139,250	220,980	360,230	3,231
100.1040		SCREEN STRUCTURE								
100.1040	1310	CONCRETE	3800.0 CY	65.00	2.200	53.00	247,000	443,080	690,080	8,360
100.[illegible]	[illegible]	[illegible]RK	6600[illegible]	1.50	0.45[illegible]	[illegible].00	[illegible]	[illegible]544,40[illegible]	1,[illegible]00	[illegible]7,700

0001- 0001750

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 15:06:08 REPORT DATE: 11/25/92
<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1040	1330	REINFORCING	285.0 TN	575.00	25.000	64.75	163,875	461,344	625,219	7,125
100.1040	1340	BAR RACKS	186.0 TN	800.00	35.000	64.75	148,800	421,523	570,323	6,510
100.1040	1350	CRANE RAILS	10.0 TN	1200.00	35.000	64.75	12,000	22,663	34,663	350
100.1040	1360	SUPERSTRUCTURE CAP-275'X35'	9600.0 SF	15.00			144,000		144,000	
100.1040	TOTAL WORK PACKAGE						814,675	2,893,010	3,707,685	52,045
100.1050		FOREBAY WALL (PERMANENT)								
100.1050	1410	SHEET PILING	345.0 TN	750.00	9.100	70.00	258,750	219,765	478,515	3,140
100.1050	1420	STEEL BRACING	90.0 TN	900.00	15.000	70.00	81,000	94,500	175,500	1,350
100.1050	1430	TREMIE CONCRETE	550.0 CY	75.00	1.500	53.00	41,250	43,725	84,975	825
100.1050	TOTAL WORK PACKAGE						381,000	357,990	738,990	5,315
100.1060		GUIDE VANES (PERMANENT)								
100.1060	1510	SHEET PILING	120.0 TN	750.00	9.100	70.00	90,000	76,440	166,440	1,092
100.1060	1520	BRACING	60.0 TN	900.00	15.000	70.00	54,000	63,000	117,000	900
100.1060	TOTAL WORK PACKAGE						144,000	139,440	283,440	1,992
100.1070		DREDGING AND FOUNDATION PREP								
100.1070	1610	DREDGE VOLUME	12000.0 CY		0.200	100.00		240,000	240,000	2,400
100.1070	1611	DISPOSAL (SPOILS)	12000.0 CY	10.00	0.050	100.00	120,000	60,000	180,000	600
100.1070	1620	TREMIE CONCRETE	1600.0 CY	75.00	1.500	53.00	120,000	127,200	247,200	2,400
100.1070	TOTAL WORK PACKAGE						240,000	427,200	667,200	5,400
100.1080		TEMPORARY COFFERDAM								
100.1080	1100	TEMP COFFERDAM DRIVEN W/RIG	665.0 TN		9.100	70.00		423,605	423,605	6,052
100.1080	1100	TEMP BRACING INSTALLED W/RIG	233.0 TN		15.000	70.00		244,650	244,650	3,495
100.1080	1100	REMOVAL OF COFFERDAM, BRACING	1.0 LS		4773.000	70.00		334,110	334,110	4,773
100.1080	1100	RENTAL OF COFFERDAM, BRACING	1.0 LS	224500.00			224,500		224,500	
100.1080	1100	DEWATERING, PUMP @ 24 HRS/DAY -2 PUMPS	16.0 MO	5000.00	720.000	50.75	80,000	584,640	664,640	11,520
100.1080	1100	SURVEY & CONTROL - 2 EMP	12.0 MO	15600.00			187,200		187,200	
100.1080	TOTAL WORK PACKAGE						491,700	1,587,005	2,078,705	25,840
100.1090		MARINE EQUIPMENT								
100.1090	1200	WORK BARGE W/4 MAN CREW	15.0 MO	42000.00			630,000		630,000	
100.1090	1200	DECK CARGO BARGE-120'X45'	15.0 MO	6000.00			90,000		90,000	
100.1090	1200	TUG BOAT W/3 MAN CREW	6.0 MO	29000.00			174,000		174,000	
100.1090	1200	CRANE-25 TN X70' REACH	12.0 MO	8100.00	173.000	61.75	97,200	128,193	225,393	2,076

0001- 0001751

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 15:06:08 REPORT DATE: 11/25/92
<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1090	1200	DIVERS - 2 DIVERS/2 TENDERS	8.0 MO	88000.00			704,000		704,000	
100.1090	TOTAL WORK PACKAGE						1,695,200	128,193	1,823,393	2,076
100.1	TOTAL SUBACCOUNT						11,805,975	6,536,035	18,342,010	109,636
100.5000		ELECTRICAL ALLOWANCE								
100.5000	5000	ELECTRICAL ALLOWANCE	1.0 LS	175000.00	3197.000	54.75	175,000	175,036	350,036	3,197
100.5000	5010	ALLOW FOR GATE OPERATOR WIRING	2.0 EA	5000.00	100.000	54.75	10,000	10,950	20,950	200
100.5000	TOTAL WORK PACKAGE						185,000	185,986	370,986	3,397
100.5	TOTAL SUBACCOUNT						185,000	185,986	370,986	3,397
100.6000		TEMPORARY DOCK FACILITIES								
100.6000	6000	TEMPORARY DOCK FACILITIES	1.0 LS	200000.00			200,000		200,000	
100.6000	6010	OPERATION	18.0 MO		346.000	50.00		311,400	311,400	6,228
100.6000	TOTAL WORK PACKAGE						200,000	311,400	511,400	6,228
100.6	TOTAL SUBACCOUNT						200,000	311,400	511,400	6,228
100.7000		TIE-INS TO EXISTING OPERATION								
100.7000	7000	TIE-INS TO EXISTING OPERATION	1.0 LS	15000.00	400.000	57.75	15,000	23,100	38,100	400
100.7000	TOTAL WORK PACKAGE						15,000	23,100	38,100	400
100.7	TOTAL SUBACCOUNT						15,000	23,100	38,100	400
100	TOTAL - DIRECT COST						12,205,975	7,056,521	19,262,496	119,661
910	CONSTRUCTION MANAGEMENT									
910.9100		CONSTRUCTION MANAGEMENT								

0001- 0001752

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 15:06:08 REPORT DATE: 11/25/92
<<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
910.9100	9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	1349000.00			1,349,000		1,349,000	
910.9100		TOTAL WORK PACKAGE					1,349,000		1,349,000	
910.9		TOTAL SUBACCOUNT					1,349,000		1,349,000	
910		TOTAL - CONSTRUCTION MANAGEMENT					1,349,000		1,349,000	
920		ENGINEERING								
920.9200		ENGINEERING								
920.9200	9000	ENGINEERING @ 10%	1.0 LS	1926000.00			1,926,000		1,926,000	
920.9200		TOTAL WORK PACKAGE					1,926,000		1,926,000	
920.9		TOTAL SUBACCOUNT					1,926,000		1,926,000	
920		TOTAL - ENGINEERING					1,926,000		1,926,000	
930		ESCALATION								
930.9300		ESCALATION								
930.9300	9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300		TOTAL WORK PACKAGE								
930.9		TOTAL SUBACCOUNT								
930		TOTAL - ESCALATION								
940		ALLOWANCE FOR INDETERMINATES/CONTINGENCY								
940.9400		ALLOW FOR INDTRMNTS/CONTINGNCY								

0001- 0001753

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 15:06:08 REPORT DATE: 11/25/92

<<<<<<<<<< FINE MESH SCREENS >>>>>>>>>>

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
940.9400 9000	ALLOW FOR INDTRMNTS/CONTINGNCY	1.0 LS	5691000.00			5,691,000		5,691,000	
940.9400	TOTAL WORK PACKAGE					5,691,000		5,691,000	
940.9	TOTAL SUBACCOUNT					5,691,000		5,691,000	
940	TOTAL - ALLOWANCE FOR INDETERMINATES/CONTINGENCY					5,691,000		5,691,000	
	TOTAL ESTIMATE					21,171,975	7,056,521	28,228,496	119,661

0001- 0001754

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 14:28:36 REPORT DATE: 11/25/92

********** WEDGE WIRE SCREENS **********

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	9,075,819	2,945,095	12,020,914	59,402
910	CONSTRUCTION MANAGEMENT	842,000		842,000	
920	ENGINEERING	1,202,000		1,202,000	
930	ESCALATION				
940	ALLOWANCE FOR INDETERMINATES	3,544,000		3,544,000	
	TOTAL ESTIMATE	14,663,819	2,945,095	17,608,914	59,402

0001- 0001755

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY REPORT DATE: 11/25/92
********** WEDGE WIRE SCREENS **********
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally, assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work included.
18. All offshore work to be scheduled other than during winter months.

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 14:29:17 REPORT DATE: 11/25/92

********** WEDGE WIRE SCREENS **********

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST									
100.		WEDGE WIRE SCREENS								
100.	TOTAL WORK PACKAGE									
100.1010		EQUIPMENT								
100.1010	1010	TEE SCREEN ASSEMBLIES-JOHNSON MODEL T-84	54.0 EA	70000.00	2.000	50.75	3,780,000	5,481	3,785,481	108
100.1010	1010	WELD KIT/INSTL FOR TEE SECTION MODEL T-84	54.0 EA	1800.00	34.000	50.75	97,200	93,177	190,377	1,836
100.1010	1020	108" DIA BUTTERFLY VALVES - MANUALLY OPERATED	6.0 EA	45000.00	240.000	57.75	270,000	83,160	353,160	1,440
100.1010	1030	STEEL STOP LOG-12' X 30'	4.0 EA	50000.00	160.000	70.25	200,000	44,960	244,960	640
100.1010	1040	COMPRESSORS WITH MOTORS-40 HP	2.0 EA	30000.00	96.000	54.75	60,000	10,512	70,512	192
100.1010	1050	AIR TANK-150 LB, 400CF	1.0 EA	2000.00	24.000	54.75	2,000	1,314	3,314	24
100.1010	1060	6" DIA BALL VALVES, FULL PORT W/AIR ACTUATOR	62.0 EA	5500.00	18.000	57.75	341,000	64,449	405,449	1,116
100.1010	1065	BY-PASS GATES W/HOISTS - 12' X 30' STEEL W/ ELECTRICAL ALLOWANCE	4.0 EA	65000.00	400.000	70.25	260,000	112,400	372,400	1,600
100.1010	1066	COLLAPSIBLE PANEL W/SHEAR PINS	2.0 EA	12500.00	160.000	70.25	25,000	22,480	47,480	320
100.1010	1070	CONTROL SYSTEM	1.0 LS	30000.00	362.000	55.25	30,000	20,001	50,001	362
100.1010	TOTAL WORK PACKAGE						5,065,200	457,934	5,523,134	7,638
100.1020		MAIN COLLECTOR CONDUIT-PIPE & FITTINGS								
100.1020	1110	108" DIA FRP COLLECTOR CONDUIT	760.0 LF	550.00	0.900	56.00	418,000	38,304	456,304	684
100.1020	1111	108" DIA FRP FIELD WELD KIT	34.0 EA	2600.00	62.000	56.00	88,400	118,048	206,448	2,108
100.1020	1120	60" DIA FRP CONNECTIONS, 5' LG	54.0 EA	1000.00	2.500	56.00	54,000	7,560	61,560	135
100.1020	1121	60" DIA FRP FIELD WELD KIT	108.0 EA	917.00	34.000	56.00	99,036	205,632	304,668	3,672
100.1020	1130	108" DIA FRP COLLECTOR PIPE	380.0 LF	550.00	0.900	56.00	209,000	19,152	228,152	342
100.1020	1131	FREIGHT FOR FRP PIPE	1.0 LS	114000.00			114,000		114,000	
100.1020	TOTAL WORK PACKAGE						982,436	388,696	1,371,132	6,941
100.1030		6" AIR BURST LINE-PIPE & FTNGS								
100.1030	1210	6" DIA PIPE-FRP.-HIGH STRENGTH	7000.0 LF	29.00	0.510	57.75	203,000	206,168	409,168	3,570
100.1030	1210	6" DIA COUPLINGS	350.0 EA	7.00	2.000	57.75	2,450	40,425	42,875	700
100.1030	1220	6" X 6" TEES, FRP	61.0 EA	58.00	4.000	57.75	3,538	14,091	17,629	244
100.1030	1230	6" 90 DEG ELBOW, S.S.	60.0 EA	42.00	2.400	57.75	2,520	8,316	10,836	144
100.1030	TOTAL WORK PACKAGE						211,508	269,000	480,508	4,658
100.1040		PLENUM CONCRETE, FORMS & REBAR								
100.1040	1310	CONCRETE	1500.0 CY	65.00	2.200	53.00	97,500	174,900	272,400	3,300

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY · WORK PACKAGE DETAIL REPORT · REPORT TIME: 14:29:17 REPORT DATE: 11/25/92

********** WEDGE WIRE SCREENS **********

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY · ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1040	1320	FORMWORK	22000.0	SF	1.50	0.450	0.45	33,000	4,455	37,455	9,900
100.1040	1330	REINFORCING	115.0	TN	575.00	25.000	25.00	66,125	71,875	138,000	2,875
100.1040	TOTAL WORK PACKAGE							196,625	251,230	447,855	16,075
100.1045		PLENUM SHEETING SIDEWALL(PERM)									
100.1045	1300	SHEET PILING	95.0	TN	750.00	9.100	70.00	71,250	60,515	131,765	865
100.1045	1310	STEEL BRACING	29.0	TN	900.00	15.000	70.00	26,100	30,450	56,550	435
100.1045	1320	TREMIE CONCRETE	152.0	CY	75.00	1.500	53.00	11,400	12,084	23,484	228
100.1045	TOTAL WORK PACKAGE							108,750	103,049	211,799	1,528
100.1050		DREDGING & BACKFILL									
100.1050	1410	DREDGING VOLUME	14000.0	CY		0.200	100.00		280,000	280,000	2,800
100.1050	1415	DISPOSAL (SPOILS)	14000.0	CY	10.00	0.050	100.00	140,000	70,000	210,000	700
100.1050	1420	BACKFILL VOLUME (SELECT STONE) - INCL BACKFILL OF PIPES	9500.0	CY	5.00	0.300	61.75	47,500	175,988	223,488	2,850
100.1050	TOTAL WORK PACKAGE							187,500	525,988	713,488	6,350
100.1060		ELECTRICAL SCOPE									
100.1060	TOTAL WORK PACKAGE										
100.1100		TEMPORARY COFFERDAM									
100.1100	1100	TEMP BRACING INSTALLED W/RIG	255.0	TN		9.100	70.00		162,435	162,435	2,321
100.1100	1120	TEMP COFFERDAM DRIVEN W/RIG	65.0	TN		15.000	70.00		68,250	68,250	975
100.1100	1130	REMOVAL OF COFFERDAM, BRACING	1.0	LS		1648.000	70.00		115,360	115,360	1,648
100.1100	1140	RENTAL OF COFFERDAM, BRACING	1.0	LS	80000.00			80,000		80,000	
100.1100	1150	DEWATERING @ 24 HRS/DAY	4.0	MO	2500.00	720.000	50.75	10,000	146,160	156,160	2,880
100.1100	1160	SURVEY & CONTROL - 2EMP	4.0	MO	15600.00			62,400		62,400	
100.1100	TOTAL WORK PACKAGE							152,400	492,205	644,605	7,824
100.1200		PLACEMENT OF PIPE SECTIONS & MARINE EQUIPMENT FOR DURATION									
100.1200	1200	WORK BARGE W/4 MAN CREW	12.0	MO	42000.00			504,000		504,000	
100.1200	1210	DECK CARGO BARGE - 120'X45'	12.0	MO	6000.00			72,000		72,000	
100.1200	1220	TUG BOAT W/3 MAN CREW	12.0	MO	29000.00			348,000		348,000	
100.1200	1221	CRANE-25TN X 70' REACH	12.0	MO	8100.00	173.000	61.75	97,200	128,193	225,393	2,076
100.1200	1222	DIVERS - 4 DIVERS/4 TENDERS	5.0	MO	176000.00			880,000		880,000	

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 14:29:17 REPORT DATE: 11/25/92
********** WEDGE WIRE SCREENS **********
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1200	1230	PLACE PIPING SECTIONS IN WATER -NOT INCL BEDDING & BACKFILL	9.0 EA		80.000	57.75		41,580	41,580	720
100.1200	TOTAL WORK PACKAGE						1,901,200	169,773	2,070,973	2,796
100.1	TOTAL SUBACCOUNT						8,805,619	2,657,875	11,463,494	53,810
100.5000		ELECTRICAL SCOPE								
100.5000	5010	BRKERS,WIRE,CONDUIT FOR COMPR	1.0 LS	3000.00	160.000	54.75	3,000	8,760	11,760	160
100.5000	5020	LOCAL WIRING @ ACTUATORS/SUPPL	62.0 EA	600.00	10.000	54.75	37,200	33,945	71,145	620
100.5000	5030	ALLOWANCE FOR GATE OPERATOR WR	4.0 EA	5000.00	100.000	54.75	20,000	21,900	41,900	400
100.5000	TOTAL WORK PACKAGE						60,200	64,605	124,805	1,180
100.5	TOTAL SUBACCOUNT						60,200	64,605	124,805	1,180
100.6000		TEMPORARY DOCK FACILITY								
100.6000	6000	TEMPORARY DOCK FACILITY	1.0 LS	200000.00			200,000		200,000	
100.6000	6000	OPERATING	12.0 MO		346.000	50.00		207,600	207,600	4,152
100.6000	TOTAL WORK PACKAGE						200,000	207,600	407,600	4,152
100.6	TOTAL SUBACCOUNT						200,000	207,600	407,600	4,152
100.7000		TIE-IN COSTS								
100.7000	6000	TIE-IN COSTS	1.0 LS	10000.00	260.000	57.75	10,000	15,015	25,015	260
100.7000	TOTAL WORK PACKAGE						10,000	15,015	25,015	260
100.7	TOTAL SUBACCOUNT						10,000	15,015	25,015	260
100	TOTAL - DIRECT COST						9,075,819	2,945,095	12,020,914	59,402
910	CONSTRUCTION MANAGEMENT									
910.9100		CONSTRUCTION MANAGEMENT								

0001- 0001759

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 14:29:17 REPORT DATE: 11/25/92
********** WEDGE WIRE SCREENS **********
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
910.9100 9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	842000.00			842,000		842,000	
910.9100	TOTAL WORK PACKAGE					842,000		842,000	
910.9	TOTAL SUBACCOUNT					842,000		842,000	
910	TOTAL - CONSTRUCTION MANAGEMENT					842,000		842,000	
920	ENGINEERING								
920.9200	ENGINEERING								
920.9200 9000	ENGINEERING @ 10%	1.0 LS	1202000.00			1,202,000		1,202,000	
920.9200	TOTAL WORK PACKAGE					1,202,000		1,202,000	
920.9	TOTAL SUBACCOUNT					1,202,000		1,202,000	
920	TOTAL - ENGINEERING					1,202,000		1,202,000	
930	ESCALATION								
930.9300	ESCALATION								
930.9300 9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300	TOTAL WORK PACKAGE								
930.9	TOTAL SUBACCOUNT								
930	TOTAL - ESCALATION								
940	ALLOWANCE FOR INDETERMINATES								
940.9400	ALLOW FOR INDETRMNTS/CONTNGNCY								

0001- 0001760

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 14:29:17 REPORT DATE: 11/25/92
********** WEDGE WIRE SCREENS **********
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/25/92

ACCOUNT CODES STEM SYS SEQ SORT ML		DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
940.9400	9000	ALLOW FOR INDETRMNTS/CONTNGNCY	1.0 LS	3544000.00			3,544,000		3,544,000	
940.9400		TOTAL WORK PACKAGE					3,544,000		3,544,000	
940.9		TOTAL SUBACCOUNT					3,544,000		3,544,000	
940		TOTAL - ALLOWANCE FOR INDETERMINATES					3,544,000		3,544,000	
		TOTAL ESTIMATE					14,663,819	2,945,095	17,608,914	59,402

0001- 0001761

SUMMARY REPORT STONE & WEBSTER ENGINEERING CORPORATION J.O. 1728303 - TWO SPEED MOTOR PAGE 1

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 09:46:23 REPORT DATE: 11/30/92

<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	1,870,506	438,009	2,308,515	8,212
910	CONSTRUCTION MANAGEMENT	162,000		162,000	
920	ENGINEERING	231,000		231,000	
930	ESCALATION				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	542,000		542,000	
	TOTAL ESTIMATE	2,805,506	438,009	3,243,515	8,212

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY REPORT DATE: 11/30/92
<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally; assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included; removal of original motors included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work is included.
18. All offshore work to be scheduled other than during winter months.

0001- 0001763

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 09:37:50 REPORT DATE: 11/30/92
<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST								
100.	TWO(2) SPEED CIRC PUMP MOTORS TO REPLACE SINGLE SPEED								
100.	TOTAL WORK PACKAGE								
100.1000	TWO(2) SPEED CIRC PUMP MOTORS								
100.1000 2500	TWO(2) SPEED CIRC PUMP MOTORS	6.0 EA	225000.00	240.000	52.75	1,350,000	75,960	1,425,960	1,440
100.1000 2510	REMOVE SINGLE SPEED MOTORS	6.0 EA		240.000	52.75		75,960	75,960	1,440
100.1000	TOTAL WORK PACKAGE					1,350,000	151,920	1,501,920	2,880
100.1600	MOTOR STARTER BUILDING								
100.1600 1600	EXCAVATION, OVERBURDEN	96.0 CY		0.120	60.50		697	697	12
100.1600 1610	ROCK EXCAVATION	48.0 CY	1.40	0.300	60.50	67	871	938	14
100.1600 1620	BACKFILL	33.0 CY		0.200	60.50		399	399	7
100.1600 1630	CONCRETE (SLAB)	42.0 CY	65.00	2.200	50.75	2,730	4,689	7,419	92
100.1600 1640	FORMWORK (SLAB)	440.0 SF	1.50	0.450	49.75	660	9,851	10,511	198
100.1600 1650	REINFORCING (SLAB)	3.5 TN	575.00	25.000	61.75	2,013	5,403	7,416	88
100.1600 1660	CONCRETE (WALL)	20.0 CY	65.00	2.200	50.75	1,300	2,233	3,533	44
100.1600 1670	FORMWORK (WALL)	1320.0 CY	1.50	0.450	49.75	1,980	29,552	31,532	594
100.1600 1680	REINFORCING (WALL)	1.5 TN	575.00	25.000	61.75	863	2,316	3,179	38
100.1600 1690	ENCLOSED STRUCTURE-BUTLER TYPE -DIMENSIONS OF 25'X30'X12'HIGH - USE $45/SF INCL ALLOW FOR HVAC	750.0 SF	27.00	0.300	60.00	20,250	13,500	33,750	225
100.1600	TOTAL WORK PACKAGE					29,863	69,511	99,374	1,312
100.1	TOTAL SUBACCOUNT					1,379,863	221,431	1,601,294	4,192
100.5010 --	ELECTRICAL EQUIPMENT								
100.5010 001 4700 AA	5 KV MOTOR STARTERS-2 SPEED	6.0 EA	30000.00	40.000	53.75	180,000	12,900	192,900	240
100.5010 003 4700 AA	MOTOR CONTROL CENTER-1 SECTION	2.0 EA	3600.00	40.000	53.75	7,200	4,300	11,500	80
100.5010 004 4700 AA	480V/277 V PANEL	1.0 EA	800.00	16.000	53.75	800	860	1,660	16
100.5010 005 4700 AA	120V/208 V PANEL	1.0 EA	600.00	16.000	53.75	600	860	1,460	16
100.5010 006 4700 AA	45 KVA TRANSFORMER	1.0 EA	1400.00	24.000	53.75	1,400	1,290	2,690	24
100.5010 007 4700 AA	5 KV CIRCUIT BREAKERS	10.0 EA	21500.00	24.000	53.75	215,000	12,900	227,900	240
100.5010 008 4700 AA	100 A 600V MCC FEED BREAKER	2.0 EA	450.00	12.000	53.75	900	1,290	2,190	24
100.5010 009 4700 AA	NEW CONTROL SWITCH-FAST/SLOW TO BE MOUNTED IN EXISTING CONTROL BOARD	6.0 EA	600.00	12.000	53.75	3,600	3,870	7,470	72
100.5010	TOTAL WORK PACKAGE					409,500	38,270	447,770	712

0001- 0001764

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 09:37:50 REPORT DATE: 11/30/92
<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5011 --	DEMOLITION-ELECTRICAL									
100.5011 001 4300 AA	REMOVE 5KV FROM EXIST MOTORS INCLUDES MISC WIRING	6.0	EA		12.000	53.75		3,870	3,870	72
100.5011 002 4300 AA	REMOVE 3/C 5KV CABLE TO MNHOLE EXISTING MANHOLE	1800.0	LF		0.120	53.75		11,610	11,610	216
100.5011 003 4300 AA	REPULL 3/C 5KV CABLE TO STRTRS	1800.0	LF		0.120	53.75		11,610	11,610	216
100.5011 003 4300 AA	TESTING OF EXIST CABLE-RECONN	1.0	LS		16.000	53.75		860	860	16
100.5011	TOTAL WORK PACKAGE							27,950	27,950	520
100.5020 --	CABLE\TERMINATIONS									
100.5020 001 4300 AA	3/C#350 5 KV CABLE W JACKET	1800.0	LF	15.00	0.100	53.75	27,000	9,675	36,675	180
100.5020 002 4300 AA	#350 5 KV TERMINATIONS	90.0	EA	75.00	4.000	53.75	6,750	19,350	26,100	360
100.5020 003 4300 AA	9/C#12 CONTROL CABLE	4800.0	LF	0.75	0.020	53.75	3,600	5,160	8,760	96
100.5020 004 4300 AA	#12 CONTROL TERMINATIONS	108.0	EA	0.50	0.200	53.75	54	1,161	1,215	22
100.5020 005 4300 AA	3/C#4/0 600 V MCC FEED	150.0	LF	10.00	0.075	53.75	1,500	605	2,105	11
100.5020 006 4300 AA	#4/0 600V TERMINATIONS	3.0	EA	8.00	1.000	53.75	24	161	185	3
100.5020	TOTAL WORK PACKAGE						38,928	36,112	75,040	672
100.5030 --	CONDUIT									
100.5030 000 4200 AA	1" RIGID ALUM.CONDUIT FOR MISC FEEDS	300.0	LF	1.50	0.160	53.75	450	2,580	3,030	48
100.5030 000 4200 AA	3" RIGID ALUM.CONDUIT ASSEMBLY FOR CIRC PUMPS- CONDUIT,FLEX,TRAY ADAPTER	16.0	EA	350.00	20.000	53.75	5,600	17,200	22,800	320
100.5030 000 4200 AA	MISC WIRING/CONNECTIONS	1.0	LS	500.00	40.000	53.75	500	2,150	2,650	40
100.5030	TOTAL WORK PACKAGE						6,550	21,930	28,480	408
100.5040 --	GROUNDING									
100.5040 000 4040 AA	4/0 BARE COPPER	500.0	LF	2.00	0.060	53.75	1,000	1,613	2,613	30
100.5040 000 4040 AA	GROUND RODS	8.0	EA	20.00	2.000	53.75	160	860	1,020	16
100.5040 000 4040 AA	MISC CADWELDS\CONN	1.0	LS	300.00	40.000	53.75	300	2,150	2,450	40
100.5040	TOTAL WORK PACKAGE						1,460	4,623	6,083	86
100.5050 --	LIGHTING									
100.5050 000 4110 AA	STRIP TYPE FIXTURES	20.0	EA	80.00	1.500	53.75	1,600	1,613	3,213	30
100.5050 000 4110 AA	EXIT FIXTURES	4.0	EA	80.00	2.500	53.75	320	538	858	10
100.5050 000 4110 AA	EMERGENCY BATTERY PACKS	4.0	EA	350.00	4.000	53.75	1,400	860	2,260	16
100.5050 000 4110 AA	OUTDOOR WALL PACKS	6.0	EA	250.00	4.000	53.75	1,500	1,290	2,790	24
100.5050 000 4110 AA	3/4" RIGID CONDUIT	600.0	LF	1.00	0.150	53.75	600	4,838	5,438	90
100.5050 000 4110 AA	#12 WIRE	1800.0	LF	0.10	0.020	53.75	180	1,935	2,115	36
100.5050	TOTAL WORK PACKAGE						5,600	11,074	16,674	206

0001- 0001765

ACCOUNT CODES STEM SYS	SEQ	SORT	ML	DESCRIPTION	QUANTITY	UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5051			--	MISC POWER									
100.5051	000	4000	AA	MISC RECEPTACLES/OUTLETS-COMPL	1.0	LS	500.00	40.000	53.75	500	2,150	2,650	40
100.5051				TOTAL WORK PACKAGE						500	2,150	2,650	40
100.5055			--	FIRE ALARM									
100.5055	000	4060	AA	PULL STATIONS	2.0	EA	80.00	2.000	53.75	160	215	375	4
100.5055	000	4060	AA	MISC DETECTORS	3.0	EA	80.00	2.000	53.75	240	323	563	6
100.5055	000	4810	AA	3/4" RIGID CONDUIT	100.0	LF	1.00	0.150	53.75	100	806	906	15
100.5055	000	4810	AA	#16 WIRE	400.0	LF	0.10	0.020	53.75	40	430	470	8
100.5055				TOTAL WORK PACKAGE						540	1,774	2,314	33
100.5060			--	COMMUNICATIONS/CONTROL									
100.5060	000	4810	AA	GAITRONICS STATIONS	1.0	EA	500.00	4.000	53.75	500	215	715	4
100.5060	000	4810	AA	3/4" RIGID CONDUIT	100.0	LF	1.00	0.150	53.75	100	806	906	15
100.5060	000	4810	AA	5/C#12 CONTROL CABLE	200.0	LF	0.45	0.020	53.75	90	215	305	4
100.5060				TOTAL WORK PACKAGE						690	1,236	1,926	23
100.5061			--	DUCTBANK-MANHOLE TO NEW BLDG. 300'									
100.5061	001	1410	AA	EXCAVATION-3.5'X 3'X300' MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH	163.0	CY		0.120	60.50		1,183	1,183	20
100.5061	001	1410	AA	FORMWORK-2'x300''X 2 SIDES	1200.0	SF	1.50	0.200	49.75	1,800	11,940	13,740	240
100.5061	002	1410	AA	CONCRETE-1.5'X 3'X 300'	50.0	CY	65.00	1.500	60.50	3,250	4,538	7,788	75
100.5061	003	1410	AA	BACKFILL	113.0	CY		0.150	60.50		1,025	1,025	17
100.5061	004	1410	AA	REBAR	2.0	TN	575.00	25.000	61.75	1,150	3,088	4,238	50
100.5061	005	4000	AA	5" SCH 40 PVC	2400.0	LF	1.50	0.080	53.75	3,600	10,320	13,920	192
100.5061	005	4000	AA	TIE TO EXIST MANHOLE	1.0	LS		12.000	53.75		645	645	12
100.5061				TOTAL WORK PACKAGE						9,800	32,739	42,539	606
100.5062			--	DUCTBANK-STARTERS TO MOTORS 100'									
100.5062	001	1410	AA	EXCAVATION-5'X 3'X 100' MULTIPLIER OF 1.4 USED FOR V SHAPED TRENCH	78.0	CY		0.120	60.50		566	566	9
100.5062	001	1410	AA	FORMWORK-3'X100'X 2 SIDES	600.0	SF	1.50	0.200	49.75	900	5,970	6,870	120
100.5062	002	1410	AA	CONCRETE-3'X3'X 100'	33.0	CY	65.00	1.500	60.50	2,145	2,995	5,140	50
100.5062	003	1410	AA	BACKFILL	45.0	CY		0.150	60.50		408	408	7
100.5062	004	1410	AA	REBAR	2.0	TN	575.00	25.000	61.75	1,150	3,088	4,238	50

0001- 0001766

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 09:37:50 REPORT DATE: 11/30/92
<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.5062 005 4000 AA	5" SCH 40 PVC	1600.0 LF	1.80	0.080	53.75	2,880	6,880	9,760	128
100.5062	TOTAL WORK PACKAGE					7,075	19,907	26,982	364
100.5	TOTAL SUBACCOUNT					480,643	197,765	678,408	3,670
100.7000	TIE-INS TO OPERATING SYSTEM								
100.7000 7000	TIE-INS TO OPERATING SYSTEM	1.0 LS	10000.00	350.000	53.75	10,000	18,813	28,813	350
100.7000	TOTAL WORK PACKAGE					10,000	18,813	28,813	350
100.7	TOTAL SUBACCOUNT					10,000	18,813	28,813	350
100	TOTAL - DIRECT COST					1,870,506	438,009	2,308,515	8,212
910	CONSTRUCTION MANAGEMENT								
910.9100	CONSTRUCTION MANAGEMENT								
910.9100 9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	162000.00			162,000		162,000	
910.9100	TOTAL WORK PACKAGE					162,000		162,000	
910.9	TOTAL SUBACCOUNT					162,000		162,000	
910	TOTAL - CONSTRUCTION MANAGEMENT					162,000		162,000	
920	ENGINEERING								
920.9200	ENGINEERING								
920.9200 9000	ENGINEERING @ 10%	1.0 LS	231000.00			231,000		231,000	
920.9200	TOTAL WORK PACKAGE					231,000		231,000	
920.9	TOTAL SUBACCOUNT					231,000		231,000	
920	TOTAL - ENGINEERING					231,000		231,000	

0001- 0001767

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 09:37:50 REPORT DATE: 11/30/92
<<<<<<< TWO SPEED CIRC WATER PUMP MOTOR >>>>>>>
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
930		ESCALATION								
930.9300		ESCALATION								
930.9300	9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300		TOTAL WORK PACKAGE								
930.9		TOTAL SUBACCOUNT								
930		TOTAL - ESCALATION								
940		CONTINGENCY								
940.9400		ALLOW FOR INDETRMNTS/CONTNGNCY								
940.9400	9000	ALLOW FOR INDETRMNTS/CONTNGNCY	1.0 LS	542000.00			542,000		542,000	
940.9400		TOTAL WORK PACKAGE					542,000		542,000	
940.9		TOTAL SUBACCOUNT					542,000		542,000	
940		TOTAL - CONTINGENCY					542,000		542,000	
		TOTAL ESTIMATE					2,805,506	438,009	3,243,515	8,212

0001- 0001768

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY STEM SUMMARY REPORT TIME: 08:52:53 REPORT DATE: 11/30/92
########## PRECAST CONCRETE SILLS ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

STEM ACCOUNT	TITLE	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST	832,415	463,875	1,296,290	8,997
910	CONSTRUCTION MANAGEMENT	91,000		91,000	
920	ENGINEERING	130,000		130,000	
930	ESCALATION				
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY	309,000		309,000	
	TOTAL ESTIMATE	1,362,415	463,875	1,826,290	8,997

0001- 0001769

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY   REPORT DATE: 11/30/92
########## PRECAST CONCRETE SILLS ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY   ESTIMATE DATE: 11/30/92

ESTIMATE NOTES

Estimate basis as follows:

1. Present day pricing as of 11/1/92.
2. Subcontracted labor rates as of 11/1/92.
3. Forty hour work week, single shift operation.
4. Dredged material to be disposed of locally; assumed to be not contaminated.
5. Required construction utilities supplied by owner.
6. Land required for construction trailers, parking, and lay down provided by owner.
7. Escalation not included.
8. Abandonment costs not included.
9. Demolition/relocation costs not included.
10. Lost revenue during station shut downs for tie-ins not included.
11. Sales, use, service or other taxes not included.
12. Builders all-risk insurance not included.
13. Severe contingency costs such as those associated with adverse weather, craft strikes not included.
14. Start-up costs not included.
15. Permits including environmental not included.
16. Employee training, certifications, security costs not included.
17. No Category 1 work is included.
18. All offshore work to be scheduled other than during winter months.

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY — WORK PACKAGE DETAIL REPORT — REPORT TIME: 08:55:23 REPORT DATE: 11/30/92

########## PRECAST CONCRETE SILLS ##########

PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY — ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100	DIRECT COST									
100.		PRECAST CONCRETE SILLS								
100.	TOTAL WORK PACKAGE									
100.1010		PRECAST CONCRETE SILLS FABRCTN								
100.1010	1010	CONCRETE	900.0 CY	65.00	2.200	50.75	58,500	100,485	158,985	1,980
100.1010	1020	FORMWORK (3 USES)	9000.0 SF	1.50	0.450	49.75	13,500	201,488	214,988	4,050
100.1010	1030	REINFORCING	27.0 TN	575.00	25.000	61.75	15,525	41,681	57,206	675
100.1010	1031	SHIP TO LOADING AREA	180.0 EA		2.000	50.75		18,270	18,270	360
100.1010	TOTAL WORK PACKAGE						87,525	361,924	449,449	7,065
100.1020		INSTALLATION - CRANE								
100.1020	1120	DECK CARGO BARGE-120'X45'	1.2 MO	6000.00			7,200		7,200	
100.1020	1130	WORK BARGE W/4 MAN CREW	1.2 MO	42000.00			50,400		50,400	
100.1020	1131	CRANE-25 TN CAP, 70' REACH	1.2 MO	8100.00			9,720		9,720	
100.1020	1134	TUG BOAT W/3 MAN CREW	1.2 MO	29000.00			34,800		34,800	
100.1020	1150	WORK CREW - CRANE OPER - FOR 10 WEEKS	1.0 EA		200.000	61.75		12,350	12,350	200
100.1020	1160	WORK CREW - 2 LABORERS - FOR 10 WEEKS	2.0 EA		200.000	53.08		21,232	21,232	400
100.1020	1175	SURVEY & CONTROL	1.2 MO	15600.00			18,720		18,720	
100.1020	1180	MOBILIZATION/DEMOBILIZATION	1.0 LS	40000.00			40,000		40,000	
100.1020	TOTAL WORK PACKAGE						160,840	33,582	194,422	600
100.1030		INSTALLATION - DIVERS - FOR 10 WEEKS	1.0 LS							
100.1030	1110	DIVERS: 4 DIVERS/4 TENDERS	1.2 MO	176000.00			211,200		211,200	
100.1030	1112	TIE-DOWN STRAPS(LABOR W/DIVERS	80.0 EA	2000.00			160,000		160,000	
100.1030	1114	DRILL EQUIP FOR TIE-DOWNS	1.2 MO	5500.00			6,600		6,600	
100.1030	TOTAL WORK PACKAGE						377,800		377,800	
100.1040		TREMIE CONCRETE								
100.1040	1110	TREMIE CONCRETE INTO 30' WATER - LABOR INCLUDED IN DIVERS AND LABORERS TIME	150.0 CY	75.00	1.500	53.08	11,250	11,943	23,193	225
100.1040	1111	ALLOWANCE FOR HOSES, PUMP, ETC	1.0 MO	5000.00			5,000		5,000	
100.1040	1120	DECK CARGO BARGE 120' X 45'	1.0 MO	6000.00			6,000		6,000	
100.1040	1122	WORK BARGE W/4 MAN CREW	1.0 MO	42000.00			42,000		42,000	
100.1040	1122	TUG BOAT W/3 MAN CREW	1.0 MO	29000.00			29,000		29,000	
100.1040	1124	DIVERS - 2 DIVERS/2 TENDERS	1.0 MO	88000.00			88,000		88,000	

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:55:23 REPORT DATE: 11/30/92
########## PRECAST CONCRETE SILLS ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS	SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
100.1040	1130	ADDTL WORK CREW - 2 LABORERS	2.0 EA		173.000	53.08		18,366	18,366	346
100.1040		TOTAL WORK PACKAGE					181,250	30,309	211,559	571
100.1		TOTAL SUBACCOUNT					807,415	425,815	1,233,230	8,236
100.6000		TEMPORARY DOCK FACILITY								
100.6000	6000	TEMPORARY DOCK FACILITY	1.0 LS	25000.00			25,000		25,000	
100.6000	6010	OPERATING	2.2 MO		346.000	50.00		38,060	38,060	761
100.6000		TOTAL WORK PACKAGE					25,000	38,060	63,060	761
100.6		TOTAL SUBACCOUNT					25,000	38,060	63,060	761
100		TOTAL - DIRECT COST					832,415	463,875	1,296,290	8,997
910		CONSTRUCTION MANAGEMENT								
910.9100		CONSTRUCTION MANAGEMENT								
910.9100	9000	CONSTRUCTION MANAGEMENT @ 7%	1.0 LS	91000.00			91,000		91,000	
910.9100		TOTAL WORK PACKAGE					91,000		91,000	
910.9		TOTAL SUBACCOUNT					91,000		91,000	
910		TOTAL - CONSTRUCTION MANAGEMENT					91,000		91,000	
920		ENGINEERING								
920.9200		ENGINEERING								
920.9200	9000	ENGINEERING @ 10%	1.0 LS	130000.00			130,000		130,000	
920.9200		TOTAL WORK PACKAGE					130,000		130,000	
920.9		TOTAL SUBACCOUNT					130,000		130,000	
920		TOTAL - ENGINEERING					130,000		130,000	

CLIENT - NORTHEAST UTILITIES SERVICE COMPANY WORK PACKAGE DETAIL REPORT REPORT TIME: 08:55:23 REPORT DATE: 11/30/92
########## PRECAST CONCRETE SILLS ##########
PROJECT - MILLSTONE UNIT 3 ALTERNATIVE COOLING WATER SYSTEMS STUDY ESTIMATE DATE: 11/30/92

ACCOUNT CODES STEM SYS SEQ SORT ML	DESCRIPTION	QUANTITY UN	MATERIAL $/UNIT	LABOR HRS PER UNIT	LABOR $/HR	MATERIAL DOLLARS	LABOR DOLLARS	TOTAL DOLLARS	LABOR HOURS
930	ESCALATION								
930.9300	ESCALATION								
930.9300 9000	ESCALATION - PRESENT DAY	1.0 LS							
930.9300	TOTAL WORK PACKAGE								
930.9	TOTAL SUBACCOUNT								
930	TOTAL - ESCALATION								
940	ALLOWANCE FOR INDETERMINATES/CONTINGENCY								
940.9400	ALLOW FOR INDTRMNTES/CONTNGNCY								
940.9400 9000	ALLOW FOR INDTRMNTES/CONTNGNCY	1.0 LS	309000.00			309,000		309,000	
940.9400	TOTAL WORK PACKAGE					309,000		309,000	
940.9	TOTAL SUBACCOUNT					309,000		309,000	
940	TOTAL - ALLOWANCE FOR INDETERMINATES/CONTINGENCY					309,000		309,000	
	TOTAL ESTIMATE					1,362,415	463,875	1,826,290	8,997

0001- 0001773

B

COST ESTIMATES OF PERFORMANCE PENALTIES

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 1

FULL SIZE NATURAL DRAFT COOLING TOWER, FULL TIME OPERATION, ANNUAL AVERAGE
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

	(A)	(B)	(C) A*B	(D) Hrs effected * C / 1000	(E)	(F)	(G) D*E/1000	(H) (C*F)/1000	(I) (G)+(H)
Year	Change in Output (KW)	NU ENTITLEMENT	NU's Entitlement of Change in Output (KW)	Increased Station Service (MWH)	Avoided Energy Rate ($/MWH)	Avoided Capacity Rate ($/kW-Yr)	Increased Fuel Expense ($000)	Capacity Penalty ($000)	Total Increased System Power Cost ($000)
1993	8,600	0.587	5,048	44,220	27	0.0	1,194	0	1,194
1994	8,600	0.633	5,444	47,689	28	0.0	1,335	0	1,335
1995	8,600	0.661	5,685	49,801	29	0.0	1,444	0	1,444
1996	8,600	0.659	5,667	49,779	36	0.0	1,792	0	1,792
1997	8,600	0.659	5,667	49,643	36	10.0	1,787	57	1,844
1998	8,600	0.662	5,693	49,871	43	20.7	2,144	118	2,262
1999	8,600	0.676	5,814	50,931	42	21.5	2,139	125	2,264
2000	8,600	0.680	5,848	51,369	53	22.4	2,723	131	2,854
2001	8,600	0.680	5,848	51,228	56	23.3	2,869	136	3,005
2002	8,600	0.680	5,848	51,228	63	24.3	3,227	142	3,369
2003	8,600	0.680	5,848	51,228	66	25.4	3,381	149	3,530
2004	8,600	0.680	5,848	51,369	76	26.6	3,904	156	4,060
2005	8,600	0.680	5,848	51,228	79	69.5	4,047	406	4,453
2006	8,600	0.680	5,848	51,228	78	116.1	3,996	679	4,675
2007	8,600	0.680	5,848	51,228	83	121.4	4,252	710	4,962
2008	8,600	0.680	5,848	51,369	88	126.9	4,520	742	5,262
2009	8,600	0.680	5,848	51,228	95	132.7	4,867	776	5,643
2010	8,600	0.680	5,848	51,228	101	138.7	5,174	811	5,985

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 2

FULL SIZE NATURAL DRAFT COOLING TOWER, FULL TIME OPERATION, ANNUAL AVERAGE
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	18,500	0.587	10,860	95,134	27	0.0	2,569	0	2,569
1994	18,500	0.633	11,711	102,588	28	0.0	2,872	0	2,872
1995	18,500	0.661	12,229	107,126	29	0.0	3,107	0	3,107
1996	18,500	0.659	12,192	107,095	36	0.0	3,855	0	3,855
1997	18,500	0.659	12,192	106,802	36	10.0	3,845	122	3,967
1998	18,500	0.662	12,247	107,284	43	20.7	4,613	254	4,867
1999	18,500	0.676	12,506	109,553	42	21.5	4,601	269	4,870
2000	18,500	0.680	12,580	110,503	53	22.4	5,857	282	6,139
2001	18,500	0.680	12,580	110,201	56	23.3	6,171	293	6,464
2002	18,500	0.680	12,580	110,201	63	24.3	6,943	306	7,249
2003	18,500	0.680	12,580	110,201	66	25.4	7,273	320	7,593
2004	18,500	0.680	12,580	110,503	76	26.6	8,398	335	8,733
2005	18,500	0.680	12,580	110,201	79	69.5	8,706	874	9,580
2006	18,500	0.680	12,580	110,201	78	116.1	8,596	1,461	10,057
2007	18,500	0.680	12,580	110,201	83	121.4	9,147	1,527	10,674
2008	18,500	0.680	12,580	110,503	88	126.9	9,724	1,596	11,320
2009	18,500	0.680	12,580	110,201	95	132.7	10,469	1,669	12,138
2010	18,500	0.680	12,580	110,201	101	138.7	11,130	1,745	12,875

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 3

FULL SIZE NATURAL DRAFT COOLING TOWER, PART TIME OPERATION (APRIL AND MAY)
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	8,600	0.579	4,979	7,289	27	0.0	197	0	197
1994	8,600	0.627	5,392	7,894	28	0.0	221	0	221
1995	8,600	0.662	5,693	8,335	29	0.0	242	0	242
1996	8,600	0.659	5,667	8,296	36	0.0	299	0	299
1997	8,600	0.659	5,667	8,296	36	10.0	299	57	356
1998	8,600	0.659	5,667	8,296	43	20.7	357	117	474
1999	8,600	0.675	5,805	8,499	42	21.5	357	125	482
2000	8,600	0.680	5,848	8,561	53	22.4	454	131	585
2001	8,600	0.680	5,848	8,561	56	23.3	479	136	615
2002	8,600	0.680	5,848	8,561	63	24.3	539	142	681
2003	8,600	0.680	5,848	8,561	66	25.4	565	149	714
2004	8,600	0.680	5,848	8,561	76	26.6	651	156	807
2005	8,600	0.680	5,848	8,561	79	69.5	676	406	1,082
2006	8,600	0.680	5,848	8,561	78	116.1	668	679	1,347
2007	8,600	0.680	5,848	8,561	83	121.4	711	710	1,421
2008	8,600	0.680	5,848	8,561	88	126.9	753	742	1,495
2009	8,600	0.680	5,848	8,561	95	132.7	813	776	1,589
2010	8,600	0.680	5,848	8,561	101	138.7	865	811	1,676

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 4

FULL SIZE NATURAL DRAFT COOLING TOWER, PART TIME OPERATION (APRIL AND MAY)
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	14,900	0.579	8,627	12,630	27	0.0	341	0	341
1994	14,900	0.627	9,342	13,677	28	0.0	383	0	383
1995	14,900	0.662	9,864	14,441	29	0.0	419	0	419
1996	14,900	0.659	9,819	14,375	36	0.0	518	0	518
1997	14,900	0.659	9,819	14,375	36	10.0	518	98	616
1998	14,900	0.659	9,819	14,375	43	20.7	618	203	821
1999	14,900	0.675	10,058	14,725	42	21.5	618	216	834
2000	14,900	0.680	10,132	14,833	53	22.4	786	227	1,013
2001	14,900	0.680	10,132	14,833	56	23.3	831	236	1,067
2002	14,900	0.680	10,132	14,833	63	24.3	934	246	1,180
2003	14,900	0.680	10,132	14,833	66	25.4	979	257	1,236
2004	14,900	0.680	10,132	14,833	76	26.6	1,127	270	1,397
2005	14,900	0.680	10,132	14,833	79	69.5	1,172	704	1,876
2006	14,900	0.680	10,132	14,833	78	116.1	1,157	1,176	2,333
2007	14,900	0.680	10,132	14,833	83	121.4	1,231	1,230	2,461
2008	14,900	0.680	10,132	14,833	88	126.9	1,305	1,286	2,591
2009	14,900	0.680	10,132	14,833	95	132.7	1,409	1,345	2,754
2010	14,900	0.680	10,132	14,833	101	138.7	1,498	1,405	2,903

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 5

2/3 SIZE NATURAL DRAFT COOLING TOWER, FULL TIME OPERATION, ANNUAL AVERAGE
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	5,700	0.587	3,346	29,311	27	0.0	791	0	791
1994	5,700	0.633	3,608	31,606	28	0.0	885	0	885
1995	5,700	0.661	3,768	33,008	29	0.0	957	0	957
1996	5,700	0.659	3,756	32,993	36	0.0	1,188	0	1,188
1997	5,700	0.659	3,756	32,903	36	10.0	1,185	38	1,223
1998	5,700	0.662	3,773	33,051	43	20.7	1,421	78	1,499
1999	5,700	0.676	3,853	33,752	42	21.5	1,418	83	1,501
2000	5,700	0.680	3,876	34,047	53	22.4	1,804	87	1,891
2001	5,700	0.680	3,876	33,954	56	23.3	1,901	90	1,991
2002	5,700	0.680	3,876	33,954	63	24.3	2,139	94	2,233
2003	5,700	0.680	3,876	33,954	66	25.4	2,241	98	2,339
2004	5,700	0.680	3,876	34,047	76	26.6	2,588	103	2,691
2005	5,700	0.680	3,876	33,954	79	69.5	2,682	269	2,951
2006	5,700	0.680	3,876	33,954	78	116.1	2,648	450	3,098
2007	5,700	0.680	3,876	33,954	83	121.4	2,818	471	3,289
2008	5,700	0.680	3,876	34,047	88	126.9	2,996	492	3,488
2009	5,700	0.680	3,876	33,954	95	132.7	3,226	514	3,740
2010	5,700	0.680	3,876	33,954	101	138.7	3,429	538	3,967

FLOUNDR.WK1 (1)
OCT 19, 1992

Internal Control 6

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

2/3 SIZE NATURAL DRAFT COOLING TOWER, FULL TIME OPERATION, ANNUAL AVERAGE
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	12,300	0.587	7,220	63,247	27	0.0	1,708	0	1,708
1994	12,300	0.633	7,786	68,205	28	0.0	1,910	0	1,910
1995	12,300	0.661	8,130	71,219	29	0.0	2,065	0	2,065
1996	12,300	0.659	8,106	71,203	36	0.0	2,563	0	2,563
1997	12,300	0.659	8,106	71,009	36	10.0	2,556	81	2,637
1998	12,300	0.662	8,143	71,333	43	20.7	3,067	169	3,236
1999	12,300	0.676	8,315	72,839	42	21.5	3,059	179	3,238
2000	12,300	0.680	8,364	73,469	53	22.4	3,894	187	4,081
2001	12,300	0.680	8,364	73,269	56	23.3	4,103	195	4,298
2002	12,300	0.680	8,364	73,269	63	24.3	4,616	203	4,819
2003	12,300	0.680	8,364	73,269	66	25.4	4,836	212	5,048
2004	12,300	0.680	8,364	73,469	76	26.6	5,584	222	5,806
2005	12,300	0.680	8,364	73,269	79	69.5	5,788	581	6,369
2006	12,300	0.680	8,364	73,269	78	116.1	5,715	971	6,686
2007	12,300	0.680	8,364	73,269	83	121.4	6,081	1,015	7,096
2008	12,300	0.680	8,364	73,469	88	126.9	6,465	1,061	7,526
2009	12,300	0.680	8,364	73,269	95	132.7	6,961	1,110	8,071
2010	12,300	0.680	8,364	73,269	101	138.7	7,400	1,160	8,560

FLOUNDR.WK1 (1)
OCT 19, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 7

2/3 SIZE NATURAL DRAFT COOLING TOWER, PART TIME OPERATION (APRIL AND MAY)
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	5,700	0.579	3,300	4,831	27	0.0	130	0	130
1994	5,700	0.627	3,574	5,232	28	0.0	146	0	146
1995	5,700	0.662	3,773	5,524	29	0.0	160	0	160
1996	5,700	0.659	3,756	5,499	36	0.0	198	0	198
1997	5,700	0.659	3,756	5,499	36	10.0	198	38	236
1998	5,700	0.659	3,756	5,499	43	20.7	236	78	314
1999	5,700	0.675	3,848	5,633	42	21.5	237	83	320
2000	5,700	0.680	3,876	5,674	53	22.4	301	87	388
2001	5,700	0.680	3,876	5,674	56	23.3	318	90	408
2002	5,700	0.680	3,876	5,674	63	24.3	357	94	451
2003	5,700	0.680	3,876	5,674	66	25.4	374	98	472
2004	5,700	0.680	3,876	5,674	76	26.6	431	103	534
2005	5,700	0.680	3,876	5,674	79	69.5	448	269	717
2006	5,700	0.680	3,876	5,674	78	116.1	443	450	893
2007	5,700	0.680	3,876	5,674	83	121.4	471	471	942
2008	5,700	0.680	3,876	5,674	88	126.9	499	492	991
2009	5,700	0.680	3,876	5,674	95	132.7	539	514	1,053
2010	5,700	0.680	3,876	5,674	101	138.7	573	538	1,111

FLOUNDR.WK1 (1)
OCT 15, 1992

Internal Control 8

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

2/3 SIZE NATURAL DRAFT COOLING TOWER, PART TIME OPERATION (APRIL AND MAY)
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	9,900	0.579	5,732	8,392	27	0.0	227	0	227
1994	9,900	0.627	6,207	9,087	28	0.0	254	0	254
1995	9,900	0.662	6,554	9,595	29	0.0	278	0	278
1996	9,900	0.659	6,524	9,551	36	0.0	344	0	344
1997	9,900	0.659	6,524	9,551	36	10.0	344	65	409
1998	9,900	0.659	6,524	9,551	43	20.7	411	135	546
1999	9,900	0.675	6,683	9,784	42	21.5	411	144	555
2000	9,900	0.680	6,732	9,856	53	22.4	522	151	673
2001	9,900	0.680	6,732	9,856	56	23.3	552	157	709
2002	9,900	0.680	6,732	9,856	63	24.3	621	164	785
2003	9,900	0.680	6,732	9,856	66	25.4	650	171	821
2004	9,900	0.680	6,732	9,856	76	26.6	749	179	928
2005	9,900	0.680	6,732	9,856	79	69.5	779	468	1,247
2006	9,900	0.680	6,732	9,856	78	116.1	769	782	1,551
2007	9,900	0.680	6,732	9,856	83	121.4	818	817	1,635
2008	9,900	0.680	6,732	9,856	88	126.9	867	854	1,721
2009	9,900	0.680	6,732	9,856	95	132.7	936	893	1,829
2010	9,900	0.680	6,732	9,856	101	138.7	995	934	1,929

FLOUNDR.WK1 (1)
OCT 15, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 9

1/2 SPEED CIRCULATING WATER PUMP OPERATION FOR APRIL AND MAY
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

	(A)	(B)	(C) A*B	(D) Hrs effected * C / 1000	(E)	(F)	(G) D*E/1000	(H) (C*F)/1000	(I) (G)+(H)
Year	Change in Output (KW)	NU ENTITLEMENT	NU's Entitlement of Change in Output (KW)	Increased Station Service (MWH)	Avoided Energy Rate ($/MWH)	Avoided Capacity Rate ($/kW-Yr)	Increased Fuel Expense ($000)	Capacity Penalty ($000)	Total Increased System Power Cost ($000)
1993	(5,950)	0.579	(3,445)	(5,043)	27	0.0	(136)	0	(136)
1994	(5,950)	0.627	(3,731)	(5,462)	28	0.0	(153)	0	(153)
1995	(5,950)	0.662	(3,939)	(5,767)	29	0.0	(167)	0	(167)
1996	(5,950)	0.659	(3,921)	(5,740)	36	0.0	(207)	0	(207)
1997	(5,950)	0.659	(3,921)	(5,740)	36	10.0	(207)	(39)	(246)
1998	(5,950)	0.659	(3,921)	(5,740)	43	20.7	(247)	(81)	(328)
1999	(5,950)	0.675	(4,016)	(5,879)	42	21.5	(247)	(86)	(333)
2000	(5,950)	0.680	(4,046)	(5,923)	53	22.4	(314)	(91)	(405)
2001	(5,950)	0.680	(4,046)	(5,923)	56	23.3	(332)	(94)	(426)
2002	(5,950)	0.680	(4,046)	(5,923)	63	24.3	(373)	(98)	(471)
2003	(5,950)	0.680	(4,046)	(5,923)	66	25.4	(391)	(103)	(494)
2004	(5,950)	0.680	(4,046)	(5,923)	76	26.6	(450)	(108)	(558)
2005	(5,950)	0.680	(4,046)	(5,923)	79	69.5	(468)	(281)	(749)
2006	(5,950)	0.680	(4,046)	(5,923)	78	116.1	(462)	(470)	(932)
2007	(5,950)	0.680	(4,046)	(5,923)	83	121.4	(492)	(491)	(983)
2008	(5,950)	0.680	(4,046)	(5,923)	88	126.9	(521)	(513)	(1,034)
2009	(5,950)	0.680	(4,046)	(5,923)	95	132.7	(563)	(537)	(1,100)
2010	(5,950)	0.680	(4,046)	(5,923)	101	138.7	(598)	(561)	(1,159)

FLOUNDR.WK1 (1)
OCT 15, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 10

1/2 SPEED CIRCULATING WATER PUMP OPERATION FOR APRIL AND MAY
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	32,840	0.579	19,014	27,836	27	0.0	752	0	752
1994	32,840	0.627	20,591	30,145	28	0.0	844	0	844
1995	32,840	0.662	21,740	31,827	29	0.0	923	0	923
1996	32,840	0.659	21,642	31,684	36	0.0	1,141	0	1,141
1997	32,840	0.659	21,642	31,684	36	10.0	1,141	216	1,357
1998	32,840	0.659	21,642	31,684	43	20.7	1,362	448	1,810
1999	32,840	0.675	22,167	32,452	42	21.5	1,363	477	1,840
2000	32,840	0.680	22,331	32,693	53	22.4	1,733	500	2,233
2001	32,840	0.680	22,331	32,693	56	23.3	1,831	520	2,351
2002	32,840	0.680	22,331	32,693	63	24.3	2,060	543	2,603
2003	32,840	0.680	22,331	32,693	66	25.4	2,158	567	2,725
2004	32,840	0.680	22,331	32,693	76	26.6	2,485	594	3,079
2005	32,840	0.680	22,331	32,693	79	69.5	2,583	1,552	4,135
2006	32,840	0.680	22,331	32,693	78	116.1	2,550	2,593	5,143
2007	32,840	0.680	22,331	32,693	83	121.4	2,714	2,711	5,425
2008	32,840	0.680	22,331	32,693	88	126.9	2,877	2,834	5,711
2009	32,840	0.680	22,331	32,693	95	132.7	3,106	2,963	6,069
2010	32,840	0.680	22,331	32,693	101	138.7	3,302	3,097	6,399

FLOUNDR.WK1 (1)
OCT 15, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 11

1/2 SPEED CIRCULATING WATER PUMP OPERATION FOR APRIL AND MAY
APPLIED TO MILLSTONE 3 ONLY

Performance Penalty Compared to Once Through

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	579,400	0.579	335,473	491,132	27	0.0	13,261	0	13,261
1994	579,400	0.627	363,284	531,848	28	0.0	14,892	0	14,892
1995	579,400	0.662	383,563	561,536	29	0.0	16,285	0	16,285
1996	579,400	0.659	381,825	558,992	36	0.0	20,124	0	20,124
1997	579,400	0.659	381,825	558,992	36	10.0	20,124	3,818	23,942
1998	579,400	0.659	381,825	558,992	43	20.7	24,037	7,904	31,941
1999	579,400	0.675	391,095	572,563	42	21.5	24,048	8,409	32,457
2000	579,400	0.680	393,992	576,804	53	22.4	30,571	8,825	39,396
2001	579,400	0.680	393,992	576,804	56	23.3	32,301	9,180	41,481
2002	579,400	0.680	393,992	576,804	63	24.3	36,339	9,574	45,913
2003	579,400	0.680	393,992	576,804	66	25.4	38,069	10,007	48,076
2004	579,400	0.680	393,992	576,804	76	26.6	43,837	10,480	54,317
2005	579,400	0.680	393,992	576,804	79	69.5	45,568	27,382	72,950
2006	579,400	0.680	393,992	576,804	78	116.1	44,991	45,742	90,733
2007	579,400	0.680	393,992	576,804	83	121.4	47,875	47,831	95,706
2008	579,400	0.680	393,992	576,804	88	126.9	50,759	49,998	100,757
2009	579,400	0.680	393,992	576,804	95	132.7	54,796	52,283	107,079
2010	579,400	0.680	393,992	576,804	101	138.7	58,257	54,647	112,904

0001- 0001785

FLOUNDR.WK1 (1)
OCT 15, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 12

OFFSHORE INTAKE, FULL TIME OPERATION
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

Year	(A) Change in Output (KW)	(B) NU ENTITLEMENT	(C) A*B NU's Entitlement of Change in Output (KW)	(D) Hrs effected * C / 1000 Increased Station Service (MWH)	(E) Avoided Energy Rate ($/MWH)	(F) Avoided Capacity Rate ($/kW-Yr)	(G) D*E/1000 Increased Fuel Expense ($000)	(H) (C*F)/1000 Capacity Penalty ($000)	(I) (G)+(H) Total Increased System Power Cost ($000)
1993	1,570	0.587	922	8,077	27	0.0	218	0	218
1994	1,570	0.633	994	8,707	28	0.0	244	0	244
1995	1,570	0.661	1,038	9,093	29	0.0	264	0	264
1996	1,570	0.659	1,035	9,091	36	0.0	327	0	327
1997	1,570	0.659	1,035	9,067	36	10.0	326	10	336
1998	1,570	0.662	1,039	9,102	43	20.7	391	22	413
1999	1,570	0.676	1,061	9,294	42	21.5	390	23	413
2000	1,570	0.680	1,068	9,381	53	22.4	497	24	521
2001	1,570	0.680	1,068	9,356	56	23.3	524	25	549
2002	1,570	0.680	1,068	9,356	63	24.3	589	26	615
2003	1,570	0.680	1,068	9,356	66	25.4	617	27	644
2004	1,570	0.680	1,068	9,381	76	26.6	713	28	741
2005	1,570	0.680	1,068	9,356	79	69.5	739	74	813
2006	1,570	0.680	1,068	9,356	78	116.1	730	124	854
2007	1,570	0.680	1,068	9,356	83	121.4	777	130	907
2008	1,570	0.680	1,068	9,381	88	126.9	826	136	962
2009	1,570	0.680	1,068	9,356	95	132.7	889	142	1,031
2010	1,570	0.680	1,068	9,356	101	138.7	945	148	1,093

FLOUNDR.WK1 (1)
OCT 15, 1992

COOLING WATER SYSTEM ALTERNATIVES
TO REDUCE LARVAL ENTRAINMENT
AT MILLSTONE UNITS 1,2 AND 3

Added Power Consumption and Performance Degradation Resulting From
Implementation of Cooling Water System Alternatives

Internal Control 12

OFFSHORE INTAKE, FULL TIME OPERATION
APPLIED TO MILLSTONE 3 ONLY

Added Pumping Power Required

	(A)	(B)	(C) A*B	(D) Hrs effected * C / 1000	(E)	(F)	(G) D*E/1000	(H) (C*F)/1000	(I) (G)+(H)
Year	Change in Output (KW)	NU ENTITLEMENT	NU's Entitlement of Change in Output (KW)	Increased Station Service (MWH)	Avoided Energy Rate ($/MWH)	Avoided Capacity Rate ($/kW-Yr)	Increased Fuel Expense ($000)	Capacity Penalty ($000)	Total Increased System Power Cost ($000)
1993	1,570	0.587	922	8,077	27	0.0	218	0	218
1994	1,570	0.633	994	8,707	28	0.0	244	0	244
1995	1,570	0.661	1,038	9,093	29	0.0	264	0	264
1996	1,570	0.659	1,035	9,091	36	0.0	327	0	327
1997	1,570	0.659	1,035	9,067	36	10.0	326	10	336
1998	1,570	0.662	1,039	9,102	43	20.7	391	22	413
1999	1,570	0.676	1,061	9,294	42	21.5	390	23	413
2000	1,570	0.680	1,068	9,381	53	22.4	497	24	521
2001	1,570	0.680	1,068	9,356	56	23.3	524	25	549
2002	1,570	0.680	1,068	9,356	63	24.3	589	26	615
2003	1,570	0.680	1,068	9,356	66	25.4	617	27	644
2004	1,570	0.680	1,068	9,381	76	26.6	713	28	741
2005	1,570	0.680	1,068	9,356	79	69.5	739	74	813
2006	1,570	0.680	1,068	9,356	78	116.1	730	124	854
2007	1,570	0.680	1,068	9,356	83	121.4	777	130	907
2008	1,570	0.680	1,068	9,381	88	126.9	826	136	962
2009	1,570	0.680	1,068	9,356	95	132.7	889	142	1,031
2010	1,570	0.680	1,068	9,356	101	138.7	945	148	1,093

C

COST ESTIMATES OF FORCED OUTAGES

FLOUNDRX.WK1 (1)
18-Sep-92

F L O U N D E R   S T U D Y

NET FUEL ($000) FOR VARIOUS SCENARIOS
Scenarios Per M. McNamara on 9/14/92

1993-2010

YEAR	CASE 1: NONVERTNERCLEAP Days	CASE 1: Mill1 Down Additional 73 Days, 4/2--6/13 ($000)	CASE 2: NONVERTNERCLEAP Days	CASE 2: Mill2 Down Additional 73 Days, 4/2--6/13 ($000)	CASE 3: NONVERTNERCLEAP Days	CASE 3: Mill 1 & 2 Down Additional 66 Days, 4/2--6/6 ($000)	CASE 4: NONVERTNERCLEAP Days	CASE 4: Mill3 Down Additional 66 Days, 4/2--6/6 ($000)	CASE 5: NONVERTNERCLEAP Days	CASE 5: Mill 1,2&3 Down Additional 21 Days, 4/22--5/12 ($000)	Case With Least $ Impact
1993		19,525		28,644		50,351	43	6,889	21	17,536	Case 4
1994		21,240	42	10,795	42	29,740		24,590	21	16,697	Case 2
1995		16,965		25,838		46,943		20,064		28,238	Case 1
1996		30,926	53	10,188	53	36,485		34,496	21	21,930	Case 2
1997		29,411		40,773		70,846	17	22,979	5	45,040	Case 4
1998		35,460	64	4,908	57	37,786		38,791	32	25,800	Case 2
1999		35,454		48,905		87,105	36	15,841	16	34,982	Case 4
2000	27	27,210	18	43,211	38	70,200		48,298	7	62,361	Case 1
2001		46,581		63,592		114,662	61	3,507	13	36,597	Case 4
2002	73	0		72,826	66	64,790		58,959	21	44,907	Case 1
2003		61,059		84,696		158,670	66	0	21	50,596	Case 4
2004	72	676		103,717	65	95,868		85,656	21	74,460	Case 1
2005		62,246		85,604		148,236	52	14,723	21	46,138	Case 4
2006	46	23,483		94,162	39	113,542		76,491	14	74,361	Case 1
2007		67,973		93,369		158,470	26	42,996	1	86,017	Case 4
2008	21	47,560		94,316	14	139,310		76,524		95,361	Case 1
2009		79,631	2	105,356	2	182,448	1	87,410		107,213	Case 1
2010		76,818		104,759		178,652		85,453		101,445	Case 1

FLOUNDRX.WK1 (1)
18-Sep-92

FLOUNDER STUDY
D E L T A S : BASE CASE Minus CHANGE CASE
1993-2010

Case 1 Base Case --> DO NOTHING TO NUCLEAR UNITS
------ Change Case --> ADDITIONAL MAINTENANCE: Millstone 1 Down 4/2 - 6/13

			(A)	(B)	(C)	(D)	(E)	(F)
						(B)+(C)	(B)/(A)	(D)/(A)
YEAR	WEIGHTED AVERAGE NU ENTITLEMENT MP1	REMOVED FROM DISPATCH MW	DISPLACED GENERATION MWH	NET FUEL ($000)	NUCLEAR FUEL COST CONSERVED ($000)	IF OPERATION CYCLE NOT EXTENDED ($000)	$/MWH	$/MWH
1993	0.872	575.4	877,034	19,525	5,958	25,483	22.26	29.06
1994	0.914	602.5	918,347	21,240	5,601	26,841	23.13	29.23
1995	0.953	628.2	957,490	16,965	5,840	22,805	17.72	23.82
1996	0.955	629.5	959,561	30,926	5,054	35,980	32.23	37.50
1997	0.949	625.7	953,755	29,411	5,022	34,433	30.84	36.10
1998	0.949	625.7	953,755	35,460	5,110	40,570	37.18	42.54
1999	0.965	636.5	970,112	35,454	5,200	40,654	36.55	41.91
2000	0.965	636.5	611,303	27,210	3,415	30,625	44.51	50.10
2001	0.965	636.5	970,112	46,581	5,420	52,001	48.02	53.60
2002	0.965	636.5	0	0	0	0	0.00	0.00
2003	0.965	636.5	970,112	61,059	5,636	66,695	62.94	68.75
2004	0.965	636.5	13,289	676	77	753	50.87	56.66
2005	0.965	636.5	970,112	62,246	5,862	68,108	64.16	70.21
2006	0.965	636.5	358,808	23,483	2,168	25,651	65.45	71.49
2007	0.965	636.5	970,112	67,973	6,095	74,068	70.07	76.35
2008	0.965	636.5	691,038	47,560	4,342	51,902	68.82	75.11
2009	0.965	636.5	970,112	79,631	6,339	85,970	82.08	88.62
2010	0.965	636.5	970,112	76,818	6,339	83,157	79.18	85.72

Case 2 Base Case --> DO NOTHING TO NUCLEAR UNITS
------ Change Case --> ADDITIONAL MAINTENANCE: Millstone 2 Down 4/2 - 6/13

			(A)	(B)	(C)	(D)	(E)	(F)
						(B)+(C)	(B)/(A)	(D)/(A)
YEAR	WEIGHTED AVERAGE NU ENTITLEMENT MP2	REMOVED FROM DISPATCH MW	DISPLACED GENERATION MWH	NET FUEL ($000)	NUCLEAR FUEL COST CONSERVED ($000)	IF OPERATION CYCLE NOT EXTENDED ($000)	$/MWH	$/MWH
1993	0.890	778.3	1,186,337	28,644	6,741	35,385	24.14	29.83
1994	0.921	805.8	521,595	10,795	2,556	13,351	20.70	25.60
1995	0.951	831.8	1,267,796	25,838	6,211	32,049	20.38	25.28
1996	0.953	833.1	347,917	10,188	1,731	11,919	29.28	34.26
1997	0.953	833.1	1,269,902	40,773	6,317	47,090	32.11	37.08
1998	0.953	833.1	156,563	4,908	778	5,686	31.35	36.32
1999	0.965	843.9	1,286,371	48,905	6,684	55,589	38.02	43.21
2000	0.965	843.9	969,186	43,211	5,036	48,247	44.58	49.78
2001	0.965	843.9	1,286,374	63,592	6,920	70,512	49.44	54.81
2002	0.965	843.9	1,286,373	72,826	6,920	79,746	56.61	61.99
2003	0.965	843.9	1,286,374	84,696	6,920	91,616	65.84	71.22
2004	0.965	843.9	1,286,373	103,717	6,920	110,637	80.63	86.01
2005	0.965	843.9	1,286,374	85,604	7,195	92,799	66.55	72.14
2006	0.965	843.9	1,286,373	94,162	7,195	101,357	73.20	78.79
2007	0.965	843.9	1,286,373	93,369	7,484	100,853	72.58	78.40
2008	0.965	843.9	1,286,373	94,316	7,484	101,800	73.32	79.14
2009	0.965	843.9	1,251,130	105,356	7,570	112,926	84.21	90.26
2010	0.965	843.9	1,286,373	104,759	7,783	112,542	81.44	87.49

FLOUNDRX.WK1 (1)
18-Sep-92

DELTAS: BASE CASE Minus CHANGE CASE
1993-2010

Case 3

Base Case --> DO NOTHING TO NUCLEAR UNITS
Change Case --> ADDITIONAL MAINTENANCE: Millstone 1 and Millstone 2 Down 4/2 - 6/6

YEAR	WEIGHTED AVERAGE NU ENTITLEMENT MP1+MP2	REMOVED FROM DISPATCH MW	(A) DISPLACED GENERATION MWH	(B) NET FUEL ($000)	(C) NUCLEAR FUEL COST CONSERVED ($000)	(D) (B)+(C) IF OPERATION CYCLE NOT EXTENDED ($000)	(E) (B)/(A) $/MWH	(F) (D)/(A) $/MWH
1993	0.882	1,353.7	1,865,508	50,351	11,480	61,831	26.99	33.14
1994	0.918	1,408.3	1,234,096	29,740	7,042	36,782	24.10	29.80
1995	0.952	1,459.9	2,011,897	46,943	10,895	57,838	23.33	28.75
1996	0.954	1,462.7	1,093,689	36,485	5,694	42,179	33.36	38.57
1997	0.951	1,458.9	2,010,429	70,846	10,251	81,097	35.24	40.34
1998	0.951	1,458.9	1,018,862	37,786	5,398	43,184	37.09	42.38
1999	0.965	1,480.4	2,040,108	87,105	10,745	97,850	42.70	47.96
2000	0.965	1,480.4	1,487,464	70,200	7,931	78,131	47.19	52.53
2001	0.965	1,480.4	2,040,110	114,662	11,156	125,818	56.20	61.67
2002	0.965	1,480.4	1,163,022	64,790	6,256	71,046	55.71	61.09
2003	0.965	1,480.4	2,040,110	158,670	11,352	170,022	77.78	83.34
2004	0.965	1,480.4	1,176,311	95,868	6,333	102,201	81.50	86.88
2005	0.965	1,480.4	2,040,110	148,236	11,805	160,041	72.66	78.45
2006	0.965	1,480.4	1,521,830	113,542	8,673	122,215	74.61	80.31
2007	0.965	1,480.4	2,040,109	158,470	12,277	170,747	77.68	83.70
2008	0.965	1,480.4	1,854,060	139,310	11,108	150,418	75.14	81.13
2009	0.965	1,480.4	2,004,866	182,448	12,555	195,003	91.00	97.26
2010	0.965	1,480.4	2,040,109	178,652	12,768	191,420	87.57	93.83

Case 4

Base Case --> DO NOTHING TO NUCLEAR UNITS
Change Case --> ADDITIONAL MAINTENANCE: Millstone 3 Down 4/2 - 6/6

YEAR	WEIGHTED AVERAGE NU ENTITLEMENT MP3	REMOVED FROM DISPATCH MW	(A) DISPLACED GENERATION MWH	(B) NET FUEL ($000)	(C) NUCLEAR FUEL COST CONSERVED ($000)	(D) (B)+(C) IF OPERATION CYCLE NOT EXTENDED ($000)	(E) (B)/(A) $/MWH	(F) (D)/(A) $/MWH
1993	0.579	665.1	319,390	6,889	1,616	8,505	21.57	26.63
1994	0.627	720.0	992,188	24,590	5,021	29,611	24.78	29.84
1995	0.662	760.2	1,047,679	20,064	5,482	25,546	19.15	24.38
1996	0.659	757.5	1,043,950	34,496	5,462	39,958	33.04	38.28
1997	0.659	757.5	775,055	22,979	4,384	27,363	29.65	35.30
1998	0.659	757.5	1,043,950	38,791	5,905	44,696	37.16	42.81
1999	0.675	775.0	485,441	15,841	2,743	18,584	32.63	38.28
2000	0.680	781.3	1,076,737	48,298	6,085	54,383	44.86	50.51
2001	0.680	781.3	81,571	3,507	485	3,992	42.99	48.94
2002	0.680	781.3	1,076,737	58,959	6,398	65,357	54.76	60.70
2003	0.680	781.3	0	0	0	0	0.00	0.00
2004	0.680	781.3	1,076,737	85,656	6,653	92,309	79.55	85.73
2005	0.680	781.3	228,399	14,723	1,411	16,134	64.46	70.64
2006	0.680	781.3	1,076,737	76,491	6,919	83,410	71.04	77.47
2007	0.680	781.3	652,568	42,996	4,193	47,189	65.89	72.31
2008	0.680	781.3	1,076,737	76,524	7,196	83,720	71.07	77.75
2009	0.680	781.3	1,060,423	87,410	7,087	94,497	82.43	89.11
2010	0.680	781.3	1,076,737	85,453	7,485	92,938	79.36	86.31

FLOUNDRX.WK1 (1)
18-Sep-92

DELTAS: BASE CASE Minus CHANGE CASE
.1993-2010

Case 5 Base Case --> DO NOTHING TO NUCLEAR UNITS
Change Case --> ADDITIONAL MAINTENANCE: Millstone 1,2, and 3 Down 4/22 - 5/12

YEAR	WEIGHTED AVERAGE NU ENTITLEMENT MP1,MP2 & MP3	REMOVED FROM DISPATCH MW	(A) DISPLACED GENERATION MWH	(B) NET FUEL ($000)	(C) NUCLEAR FUEL COST CONSERVED ($000)	(D) (B)+(C) IF OPERATION CYCLE NOT EXTENDED ($000)	(E) (B)/(A) $/MWH	(F) (D)/(A) $/MWH
1993	0.753	2,018.8	593,570	17,536	3,652	21,188	29.54	35.70
1994	0.793	2,128.3	579,874	16,697	3,208	19,905	28.79	34.33
1995	0.828	2,220.2	973,500	28,238	5,211	33,449	29.01	34.36
1996	0.828	2,220.2	608,200	21,930	3,192	25,122	36.06	41.31
1997	0.826	2,216.4	1,149,952	45,040	6,098	51,138	39.17	44.47
1998	0.826	2,216.4	606,533	25,800	3,348	29,148	42.54	48.06
1999	0.841	2,255.4	730,032	34,982	3,877	38,859	47.92	53.23
2000	0.843	2,261.7	1,145,401	62,361	6,180	68,541	54.44	59.84
2001	0.843	2,261.7	649,126	36,597	3,549	40,146	56.38	61.85
2002	0.843	2,261.7	712,650	44,907	4,026	48,933	63.01	68.66
2003	0.843	2,261.7	649,126	50,596	3,612	54,208	77.94	83.51
2004	0.843	2,261.7	712,650	74,460	4,107	78,567	104.48	110.25
2005	0.843	2,261.7	649,126	46,138	3,756	49,894	71.08	76.86
2006	0.843	2,261.7	805,674	74,361	4,833	79,194	92.30	98.30
2007	0.843	2,261.7	975,409	86,017	6,002	92,019	88.19	94.34
2008	0.843	2,261.7	1,137,904	95,361	7,114	102,475	83.80	90.06
2009	0.843	2,261.7	991,723	107,213	6,351	113,564	108.11	114.51
2010	0.843	2,261.7	991,723	101,445	6,444	107,889	102.29	108.79

FLOUNDRX.WK1 (1)
18-Sep-92

FLOUNDER STUDY

UNIT	YEAR	NU ENTITLEMENT APR	NU ENTITLEMENT MAY	NU ENTITLEMENT JUN	MAX CLAIMED CAPABILITY MW	NU CLAIMED CAPABILITY MW APR	NU CLAIMED CAPABILITY MW MAY	NU CLAIMED CAPABILITY MW JUN
MILLSTONE 1	1993	0.872	0.872	0.873	659.5	575.4	575.4	575.4
	1994	0.914	0.914	0.914	659.5	602.5	602.5	602.5
	1995	0.952	0.952	0.953	659.5	628.2	628.2	628.2
	1996	0.955	0.955	0.955	659.5	629.5	629.5	629.5
	1997	0.949	0.949	0.949	659.5	625.7	625.7	625.7
	1998	0.949	0.949	0.949	659.5	625.7	625.7	625.7
	1999	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2000	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2001	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2002	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2003	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2004	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2005	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2006	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2007	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2008	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2009	0.965	0.965	0.965	659.5	636.5	636.5	636.5
	2010	0.965	0.965	0.965	659.5	636.5	636.5	636.5

UNIT	YEAR	NU ENTITLEMENT APR	NU ENTITLEMENT MAY	NU ENTITLEMENT JUN	MAX CLAIMED CAPABILITY MW	NU CLAIMED CAPABILITY MW APR	NU CLAIMED CAPABILITY MW MAY	NU CLAIMED CAPABILITY MW JUN
MILLSTONE 2	1993	0.890	0.890	0.890	874.5	778.3	778.3	778.3
	1994	0.921	0.921	0.921	874.5	805.8	805.8	805.8
	1995	0.951	0.951	0.951	874.5	831.8	831.8	831.8
	1996	0.953	0.953	0.953	874.5	833.1	833.1	833.1
	1997	0.953	0.953	0.953	874.5	833.1	833.1	833.1
	1998	0.953	0.953	0.953	874.5	833.1	833.1	833.1
	1999	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2000	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2001	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2002	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2003	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2004	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2005	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2006	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2007	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2008	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2009	0.965	0.965	0.965	874.5	843.9	843.9	843.9
	2010	0.965	0.965	0.965	874.5	843.9	843.9	843.9

UNIT	YEAR	NU ENTITLEMENT APR	NU ENTITLEMENT MAY	NU ENTITLEMENT JUN	MAX CLAIMED CAPABILITY MW	NU CLAIMED CAPABILITY MW APR	NU CLAIMED CAPABILITY MW MAY	NU CLAIMED CAPABILITY MW JUN
MILLSTONE 3	1993	0.579	0.579	0.579	1,148.7	665.1	665.1	665.1
	1994	0.627	0.627	0.627	1,148.7	720.0	720.0	720.0
	1995	0.662	0.662	0.662	1,148.7	760.2	760.2	760.2
	1996	0.659	0.659	0.659	1,148.7	757.5	757.5	757.5
	1997	0.659	0.659	0.659	1,148.7	757.5	757.5	757.5
	1998	0.659	0.659	0.659	1,148.7	757.5	757.5	757.5
	1999	0.675	0.675	0.675	1,148.7	775.0	775.0	775.0
	2000	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2001	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2002	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2003	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2004	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2005	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2006	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2007	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2008	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2009	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3
	2010	0.680	0.680	0.680	1,148.7	781.3	781.3	781.3

PART II

ENVIRONMENTAL AND BIOLOGICAL EVALUATION

TABLE OF CONTENTS - PART II

TABLE OF CONTENTS (Cont)

LIST OF TABLES - PART II

LIST OF TABLES (Cont)

0001- 0001798

LIST OF FIGURES - PART II

LIST OF FIGURES (Cont)

1

ENTRAINMENT OF WINTER FLOUNDER LARVAE AT MILLSTONE NUCLEAR POWER STATION

1.1 INTRODUCTION

Since 1973, the winter flounder (*Pleuronectes americanus*) has been the focus of detailed environmental impact studies by Northeast Utilities Service Company (NUSCO) at the Millstone Nuclear Power Station (MNPS) because of the importance of this species to the sport and commercial fisheries of Connecticut (Smith et al. 1989) and its abundance in the local demersal fish community. In particular, the population of winter flounder spawning in the nearby Niantic River has been studied in detail primarily to assess the long-term effect of MNPS operation on the size of this stock (NUSCO 1992a). MNPS directly affects winter flounder in two ways: demersal juvenile and adult winter flounder may be impinged throughout the year on traveling screens at the cooling-water intakes, and pelagic larvae may be entrained through the condenser cooling-water systems each spring. The impact of impingement has been largely mitigated by the installation and operation of fish return sluiceways at MNPS Units 1 and 3. The mortality of entrained larvae, however, potentially has greater significance. This is because the winter flounder, unlike most marine fishes, is a product of local spawning with geographically isolated stocks associated with individual estuaries or specific coastal areas (Lobell 1939; Perlmutter 1947; Saila 1961). Thus, losses may be disproportionately high on a relatively small spawning stock.

Estimates of the long-term effect of MNPS operation have been made several times using various impact assessment models as part of licensing requirements of the Connecticut Department of Environmental Protection (DEP) and other state and federal agencies. Initially, effects of entrainment and impingement were considered together in the MNPS 316(b)

demonstration (NUSCO 1976). The larval entrainment portion of the deterministic model used to assess impact in NUSCO (1976) was based on work completed by the University of Rhode Island (URI), which was summarized by Hess et al. (1975) and Saila (1976). Based on the few years of information available at that time, impingement was considered to be the most detrimental impact. An 18% reduction was predicted for the Niantic River winter flounder population after 35 years of three-unit operation, with one-third of this attributed to larval entrainment and the rest to impingement. The next formal application of an assessment model was for the MNPS Unit 3 Environmental Report - Operating License Stage (NUSCO 1983b), which was prepared for the U.S. Nuclear Regulatory Agency and was also reviewed by other federal and state agencies. As data from additional years of operating experience were then available and because of the actual or planned operation of fish return sluiceways at Units 1 and 3, impingement was determined to have little long-term significance in this particular analysis. Larval entrainment was the primary focus for impact assessment and a potential 5 to 6% reduction in the Niantic River winter flounder population was predicted after 35 years of three-unit operation using the URI model with the updated information.

In recent years, winter flounder abundance has declined in Connecticut and throughout the northeast (Howell et al. 1992). Because of their concern, the DEP began increased scrutiny of winter flounder studies at MNPS during the late 1980s. This resulted in several meetings among DEP and NUSCO personnel to discuss the situation and the potential relation between MNPS operation and decreasing winter flounder abundance. In addition to Annual Reports regularly submitted in April, annual updates of winter flounder abundance were presented to the DEP each October beginning in 1988. Furthermore, beginning in 1988 a series of special reports and model impact assessment simulations were sent to the DEP (**Table 1-1**). Along with the increased emphasis on winter flounder studies during this period was the development of the NUSCO stochastic population dynamics model (SPDM), which is currently used for assessment of long-term impacts. The SPDM assesses effects of MNPS operation on the Niantic River population by simulating the long-term effects of historical and projected rates of fishing mortality and simultaneous annual production losses due to larval entrainment. Presently, 40-year operation is assumed for each unit. The rate of production loss was determined indirectly from mass-balance calculations used to estimate annual fractions of larvae from the Niantic River population that were entrained. The SPDM also includes the relatively minor effect of impingement of juvenile and adult winter flounder, which is implemented as additional fishing mortality. A complete model description and assessments of potential reduction in entrainment rates as a result of various cooling water alternatives will be discussed below.

TABLE 1-1. Recent special submittals made to DEP concerning impact of MNPS on winter flounder.

Date	NUSCO correspondence number	Title
October 7, 1987	B12700	Millstone Unit No. 3 equivalent-adult revised calculation (submitted to the U.S. Nuclear Regulatory Commission with copy to DEP)
January 29, 1988	D01830	Overview of NU's winter flounder studies and the effectiveness of the MNPS fish return system
October 14, 1988	D02227	Absolute abundance estimates for the Niantic River population of winter flounder
July 20, 1989	D02901	Assessment of population differentiation in winter flounder: a preliminary report (prepared by J.R. Powell and K.A. Goddard, Yale University)
February 7, 1990	D03431	Application of a 2-D particle model tracking model to simulate entrainment of winter flounder larvae at the Millstone Nuclear Power Station (prepared by N.K. Dimou and E.E. Adams, Massachusetts Institute of Technology)
October 30, 1990	D04143	Mass-balance calculations for assessing production losses due to entrainment of winter flounder
January 23, 1991	D04339	Niantic River winter flounder population: simulation of long-term effects of larval entrainment at MNPS
January 23, 1991	D04343	Evaluation of the larval winter flounder sampling program in the Niantic River
June 20, 1991	D04716	Reassessment of impingement effects on winter flounder at MNPS
May 29, 1992	D05565	Scope of work for cooling water alternatives feasibility study to reduce larval winter flounder entrainment

NUSCO agreed to conduct the present entrainment mitigation study during a meeting held on October 24, 1991 between representatives of NUSCO and DEP regarding the entrainment of larval winter flounder and the renewal of the MNPS National Pollutant Discharge Elimination System permit. DEP staff indicated the need for a feasibility study to investigate alternative means of reducing larval entrainment. Consequently, a scope of study for this report was developed and submitted to DEP in May 1992 (NUSCO 1992c).

1.2 ENTRAINMENT OF LARVAL WINTER FLOUNDER AT MNPS

1.2.1 WINTER FLOUNDER EARLY LIFE HISTORY

Adult winter flounder spawn in the Long Island Sound (LIS) area from January through April. Local spawning takes place in the mid to upper Niantic River with little or no reproduction in Niantic Bay (NUSCO 1992a). Based on collections of yolk-sac larvae by Pearcy (1962) and NUSCO, other nearby spawning grounds include an area just to the west of the Connecticut River mouth, the Thames River north of the Coast Guard Academy, and the upper Mystic River. The average fecundity of Niantic River females is about 572,000 eggs per fish. Development proceeds through several distinct early life history stages, which are briefly summarized in **Table 1-2.** The demersal eggs hatch in about 15 days and development of larvae through metamorphosis takes about 40 to 60 days, depending upon water temperature. Small larvae are planktonic and although many remain near estuarine spawning grounds, others are swept into coastal waters by tidal currents (Smith et al. 1975; NUSCO 1989). Some of these larvae may be returned to the estuary on subsequent incoming tides, but many of the displaced larvae are carried further away from their source area. Following fin ray development, the larger larvae maintain some control over their position by vertical movements and also may spend considerable time on the bottom. Following metamorphosis, young-of-the-year winter flounder become wholly demersal and are found in shallow inshore waters.

1.2.2 NATURAL MORTALITY OF LARVAE

The rate of natural mortality during the early life history of a fish is an important factor in a life-stage based assessment model. Furthermore, large changes in mortality rate or changes in mortality associated with density may be an indication of biological compensation occurring during a particular period of development. Total mortality of Niantic River winter flounder larvae until metamorphosis for 1984-91 ranged from 82.4 to 97.9%, with a mean instantaneous rate of 2.75 (NUSCO 1992a). Pearcy (1962) found a mortality rate of 98.6% during the first 2.4 months of life of Mystic River winter flounder larvae.

Length-frequency distributions of winter flounder larvae in the Niantic River from 1983 through 1991 suggested that most mortality occurs between the 3.0- to 4.0-mm size -classes (NUSCO 1992a). The decline in frequency between these two size-classes, which includes yolk-sac (Stage 1) and first-feeding Stage 2 larvae, has been about 90% each year.

TABLE 1-2. Brief description of winter flounder early life history stages.

Stage	Brief description	Approximate duration of stage in days[a]	Approximate size (mm) of stage[b]
Egg	Demersal and adhesive	15	0.70 - 0.85
1	Yolk-sac present or eyes not pigmented	10	2.5 - 3.5
2	Eyes pigmented, but no yolk-sac present, no fin ray development, and no flexion of notochord	20	3.0 - 4.0
3	Fin rays present and flexion of notochord started, but left eye not yet migrated to the midline	10	4.5 - 7.5
4	Left eye migrated to midline, but typical juvenile characteristics not present	10	7.0 - 9.0
5	Transformation to juvenile complete with intense pigmentation present near the caudal fin base	-	> 9.0

[a] Developmental rates dependent upon water temperature.
[b] To nearest 0.05 mm for eggs and 0.5 mm for larvae. Includes most individuals in life stage, although some may be smaller or larger than the ranges given.

This initial large decline is followed by a smaller decrease to the 4.5-mm size-class, indicating a reduction in mortality rate with age and stage of development. Pearcy (1962) also reported a greater mortality for young winter flounder larvae (20.7% per day) compared to older individuals (9.1% per day). In a laboratory study on winter flounder larvae, Chambers et al. (1988) found that larval mortality was concentrated during the first 2 weeks after hatching. Laurence (1977) noted that winter flounder larvae had a low energy conversion efficiency at first feeding compared to later development, and that this stage of development was probably a critical period for mortality. Hjorleifsson (1989) showed that the ratio between RNA and DNA, an index of condition and growth rate, was lowest at the time of first feeding of winter flounder (about 4 mm in length) and that these ratios were affected by food availability. Thus, the strength of a year-class may be determined by the availability of sufficient food after completion of yolk absorption.

Annual instantaneous mortality rates were compared to annual egg production estimates from adult spawning surveys (described in NUSCO 1992a) to determine if density-dependent compensatory mortality could be identified in the larval stage of Niantic River winter flounder. A significant ($p < 0.05$) relationship was reported such that when egg production increased, larval mortality also increased (NUSCO 1991a). Although a more recent examination of the data suggests that a compensatory effect remains plausible, this relationship was no longer

significant (p = 0.061) with the addition of the 1991 data point (NUSCO 1992a); the estimated mortality rate was lower than expected when total egg production for that year was considered (Fig. 1-1).

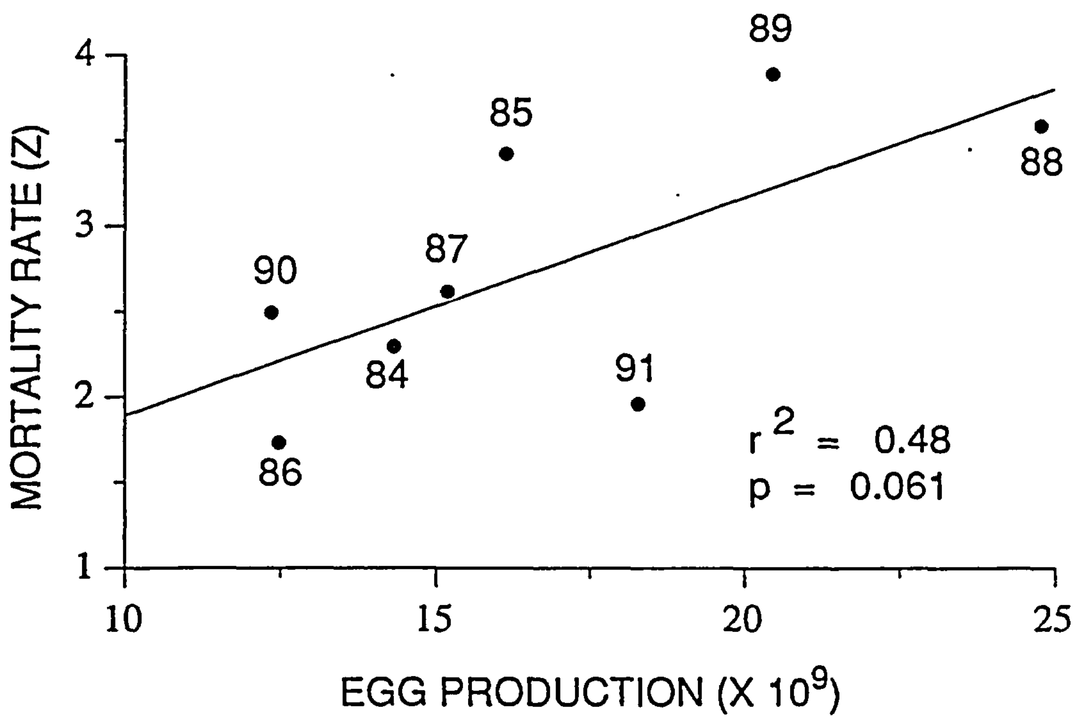


Fig. 1-1. The relationship between the annual winter flounder egg production and instantaneous larval mortality rate in the Niantic River from 1984 through 1991.

1.2.3 LARVAL WINTER FLOUNDER STUDIES AT MNPS

Since 1976, winter flounder larvae entrained through the MNPS cooling-water system have been collected at the discharges into the quarry (Fig. 1-2). Larvae are collected there from February through June, with more than 90% found in April and May. Annual dates of peak abundance have been highly correlated to mean water temperature in March and April (Fig. 1-3), which reflected varying rates of development. Peak abundance varied by 41 days over 16 years of sampling and there was a 3.6°C difference in the March-April water temperature between the earliest (April 13, 1991) and the latest (May 23, 1978) dates of peak abundance.

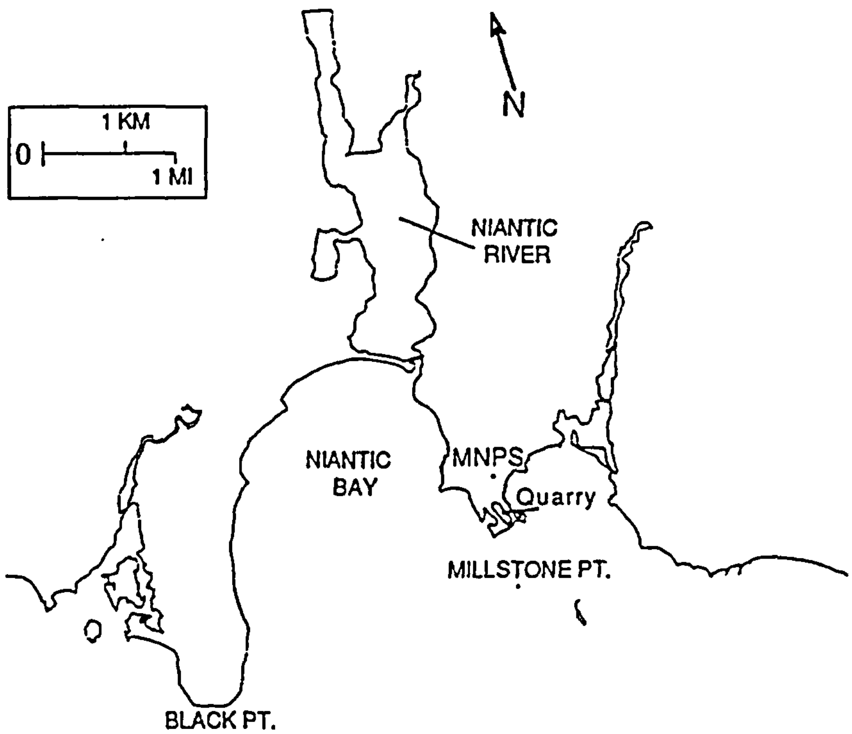


Fig. 1-2. Location of MNPS at Millstone Point, Waterford, CT in relation to the Niantic River and Niantic Bay.

This agreed with the results of Laurence (1975), who found that winter flounder larvae in the laboratory metamorphosed 31 days earlier at 8°C than at 5°C. Larvae have also been collected regularly at a station in Niantic Bay since 1979 and in the Niantic River at three stations since 1983. A history of NUSCO winter flounder studies and the evolution of various sampling programs was given in NUSCO (1987). The long-term sampling programs at MNPS have provided information on the abundance, distribution, development, growth, and mortality of larval winter flounder. Larval sampling for specific purposes also has been undertaken periodically (Table 1-3). Descriptions of current sampling programs, methodologies of data analyses, and detailed results of larval studies through 1991 may be found in NUSCO (1992a).

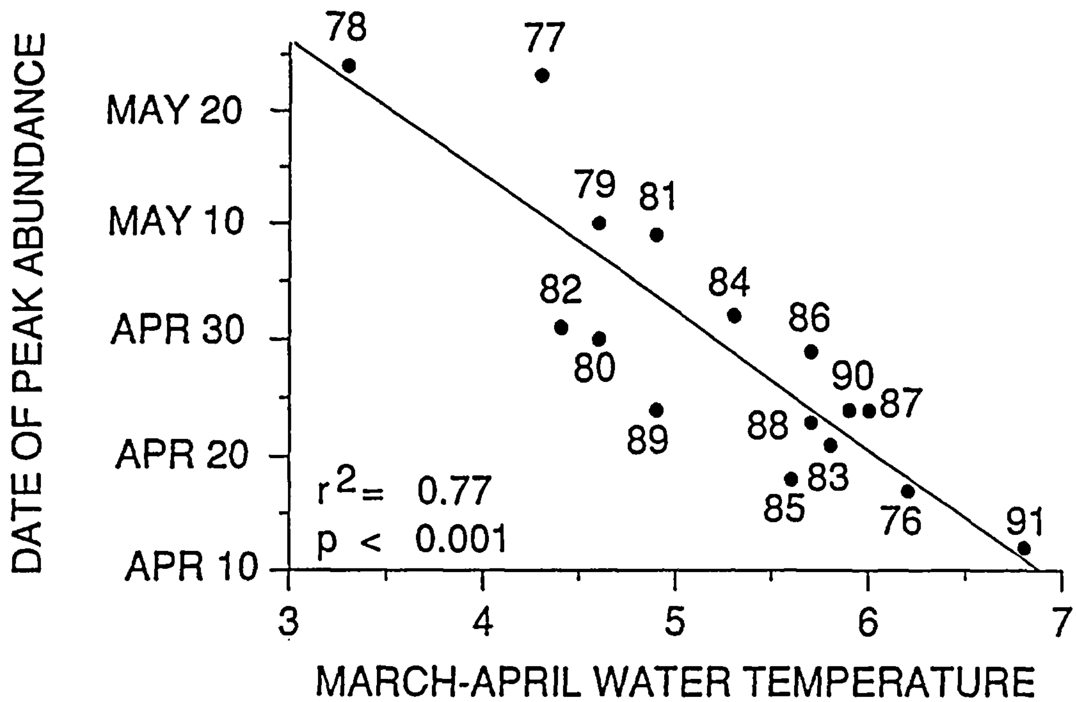


Fig. 1-3. The relationship between March-April mean water temperature (°C) and the annual date of peak abundance (estimated from the Gompertz function) of winter flounder larvae at the MNPS discharges from 1976 through 1991.

1.2.4 ESTIMATES OF LARVAL ENTRAINMENT AT MNPS

The estimated number of larvae entrained in the MNPS condenser cooling-water system each year is a direct measure of impact on the local winter flounder stock. Because the distribution of larval winter flounder abundance data over time is usually skewed, densities increase rapidly to a maximum and decline slowly. A cumulative density over time from this type of distribution results in a sigmoid- shaped curve, where the time of peak abundance coincides with the inflection point. Therefore, the Gompertz function (Draper and Smith 1981) was used to describe cumulative abundance distributions of winter flounder larvae because the inflection point of this function is not constrained to the mid-point of the sigmoid curve. The form of the Gompertz function used was described in detail in NUSCO (1992a). The entrainment estimates were obtained from larval densities measured in the MNPS discharge and the actual volume of

TABLE 1-3. Special sampling or studies conducted from 1973 through 1991 relating to Niantic River larval winter flounder.

Year[a]	Description	Reference[a]
1973, 1974	Thermal tolerance of entrained larvae	NUSCO (1975)
1983	Limited entrainment survival study in the Millstone Quarry	NUSCO (1984)
1983, 1984	24-hour studies examining diel and tidal effects on sampling densities in the lower Niantic River	NUSCO (1984, 1985)
1983, 1984, 1985, 1988	Import-export studies conducted at the mouth of the Niantic River	NUSCO (1984, 1985, 1986, 1989)
1984, 1985	Attempts to age larvae using daily otolith rings	NUSCO (1985, 1986)
1984, 1985	Mesh size and tow duration effects on net extrusion	NUSCO (1985, 1986)
1986	Predation by *Cyanea* sp. jellyfish	NUSCO (1987)
1988	Two 24-hour studies examining diel and tidal effects on sampling densities in Niantic Bay and Twotree Island Channel	NUSCO (1989)
1988, 1989	Dye study and model of Niantic River water circulation (larval flushing and MIT model)	Dimou (1989); Dimou and Adams (1989)
1990, 1991	Mitochondrial DNA stock identification studies of larval winter flounder (Niantic, Connecticut, and Thames River populations)	Goddard (1992)
1991	Drogue studies of tidal currents in Niantic Bay	NUSCO (1992b)
1991	Vertical distribution of yolk-sac larvae in the Niantic River using a pump sampler	NUSCO (1992a)
1991	Three additional stations sampled in Niantic Bay to determine larval winter flounder abundance and spatial distribution relative to tidal currents	NUSCO (1992a)

[a] Studies completed through 1986 are also summarized in NUSCO (1987).

cooling water. The Gompertz density function (Eq. 3 of NUSCO 1992a) was fit to larval data and daily densities (number per 500 m^3) were calculated. Daily entrainment estimates were determined after adjusting for the daily condenser cooling-water volume. An annual estimate was determined by summing all daily estimates during the larval season. An evaluation of this method for determining entrainment estimates was given in NUSCO (1991b). The newer estimates were judged superior to those previously generated using a seasonal median density estimate. The Gompertz-based estimates accounted better for fluctuations in condenser cooling-water flow and could also provide daily entrainment estimates, which could not be derived from

the median-based method. In turn, entrainment estimation methodology using the sample median had replaced the prior use of the arithmetic mean density of weekly samples, which likely overestimated entrainment because of a skewed distribution of the sample densities (NUSCO 1983a).

The largest annual entrainment estimate since 1976 was 219.3 million, which occurred in 1983 (**Table 1-4**). The 1991 estimate of 121.3 million was the smallest since the start of three-unit operation in 1986 and was attributed to reduced cooling-water volume due to plant outages. Although no confidence intervals (CI) are available for annual entrainment estimates using the Gompertz model, the 95% CI for the total cumulative density indicated good precision. The standard errors, expressed as a percentage of the parameter estimates, were 6.3% or less with most values 3.0% or smaller, except for 1978 (18.1%).

Of all the winter flounder larvae in entrainment collections from 1983 through 1991, most (62.0%) were in Stage 3 of development. Stage 1 larvae comprised 2.0%, Stage 2 24.7%, and Stage 4 10.6%. Despite the relatively high abundance of newly metamorphosed young (Stage 5) in 1-m beam trawl samples taken near the intakes (NUSCO 1992a), almost none (0.8%) of these fish have been entrained at MNPS during these years.

TABLE 1-4. Annual abundance index (α parameter of the Gompertz function) with 95% confidence interval of winter flounder larvae in entrainment samples and total annual entrainment estimates during the larval season of occurrence, and the volume of seawater entrained at MNPS each year during an 136-day period from February 15 through June 30.

Year	α parameter	Standard error	95% confidence interval	Number entrained in millions	Seawater volume entrained ($m^3 \times 10^6$)
1976	1,656	32	1,588-1,724	107.6	662.8
1977	751	47	650-852	31.2	585.6
1978	1,947	352	1,186-2,706[a]	87.4	490.9
1979	1,296	81	1,121-1,470	47.7	474.1
1980	2,553	37	2,475-2,632	175.7	633.3
1981	1,163	23	1,113-1,213	47.7	455.2
1982	2,259	36	2,184-2,334	170.4	674.1
1983	2,966	21	2,921-3,012	219.3	648.0
1984	1,840	47	1,741-1,939	88.3	573.8
1985	1,585	48	1,483-1,686	83.4	528.1
1986	903	31	837-968	130.8	1353.4
1987	1,194	23	1,145-1,242	172.2	1323.6
1988	1,404	42	1,315-1,493	193.4	1381.7
1989	1,677	13	1,650-1,704	174.7	1045.9
1990	1,073	25	1,021-1,125	138.9	1302.7
1991	1,149	18	1,110-1,189	121.3	934.4

[a] Correction from values given in NUSCO (1992a).

1.2.5 ENTRAINMENT SURVIVAL

For assessment purposes, all winter flounder larvae are presumed to die during passage through the MNPS condenser cooling-water system. Thermal tolerance studies were conducted in the laboratory during 1973 and 1974 to estimate the effect of increased temperature on larvae during entrainment (NUSCO 1975, 1987). Fish were grouped as pre-metamorphosed (< 5 mm) and metamorphosing (> 5 mm) larvae and were exposed to 21°C after acclimation at 8°C (i.e., Δ-T of 13°C). Pre-metamorphosed larvae died as exposure time increased. At 1 hour 29% died, 48% died at 2 hours, 53% at 3 hours, and 89% at 6 hours. No mortality occurred for metamorphosing larvae exposed to elevated temperature for up to 9 hours. Because most entrained larvae are 5 mm or larger and during two- or three-unit operation are exposed to elevated temperatures for less than 9 hours, most larvae would survive the thermal increase associated with entrainment. However, the effects due to mechanical damage and the interaction between mechanical and thermal effects were not measured.

A preliminary field study of entrainment survival was conducted in 1983 (NUSCO 1984). Winter flounder larvae (n = 135) were collected in the quarry following passage through the condenser cooling-water system (Δ-T of 8.0 to 11.5°C) using a 0.5-m net that was slowly hauled from the bottom to the surface (ca. 15 m) by hand. Specimens were held at elevated temperatures for 2 to 4 hours (approximating retention time in the quarry for three- and two-unit operation, respectively). Following this, they were held at ambient water temperature for 96 hours to observe latent mortality. All Stage 4 larvae collected were initially alive and 79% survived the holding period. Although a portion of the Stage 2 and 3 larvae were alive at time of collection (33 and 79%, respectively), all of these larvae died after 96 hours. Because of the relatively small (11.4%) proportion of entrained larvae that are in Stage 4 and 5 of development, the overall survival of entrained larvae is likely less than 1%.

1.2.6 SOURCES OF ENTRAINED LARVAE

The number of winter flounder larvae entrained ultimately depends upon larval densities in Niantic Bay. The magnitude of the impact to the Niantic River stock due to larval entrainment should be related to the proportion of larvae in Niantic Bay originating from the river. However, the possibility exists that some winter flounder larvae enter the bay from LIS as progeny from other spawning stocks to the east or west. Knowledge of the sources of larvae entrained at MNPS and the proportion of larvae entrained from the Niantic River population are

important factors for impact assessment. Depending upon the relative proportions, entrained larvae originating from two or more sources would lessen the impact on any particular stock. Effects on the Niantic River population are of primary concern, however, because of its relatively small size and close proximity to MNPS. Direct evidence for multiple sources of entrained larvae could be demonstrated by examination of the genetic composition of the stocks most likely to be affected. Once source stocks are characterized genetically, entrained larvae may be examined to determine the relative contribution of each in the sample. NUSCO supported a study to assign winter flounder larvae to natal populations by characterizing the mitochondrial DNA of individual larvae. However, due to insurmountable technical problems this approach was not successful (Goddard 1992). Thus, indirect methods are for now the only way to ascertain and quantify sources of larvae entrained at MNPS.

An indirect method called a mass-balance calculation was used to quantify the sources of entrained larvae at MNPS (NUSCO 1992a). This method indicated whether the number of winter flounder larvae entering Niantic Bay from the Niantic River could sustain the number of larvae observed in the bay during the winter flounder larval season. Three potential larval inputs to Niantic Bay include eggs hatching in the bay, larvae flushed from the Niantic River, and larvae entering the bay from LIS across the boundary between Millstone Point and Black Point. The few yolk-sac larvae collected annually in Niantic Bay suggested that minimal spawning and subsequent hatching occurred in the bay and this area was considered a negligible source of larvae. Larvae were known to be flushed from the river into the bay and, thus, this input to the bay was estimated from available data. However, the number of larvae exiting or entering Niantic Bay to or from LIS was unknown. Four ways in which larvae may leave Niantic Bay include natural mortality, by entering the Niantic River during a flood tide, through entrainment at MNPS, and by flushing from the bay into LIS. Estimates could be made for the number of larvae lost through natural mortality, entering the Niantic River, and entrained at MNPS, but little was known about the number of larvae flushed into LIS. The numbers of larvae flushed to and from LIS were combined as the unknown in the mass-balance equations. The data used, derivation of the equations, and other methods used to calculate terms of the mass-balance calculation were described in NUSCO (1992a).

Mass-balance calculations were made using data from 1984 through 1991; six of these years (1986-91) coincided with MNPS three-unit operation. Detailed results of these calculations were presented in NUSCO (1992a); the patterns found were generally consistent for all years examined. In summary, a net loss of larvae was indicated from Niantic Bay during the first part

of the larval season. However, beginning in late March larvae from other source areas in LIS were required to support changes observed in larval abundance. The timing of this change agreed with results from independent special bay sampling conducted in 1991, which showed a net import of larvae from LIS in late March or early April (NUSCO 1992a). During the period of peak entrainment (mid-April), fewer larvae were entrained at MNPS than were imported into Niantic Bay from LIS, indicating that other stocks likely were sources of larvae found in the bay. In addition, the results of special bay-wide sampling completed in 1991 also suggested that a large number of entrained larvae came from areas other than the Niantic River. This was consistent with hydrodynamic modeling (NUSCO 1976) and current drogue studies (NUSCO 1992b), which indicated that much of the condenser cooling-water enters Niantic Bay from LIS.

1.2.7 QUANTIFICATION OF LARVAL ENTRAINMENT IMPACT

The proportion of entrained larvae determined to have come from the Niantic River was estimated from the ratio of larvae entering the bay from the river to the total input from all sources. This proportion was applied to the total number entrained to estimate the number entrained from the Niantic River. When mass-balance calculations indicated that a sufficient number of larvae entered Niantic Bay from the river to support the observed change in abundance every 5 days, all entrained larvae were assumed to have originated from the Niantic River. This is conservative because dye studies have indicated that only 20% of the discharge volume of the Niantic River passes through MNPS (Dimou and Adams 1989). Based on mass-balance calculations for data collected in 1984-91, about 25 to 56% of winter flounder larvae entrained by MNPS originated from the Niantic River (Table 1-5).

The potential impact of larval entrainment depends upon the age of each larva at the time it is entrained, because an older individual has a greater probability of contributing to the year-class than a younger one due to a higher probability of survival. The number of each developmental stage entrained was estimated from the proportion of each stage collected at the MNPS discharge. Since the proportion of entrainment attributed to the Niantic River had been estimated from the mass-balance calculations, the number of larvae for each stage could be allocated to the Niantic River and to other sources. Except for 1984, most of the Stage 3 larvae entrained (the predominant stage collected at the MNPS discharges) apparently originated from sources other than the Niantic River (NUSCO 1992a). Because the number of larger larvae found in the Niantic River increased over the season, many larvae from other areas also may have entered the river during flood tides.

TABLE 1-5. Larval winter flounder estimates of total entrainment, number of larvae entrained from the Niantic River, and the percentage of total entrainment attributed to the Niantic River for 1984 through 1991.

Year	Total entrainment ($X 10^6$)	Niantic River larval entrainment ($X 10^6$)	% entrainment attributed to the Niantic River
1984	88.3	49.1	55.6
1985	83.4	37.0	44.5
1986	130.8	37.0	28.3
1987	172.2	55.0	31.9
1988	193.4	52.7	27.2
1989	174.7	44.2	25.3
1990	138.9	53.7	38.7
1991	121.3	50.1	41.3

The estimated number of each larval stage entrained from the river was compared to the annual abundance estimates for each larval stage in the Niantic River and the estimated percentage of the Niantic River winter flounder production that was entrained annually was calculated (Table 6). Since 1984, this percentage ranged from about 6 to 17%, with a geometric mean of 10.9%. However, the mass-balance calculations used to generate these percentages were based on actual daily condenser cooling-water volumes, which were generally less than full cooling-water capacity at MNPS. To determine the production loss for projected full (100% capacity) three-unit operations, the percentages were recomputed assuming a maximum daily condenser cooling-water volume of 11.1 million m^3 per day (Table 1-6). To lengthen the time-series, three-unit operation was simulated to include the period from 1984 through 1985, which was prior to the start-up of Unit 3. Estimated annual percentages of the Niantic River winter flounder production that would have been entrained since 1984 under simulated three-unit operation ranged from about 8 to 20%. These values had a geometric mean of 13.9% and this estimated reduction in year-class strength was used in impact assessment simulations with the SPDM.

TABLE 1-6. Estimated abundance of winter flounder larvae in the Niantic River and the number and percentage of the production entrained from the Niantic River by developmental stage for 1984-91. The number of larvae from the Niantic River was based on mass-balance calculations.

Year	Stage of development	Niantic River abundance[a] (X 10^6)	Actual MNPS operating conditions: Entrainment from the Niantic River[b] (X 10^6)	Actual MNPS operating conditions: % of the production	Projected full MNPS three-unit operating conditions: Entrainment from the Niantic River (X 10^6)	Projected full MNPS three-unit operating conditions: % of the production
1984[c]	Stage 1	2864	0.3	0.0	0.5	0.0
	Stage 2	685	21.9	3.2	4.2	0.6
	Stage 3	337	22.3	6.6	4.7	13.9
	Stage 4	235	4.6	2.0	11.8	5.0
	Total		49.1	11.8	63.5	19.6
1985	Stage 1	3228	3.9	0.1	9.9	0.3
	Stage 2	773	21.2	2.7	50.8	6.6
	Stage 3	380	11.1	2.9	21.6	5.7
	Stage 4	265	0.8	0.3	1.8	0.7
	Total		37.0	6.1	84.1	13.2
1986	Stage 1	2494	0.8	0.0	1.0	0.0
	Stage 2	700	9.3	1.3	10.1	1.4
	Stage 3	366	21.1	5.8	21.8	6.0
	Stage 4	255	5.8	2.3	6.1	2.4
	Total		37.0	9.4	39.0	9.8
1987	Stage 1	3036	1.0	0.0	1.3	0.0
	Stage 2	853	19.2	2.3	22.0	2.6
	Stage 3	445	32.2	7.2	33.3	7.5
	Stage 4	311	2.7	0.9	2.8	0.9
	Total		55.1	10.4	59.4	11.0
1988	Stage 1	4951	4.4	0.1	4.6	0.1
	Stage 2	741	11.3	1.5	11.8	1.6
	Stage 3	267	34.4	12.9	36.4	13.6
	Stage 4	192	2.7	1.4	2.8	1.5
	Total		52.8	15.9	55.6	16.8
1989	Stage 1	4091	3.4	0.1	4.0	0.1
	Stage 2	570	14.6	2.6	17.6	3.1
	Stage 3	188	25.2	13.4	30.2	16.1
	Stage 4	126	1.0	0.8	1.3	1.0
	Total		44.2	16.8	53.1	20.3
1990	Stage 1	2468	1.2	0.0	1.4	0.1
	Stage 2	1013	8.3	0.8	9.7	1.0
	Stage 3	279	39.0	14.0	43.5	15.6
	Stage 4	240	5.2	2.2	5.8	2.4
	Total		53.7	17.0	60.4	19.0
1991	Stage 1	3653	0.3	0.0	0.5	0.0
	Stage 2	2549	4.9	0.2	6.6	0.3
	Stage 3	775	38.3	4.9	48.1	6.2
	Stage 4	628	6.6	1.1	8.3	1.3
	Total		50.1	6.2	63.5	7.8
Geometric mean				10.9		13.9

[a] Abundance estimates for 1984-89 were from Crecco and Howell (1990) and for 1990-91 were calculated by NUSCO staff.

[b] Some entrainment estimates attributed to the Niantic River may differ slightly from those in Table 1-5 because of rounding error.

[c] Although only MNPS Units 1 and 2 operated in 1984 and 1985, the projected values assume full three-unit operation for all years.

1.3 REFERENCES

Chambers, R.C., W.C. Leggett, and J.A. Brown. 1988. Variation in and among early life history traits of laboratory-reared winter flounder *Pseudopleuronectes americanus*. Mar. Ecol. Prog. Ser. 47:1-15.

Crecco V.A., and P. Howell. 1990. Potential effects of current larval entrainment mortality from the Millstone Nuclear Power Station on the winter flounder, *Pseudopleuronectes americanus*, spawning population in the Niantic River. Connecticut Dept. Envir. Prot., Bu. Fish., Spec Pub. 37 pp.

Dimou, K. 1989. Simulation of estuary mixing using a 2-D random walk model. M.S. Thesis, Massachusetts Institute of Technology, Cambridge, MA. 138 pp.

Dimou, N.K., and E.E. Adams. 1989. Application of a 2-D particle tracking model to simulate entrainment of winter flounder larvae at the Millstone Nuclear Power Station. Energy Laboratory Report No. MIT-EL 89-002. Massachusetts Institute of Technology, Cambridge, MA. 73 pp.

Draper, N., and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, New York. 709 pp.

Goddard, K. 1992. Final report to Northeast Utilities on the project entitled: assignment of winter flounder larvae to natal populations. The American University, Washington, DC. 27 pp + 2 tab. + 5 fig.

Hess, K.W., M.P. Sissenwine, and S.B. Saila. 1975. Simulating the impact of entrainment of winter flounder larvae. Pages 1-30 *in* S.B. Saila, ed. Fisheries and energy production: a symposium. D.C. Heath and Co., Lexington, MA.

Hjorleifsson, E. 1989. (Abstr.). Condition of winter flounder larvae in Narragansett Bay as measured by RNA/DNA ratio. Workshop on winter flounder biology, Mystic, CT, December 5-6, 1989.

Howell, P., A. Howe, M. Gibson, and S. Ayvazian. 1992. Fishery management plan for inshore stocks of winter flounder. Fisheries management rep. no. 21 of the Atlantic States Marine Fisheries Commission. 138 pp.

Laurence, G.C. 1975. Laboratory growth and metabolism of the winter flounder *Pseudopleuronectes americanus* from hatching through metamorphosis at three temperatures. Mar. Biol. (Berl.) 32:223-229.

Laurence, G.C. 1977. A bioenergetic model for the analysis of feeding and survival potential of winter flounder, *Pseudopleuronectes americanus*, larvae during the period from hatching through metamorphosis. Fish. Bull., U.S. 75:529-546.

Lobell, M.J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder (*Pseudopleuronectes americanus*). Suppl. 28th Ann. Rep., N.Y. Cons. Dep., Pt. I:63-96.

NUSCO (Northeast Utilities Service Company). 1975. Summary report ecological and hydrographic studies. May 1966 through December 1974. Millstone Nuclear Power Station.

NUSCO. 1976. Environmental assessment of the condenser cooling water intake structures (316b demonstration). Vol. 1 and 2.

NUSCO. 1983a. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report, 1982. 53 pp.

NUSCO. 1983b. Millstone Nuclear Power Station Unit 3 environmental report. Operating license stage. Vol. 1-4.

NUSCO. 1984. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report, 1983. 65 pp.

NUSCO. 1985. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report, 1984. 74 pp.

NUSCO. 1986. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report, 1985. 69 pp.

NUSCO. 1987. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Summary of studies prior to Unit 3 operation. 151 pp.

NUSCO. 1989. Winter flounder studies. Pages 239-316 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1988.

NUSCO. 1991a. Winter flounder studies. Pages 9-86 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1990.

NUSCO. 1991b. Ichthyoplankton entrainment estimation. Pages 261-270 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1990.

NUSCO. 1992a. Winter flounder studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992b. Niantic Bay current studies. Pages 317-331 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992c. Scope of work for cooling water alternatives feasibility study to reduce larval winter flounder entrainment. Enclosure 1 to letter D05565 dated May 29, 1992 from C.F. Sears, NUSCO, to T. Keeney, Commissioner, CT DEP.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder *Pseudopleuronectes americanus* (Walbaum). Bull. Bingham Oceanogr. Coll. 18(1):1-78.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham Oceanogr. Coll. 11:1-92.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanogr. 6:292-298.

Saila, S.B. 1976. Effects of power plant entrainment of winter flounder populations near Millstone Point, Connecticut. URI-NUSCO Rep. No. 5. 139 pp + 4 app.

Smith, E.M., E.C. Mariani, A.P. Petrillo, L.A. Gunn, and M.S. Alexander. 1989. Principal fisheries of Long Island Sound, 1961-1985. Connecticut Dept. Envir. Prot., Bu. Fish., Mar. Fish. Program. 47 pp. + app.

Smith, W.G., J.D. Sibunka, and A. Wells. 1975. Seasonal distributions of larval flatfishes (Pleuronectiformes) on the continental shelf between Cape Cod, Massachusetts and Cape Lookout, North Carolina, 1965-1966. NOAA Tech. Rep. NMFS SSRF-691.

2

ENVIRONMENTAL CONSIDERATIONS FOR SELECTIVE ENTRAINMENT MITIGATION ALTERNATIVES

2.1 NATURAL DRAFT COOLING TOWER

While the construction of a full-size natural draft cooling tower for MNPS Unit 3 would greatly diminish many of the environmental impacts associated with the present intake structure, other disadvantages may nullify any gains. The need for cooling water would decrease significantly, from about 61 m^3/s to about 3.25 m^3/s, a reduction of approximately 95%. Entrainment should be reduced in proportion and the low flow would make impingement inconsequential at the Unit 3 intake. A blowdown of approximately 1.7-2.5 m^3/s containing concentrations of salts 1.5 times that of natural seawater would be discharged from the cooling system into the Millstone Quarry. The cooling tower blowdown discharge described in Part I of this report was shown to empty into the Quarry at the present Unit 3 discharge. However, the blowdown may require a waste treatment facility as a new point source discharge under the current MNPS NPDES permit. The costs of this facility were not included with other price estimates for the full-size and the 2/3-size cooling tower alternatives that were presented and, if required, would represent an additional expense. The small volume of a waste treatment facility should be rapidly diluted by the discharge of once-through cooling water from Units 1 and 2 before entering Long Island Sound and would not have any adverse environmental effects. Because of an approximate 50% reduction in cooling-water flow, the MNPS thermal discharge would revert to a pre-Unit 3 condition, with a higher Δ-T (12.8° C; 11.9° C under three-unit operation). Because of the reduced volume, however, the volume of Long Island Sound subjected to thermal addition should decrease and no thermal impacts would be expected.

The construction of a cooling tower for Unit 3 would affect land that is now undeveloped at the site and dedicated for use as a wildlife refuge. Along with the clearing of nearly all vegetation from this mostly wooded area, a long-occupied osprey nesting platform would likely be disturbed. The Millstone Nature Trail, a public recreational use area, would also be disrupted. Native wildlife throughout this area would necessarily be displaced through loss of habitat.The potential effects of salts discharged from a natural draft cooling tower were discussed in NUSCO (undated). In the original analysis, salt deposition rates much greater than under natural conditions were predicted. A continuous daily deposition of salts could harm or eliminate local vegetation by direct contact or soil contamination, even though coastal plants are tolerant of increased concentrations of salts. Wildlife habitat could therefore be altered. Salt deposition could also lead to increased corrosion and necessary maintenance for exposed metal structures that would be affected. However, current drift elimination technology has largely reduced salt drift as a potential significant environmental impact.

As with other tall structures, cooling towers can cause mortalities of migrating birds through collisions, particularly at night or during other periods of low visibility (e.g., fog, rain) or under conditions of low cloud cover. Because many passerine birds migrate at night and follow the coast, cooling towers sited along shorelines may be particularly hazardous. In addition, birds may be attracted or orient to lights that would likely be required to mark the structure. Continuous illumination at night attracts and disorients birds and many eventually collide with the structure (Jaroslow 1979).

The frequency of fogging and icing created by the cooling tower vapor plume may be enhanced, depending upon ambient meteorological conditions (temperature, humidity, and wind). Ground level fog rarely occurs because of the height of a natural draft cooling tower and the initially high temperature and exit velocity of the plume. An analysis presented in NUSCO (undated) showed that a plume from a natural draft cooling tower at MNPS would not hamper air, ground, or water transportation because its range would be limited. Some increased icing was indicated in winter, but its effects would be local and not severe.

Other impacts associated with natural draft cooling towers include aesthetics and noise. The size (163 m tall) of a full-size cooling tower is significant in itself and a tower would be a dominating visual intrusion on the coastal landscape near Millstone Point. Cooling towers and their vapor plumes can be visible for many miles. An estimate of visibility for a similiarly sized natural draft cooling tower proposed for the Salem (New Jersey) Nuclear Generating

Station was 20 miles (PSE&G 1984). A tower would therefore be highly visible in local residential areas, from nearby transportation corridors, and from Long Island Sound. In addition, noise, resulting from the cascading water within the tower, may exceed prevailing standards in nearby residential areas and should be evaluated fully before a cooling tower is considered for MNPS.

2.2 OFFSHORE INTAKE

The location for the offshore intake evaluated for MNPS was selected on the basis of hydrodynamics of Niantic Bay in relation to the distribution of Niantic River winter flounder larvae in the bay (NUSCO 1992a, c). The location, just outside a line extending from Black Point to Millstone Point, is in an area of the bay that exchanges a considerable amount of water with Long Island Sound. Because water in this area is well-mixed and flushes with each tidal cycle, it is not a good retention area for Niantic River winter flounder larvae. Nevertheless, waters near the offshore site may have high densities of winter flounder larvae, particularly during April and May. Most of these larvae presumably have originated from spawning stocks both to the east and west of Niantic Bay and were transported by tidal currents into the area off MNPS. Entrainment of Niantic River winter flounder larvae would likely be reduced by an estimated 25% from placing an offshore intake at the designated location. This is based on the assumptions that an offshore intake would provide cooling water for only Unit 3 (ca. 50% of the total MNPS cooling-water demand) and that the intake location is removed far enough from the mouth of the Niantic River to have diluted larvae flushing from there by about one-half.

Impact of an offshore intake may partly depend upon the depth from which water is drawn. An analysis was made recently of data collected in 1974 and 1975 during April and May in offshore waters of Long Island Sound during initial ichthyoplankton studies at MNPS. During these years, bongo sampler collections were taken just below the surface, near the bottom, and obliquely throughout most of the water column during both day and night. A non-parametric Wilcoxon's signed rank test was used to compare densities by tow type within time of day. During daylight, densities of winter flounder larvae collected near the bottom were significantly higher than densities near the surface and for the oblique tows. Significantly more larvae were found in oblique tows (a sample integrating most of the water column) than in surface tows. During the night, bottom and oblique tows again had significantly more larvae collected than surface tows, but no significant difference was found between bottom and oblique tows. This implied that, in general, concentrations of winter flounder larvae were highest closer to the

bottom, but at night more larvae dispersed into the water column. Thus, an offshore intake situated closer to the bottom would likely entrain more larvae than one constructed closer to the surface. However, the densities of winter flounder by depth were only measured at two discrete locations - very near the surface and very near the bottom. The physical size of an offshore intake structure with a velocity cap may result in relatively small differences in total entrainment of winter flounder larvae whether it is located closer to the bottom or the surface. The location of an offshore intake would reduce the probability of entraining larvae that were produced in the Niantic River because of dilution. The approximate volume of Niantic Bay is about 50 million m^3 (E. Adams, Massachusetts Institute of Technology, pers. comm.), while the average tidal prism of the Niantic river is 2.7 million m^3 (Kollmeyer 1972). With 1.9 tidal cycles per day, this tidal prism would dilute Niantic River water by about 1:10. Although the fraction of entrained winter flounder larvae attributed to the Niantic River winter flounder stock may decrease by using an offshore intake, overall entrainment totals may increase rather than decrease. Based on special bay-wide sampling conducted in 1991 (NUSCO 1992a), entrainment of winter flounder larvae, particularly those in Stage 3 of development, may increase during flood tides. However, as inferred from the densities of larvae found in water masses entering Niantic Bay (NUSCO 1992a), many of these larvae would likely have drifted in from other areas. This would proportionately shift more of the MNPS-imposed entrainment mortalities to stocks other than the one spawning in the Niantic River. The ultimate contribution of larvae flushed away from spawning and nursery grounds to future adult stocks is not known, but has been thought to be relatively small because of higher mortality in offshore waters (Pearcy 1962). Increasing the number of larvae entrained from other stocks and decreasing the number specifically from the Niantic River should lessen the compensatory responses necessary to stabilize population abundance.

A change from the present intake located on the shoreline at MNPS to one offshore may detrimentally affect other species through increased entrainment. Of the most abundant fishes collected as larvae, only the grubby is found in higher densities at the entrainment monitoring station at the MNPS discharge than at a station in mid-Niantic Bay (NUSCO 1992b). Presumably, more grubby spawn in the Niantic River (as does the winter flounder) and also in inner areas of Niantic Bay, with less spawning taking place in more offshore waters. Conversely, larvae of the American sand lance and bay anchovy are generally more abundant in mid-Niantic Bay than at the MNPS discharge. More adults of these species probably spawn either in deeper waters of the bay or offshore in Long Island Sound. Their eggs and larvae are then advected into the bay to join production from any fish spawning closer to MNPS. An

0001- 0001823

offshore intake may increase larval entrainment estimates of these species. Also, most older tautog collected in the trawl monitoring program have been taken at the two deeper offshore stations (NUSCO 1992b). Like an artificial reef, an offshore intake structure may attract fishes such as the tautog and cunner. Local spawning of resident fish near the intake would result in increased egg and larval entrainment. Unless these species are habitat-limited and a new structure would afford additional shelter for recruiting juveniles, most of the reproductive effort of resident adults that could have spawned elsewhere would be lost to the population.

Increased impingement mortality of juvenile and adult fish is another consideration for an offshore intake. It is possible that impingement of some species would increase, particularly for those likely to be attracted to the structure (e.g., cunner, tautog, black sea bass) or more common offshore (e.g., skates, searobins, windowpane). Impingement of fish more commonly found inshore (e.g., silversides, sticklebacks, northern pipefish), however, would likely decrease. Impingement to a large degree is a far less passive phenomenon than entrainment and behavior of larger fish, as well as their distribution, largely influences the availability of individuals to entrapment. This process may vary diurnally, seasonally, or in response to variable environmental conditions, such as storms or periods of rapidly changing water temperature (NUSCO 1987a). For example, scup (mostly young-of-the-year) are second only to winter flounder in trawl catches at the stations just off the MNPS intake and in mid-Niantic Bay (NUSCO 1992b), yet relatively few of them were impinged from 1976 through 1987 (NUSCO 1987b, 1988). Conversely, Atlantic tomcod were much more common in impingement samples than in trawl collections during the same years.

Insights to potential impingement effects for an offshore intake may be provided by experience of the Seabrook Nuclear Generating Station, an 1,150 MWe plant located in Seabrook, NH. This station has an intake located in the Atlantic Ocean approximately 1.5 km offshore of the coast. The intake is about 5 m off the bottom in 17 m of water. Relatively few fish have been drawn into this offshore intake and impinged on the traveling screens at the plant. In 1985, 970 fish were impinged over a 5-month period, 1,212 were taken throughout all of 1986, 502 in 1987, 499 in 1990, and 1,019 in 1991 (Normandeau Associates Inc. 1991, 1992). In contrast, annual totals at MNPS Unit 2 from 1976 through 1987 have ranged from 8,650 to 60,410 (disregarding one large [480,000] impingement event of Atlantic sand lance in 1984; NUSCO 1988). Species most frequently impinged at Seabrook included demersal fishes such as sculpins, snailfishes, lumpfish, windowpane, and winter flounder. Except for pollock, relatively few pelagic fish were impinged, which suggested that the intake velocity cap was

performing as expected in minimizing impingement. It was thought that demersal fish were attracted to the structure and seeking cover, which increased their likelihood of being drawn into the intake tunnel.

An offshore intake would require a significant increase in the amount of biocide needed to control fouling in the intake structure and long intake tunnel. Because of a potential increase in the use of chlorine, the condenser cooling water from an offshore intake may require a dechlorination unit. This would also be true of other alternatives, such as wedgewire screens, that may need additional biofouling control. This would be necessary so that NPDES permit limits for discharged chlorine are not exceeded. The costs of a declorination unit were not included in estimates presented in Part I of this report. Biofouling control for an offshore intake would also result in much additional resources (personnel, materials, and labor costs) to properly maintain reliability. The environmental impacts from construction of an offshore intake would also have to be evaluated in detail and would require significant permitting from a number of state and federal agencies. Impacts would include, at minimum, a displacement of benthic flora and fauna due to dredging and other activities associated with construction and increased turbidity during the period of work.

2.3 FINE-MESH SCREENS

The objective of fitting intake screen panels with fine mesh is to impinge and remove larvae before they are entrained through the condenser cooling-water system of a power plant. Fine-mesh screens may be fitted to conventional through-flow traveling screens, dual-flow screens, rotary drum screens, or angled screens. The latter system also is designed to divert larvae (as well as juveniles and adults) through a fish bypass pump so that larvae are neither entrained nor impinged. Data from laboratory studies, field evaluations at test facilities, and plant operating experience are available to evaluate the use of fine-mesh screens in reducing the entrainment mortality of larval winter flounder.

A number of laboratory studies have been conducted to evaluate fine-mesh screens. Edwards et al. (1981) tested a number of Pacific marine fishes in a laboratory flume with fine-mesh screens of several types (Nytex and carbon steel) that ranged in mesh size from 0.5 to 3.3 mm. Retention and survival varied widely among the species tested and were related to the size, age, and behavior of the test organisms. Two species (goby and white croaker) were particularly hardy, whereas few northern anchovy or giant kelpfish survived impingement on these screens.

Laboratory evaluations of fine-mesh screening that included tests on winter flounder larvae were reported by ARL and SWEC (1981) and Taft et al. (1981). Small (0.355 and 0.5 mm) mesh screens were needed for these tests because of the small size of winter flounder larvae; nearly all fish passed through 1.0-mm mesh screens. They concluded that small winter flounder larvae (of a size most likely equivalent to Stage 1 and 2) were not effectively removed by the spraywash system evaluated. Larger larvae (likely Stage 3) were removed to a greater extent, but suffered high latent mortality; this finding, however, was confounded by high control mortality. Air exposure (to simulate a screenwash) caused little (0-8%) mortality in Stage 1 and 3 larvae, but mortality was 32-64% for Stage 2 larvae exposed to air for 1-5 min. Larvae were also particularly difficult to wash out of the test screen buckets because the fish were so small. A tentative conclusion of ARL and SWEC (1981) was that winter flounder larvae would not be successfully diverted by a fine-mesh angled screen.

Research was reported by Matousek et al. (1988) that evaluated the diversion efficiency and survival of larval fish at a full-scale angled screen demonstration facility located on the Hudson River. They concluded that the 1.0-mm fine-mesh screen was ineffective in mitigating ichthyoplankton entrainment. Overall, the efficiency in removing fish larvae was only 1.7%. LMS (1985) also reported on a 3-year study of a fine-mesh angled screen diversion system at a testing facility at the Central Hudson Gas & Electric Corporation Danskammer Point Generating Station located on the Hudson River near Newburgh, NY. This facility was described in detail by Holsapple et al. (1981). The full-size screen was used with 1.0-mm mesh screen panels to examine the impingement and removal of ichthyoplankton. The species examined were larvae of *Alosa* spp. herrings, white perch, striped bass, and Atlantic tomcod; all but the latter are generally larger larvae than the winter flounder. Although survival of Atlantic tomcod larvae was good (ca. 85%), diversion efficiency was very low. Calculated total survival of Atlantic tomcod larvae after subtracting for larvae not returned by the fish removal system was 3.9% for yolk-sac larvae and 5.3% for post-yolk-sac larvae.

Kuhl and Mueller (1988) and Berrington and Mueller (1991) summarized impingement survival of larval and juvenile freshwater fishes on the fine-mesh screens of the Northern States Power Company Prairie Island Nuclear Generating Plant (two 1,000 MWe units), located on the Mississippi River in Welch, MN. An initial 3-year study showed that overall survival of most postlarval fish to be 0-10%, except for suckers (31-50%) and walleye (> 51%). Survival may have been underestimated because control mortality was not considered (Berrington and Mueller 1991). However, high debris and zooplankton loading significantly

reduced survival (to near zero in many instances) when it occurred.

Fine-mesh screens have been operated since 1985 at the Tampa Electric Company Big Bend Station Units 3 and 4 (ca. 400 MWe each), located on an arm of Tampa Bay in North Ruskin, FL. Tampa Electric Company conducted studies of prototype fine-mesh screens between 1979 and 1981. Results of these studies showed that invertebrates survived best (>90%), while fragile fishes, such as the bay anchovy, had low survival rates. However, survival among control fish was also low. Brueggemeyer et al. (1988) reported on the full-scale operational demonstration of 0.5-mm fine-mesh screens at Big Bend Units 3 and 4, which were fitted with six continuously operating traveling screens and specially designed return troughs and spraywash systems. Initially, a number of operating and maintenance problems were encountered, including frequent screen outages because of mechanical problems. This led to higher approach velocities at the screens remaining in operation and subsequent decreased efficiencies in larval fish removal. Mortality of fish eggs and larvae were initially high (78.3% and 94.1%, respectively) at this station. Biofouling, particularly by barnacles and oysters, caused screen mesh and seal failures, and spray line and screenwash nozzle clogging. Gaps and tears in seals and screens also allowed increased entrainment of ichthyoplankton. A daily surveillance and preventative maintenance plan was put into effect to reduce these problems. On the basis of a brief follow-up study, preliminary results indicated that efficiency in screening of fish eggs (primarily drums and bay anchovy) exceeded 95% and fish larvae (primarily drums, bay anchovy, blennies, and gobies) was about 86%. Other studies indicated latent (48-h) survival of fish eggs and larvae of about 80% and 65%, respectively, for drums, and 93% and 66% for bay anchovy.

In the study most pertinent to the entrainment mitigation evaluation at MNPS, angled fine-mesh screens with fish diversion pumps were extensively evaluated at the New England Power Company (NEPCO) Brayton Point Generating Station. This station is located at the head of Mount Hope Bay in Somerset, MA on a peninsula between the Lee and Taunton Rivers and with four fossil-fueled units having a total net generating capacity of 1,610 MWe, it is the second largest electrical generating station in New England after MNPS. The station and biological studies conducted at the intakes were described in detail by LMS (1987). Unit 4, a 460 MWe unit has an intake with six traveling screens set in a canal at an angle of 25° to the intake flow. The screens were originally fitted with panels of 1.0-mm fine-mesh screen. Organisms that pass along the front of the traveling screens can enter a fish bypass by passing through a 15 cm wide by 5.2 m high slot located at the apex of each screenwell. These organisms are returned to the

Lee River through a Hidrostal screw impeller pump. Other organisms encountering the screens are either entrained through the cooling-water system or are impinged on the fine-mesh screens and periodically washed off into a fish trough for return to the river. In a 1984-86 study on the effectiveness of this system in reducing entrainment mortality, a total of 52,847 larval winter flounder was examined. Of these, a calculated fraction of 19.8% of the larvae were diverted through the fish diversion pumps, 28.1% were impinged on the fine-mesh screens, and 52.0% were entrained. Some 11,426 specimens were examined for survival, which was determined upon initial collection and after 72 h. Survival estimates were adjusted for control (collection and handling) mortality. For larvae entering the fish diversion system, 44.1% were alive initially. Of these, 57.0% were alive after 72 h, for a total bypass system survival of 25.1%. Only a small (11.1%) fraction of larvae were alive after impingement on the fine-mesh traveling screens and only about half of these survived after 72 h, for a total impingement survival of 5.5%. Entrained winter flounder larvae were not examined for survival, but other species had an overall survival of 20.3%. Total system efficiency (TSE) was defined as the probability that a larva would be alive after 72 h, whether it had been entrained, impinged on the fine-mesh screens and returned, or entered the fish diversion pumps. For winter flounder, the TSE was 6.5%. Thus, based on operating experience at Brayton Point, fine-mesh screens did not substantially alleviate entrainment mortality of larval winter flounder. Further, TSE for other larval fishes, including herrings, bay anchovy, seaboard goby, and tautog, was even less (≤ 0.6%) than for winter flounder. Only northern pipefish (18.6%) showed some minor capability of survival with this system. LMS (1987) concluded that "when the angled screen system was equipped with fine mesh (1.0-mm) panels, it was not effective at mitigating larval entrainment." NEPCO has subsequently removed the fine-mesh screen panels its Brayton Point Station and replaced them with conventional 9.5-mm mesh panels (M. Anderson, New England Power Service Company, Westborough, MA, pers. comm.).

The conclusions given above were restated by LMS (1989), who concluded that "the use of fine mesh on conventional vertical traveling screens has not been demonstrated as an effective technology for reducing impingement mortality or entrainment losses." SWEC (1984) also concluded that fine-mesh screens were not effective in reducing mortality of larvae less than 10 mm in length (which would include all larval stages of winter flounder). A full-scale demonstration of a fine-mesh screen would necessarily be required at MNPS to quantify the potential biological effectiveness of the system, to identify optimum design features and operating conditions, and to identify engineering problems or constraints which might be

imposed by site conditions. The debris removal capability would be of significant importance. Because of the potential for debris loading, biofouling, and increased impingement and the lack of evidence for increased larval winter flounder survival, fine-mesh screens are an unlikely mitigation alternative at MNPS.

2.4 WEDGEWIRE SCREENS

Wedgewire screens with small (0.5-1.0 mm) mesh can be effective in providing protection against the entrainment of ichthyoplankton because they operate with low (ca. 15 cm/s) intake velocities in relation to the water around them (SWEC 1984). Key and Miller (1978) and Hanson et al. (1978) first reported on the potential for this type of screening to reduce fish impingement and entrainment at power plants. Using scaled-down screens for testing, Hanson (1981) in a laboratory test with yellow perch and striped bass, Browne et al. (1981) in a field marine study, and Otto et al. (1981) in a field freshwater study each indicated that wedgewire screens may be useful in some instances in reducing ichthyoplankton entrainment. Their results, however, were often dependent upon the species, size of larvae encountered, and time of day. Furthermore, in terms of practical application, this type of screen almost exclusively has been used for closed-cycle applications using small volumes of intake water and not at locations with large water volume requirements.

Zeitoun et al. (1981) reported that ambient larval fish densities were about eleven times greater in waters near an offshore Lake Michigan power plant intake equipped with wedgewire screens than in entrainment samples. They estimated that 90% of the larvae (mostly rainbow smelt, alewife, and yellow perch) avoided entrainment through the screens tested (2.0 and 9.5-mm slot openings), mainly by behavioral mechanisms, and, to a lesser extent, by screen exclusion. The flow rate during the test was 1.9 m^3/min at an intake velocity of 15.2 cm/sec. This work was done at the Consumers Power Company J.H. Campbell Plant, whose 770 MWe Unit 3 has a summer peak cooling-water demand of 1,126 m^3/min (Robinson and Kitchen 1981). With 28 cylindrical wedgewire screens arrayed in a manifold, this is the only station in the United States with once-through cooling using this type of screening. MNPS Unit 3, however, requires more than three times this cooling-water volume (3,659 m^3/min at an intake velocity of 24.3 cm/s), and, as noted in Part I, would require more wedgewire screens.

The exclusion efficiency of cylindrical wedgewire screens in estuarine waters was investigated at the Potomac Electric Power Company Chalk Point Steam Electric Station, located on the

Patuxent River in Aquasco, MD (Weisberg et al. 1987). Entrainment of larval bay anchovy and naked goby was studied using a barge-mounted intake test facility with wedgewire screen slot sizes of 1, 2, and 3 mm. No fish smaller than 5 mm were excluded, but exclusion increased as larval size increased. About 80% of large larvae were excluded from entrainment, including 100% of larvae longer than 10 mm when the 1-mm screen was used. The 2- and 3-mm screens were not as effective, but slot width was determined to be less important than fish size.

McGroddy et al. (1981) concluded that fine-mesh cylindrical wedgewire screens may not be feasible for offshore marine installations because of excessive fouling and debris (e.g., macroalgae, detritus) loading. Their study results indicated that this type of screen could become clogged daily or even more frequently during high ambient debris concentrations; this could compromise plant operation and safety. Also, within a few weeks biofouling could reduce water flow enough to degrade effective operation. Frequent cleaning and the need for reliable systems to accomplish this in marine waters makes the retrofit of fine-mesh wedgewire screens an inadequate option for once-through cooling-water systems. Nonetheless, Browne et al. (1981) concluded that wedgewire screens of 1- and 2-mm slot width were a feasible alternative in an estuarine environment when used with an air backwash system and manufactured with screening material more resistant to biofouling. Their work showed that entrainment densities of some larval fishes and zooplankton species were lower than in ambient waters. Weisberg et al. (1986) also suggested back-flushing the screens with air and using toxic coatings to reduce or control biofouling in marine applications.

2.5 DIVERSION SILLS AND CURTAIN WALLS

Sills, curtain walls, or other devices that restrict flow of water into an intake structure would likely be ineffective in reducing the entrainment mortality of winter flounder. Although there is a tendency for older larvae to be found closer to the bottom, particularly during daylight hours, they remain essentially planktonic. Much of the entrainment of older larvae occurs at night when fish disperse more throughout the water column. As long as water volume is not reduced, larvae should be entrained in proportion to their relative densities in the water. Further, any larvae diverted may be entrained at Unit 1 or 2, particularly during ebb tides. Structures such as sills placed in the water near the intake may also act as an attractant to other fishes, such as tautog and cunner, thereby increasing their availability to impingement and entrainment. Finally, the effectiveness of an air bubbler system in reducing larval fish entrainment has not been demonstrated and it remains an unproven technology.

2.6 REFERENCES

ARL and SWEC (Alden Research Laboratory and Stone & Webster Engineering Corporation). 1981. Laboratory evaluation of fine-mesh screening for the protection of fish larvae at intakes. Prepared for Empire State Electric Energy Research Corporation.

Berrington, J.J., and K.N. Mueller. 1991. Fine mesh vertical traveling screens impingement survival study and sampling mortality assessment. *In* Prairie Island Nuclear Generating Plant environmental monitoring program 1990 annual report.

Browne, M.E., L.B. Glover, D.W. Moore, and D.W. Ballangee. 1981. In-situ biological and engineering evaluation of fine-mesh profile-wire cylinders as power plant intake screens. Pages 36-46 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

Brueggemeyer, V., D. Cowdrick, K. Durrell, S. Mahadevan, and D. Bruzek. 1988. Full-scale operational demonstration of fine mesh screens at power plant intakes. Pages 2-51-2-65 *in* W.C. Micheletti, ed. Proceedings: fish protection at steam and hydroelectric power plants. Electric Power Research Institute, Palo Alto. EPRI CS/EA/AP-5663-SR.

Edwards, S.J., P.M. McGroddy, D. Lispi, and P. Dorn. 1981. Fine-mesh screens as impingement-release system for marine fish larvae. Pages 128-137 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

Hanson, B.N. 1981. Studies of larval striped bass (*Morone saxatilis*) and yellow perch (*Perca flavescens*) exposed to a 1 mm slot profile-wire screen model intake. Pages 22-35 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

Hanson, B., W.H. Bason, B. E. Beitz, and K. E. Charles. 1978. A practical intake screen which substantially reduces the entrainment and impingement of early life stages of fish. Pages 393-408 *in* L.D. Jensen, ed. Fourth national workshop on entrainment and impingement. EA Communications, Melville, NY.

Holsapple, J.G., R.C. Roberts, and Y.G. Mussalli. 1981. Development of an angled fine/coarse mesh traveling screen demonstration facility. Pages 184-192 *in* P.B. Dorn and J.T. Johnson,

eds. Advanced intake technology for power plant cooling water systems.

Jaroslow, B.N. 1979. A review of factors involved in bird-tower kills, and mitigative procedures. Pages 469-473 *in* G.A. Swanson, tech. coord. The mitigation symposium: a national workshop on mitigating losses of fish and wildlife habitats. Gen. Tech. Rep. RM-65. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Dept. Agriculture, Fort Collins, CO.

Key, T.H., and J.C. Miller. 1978. Preliminary studies on the operating aspects of small slot wedgewire screens with conceptual designs for power station use. Pages 385-392 *in* L.D. Jensen, ed. Fourth national workshop on entrainment and impingement. EA Communications, Melville, NY.

Kollmeyer, R.C. 1972. A study of the Niantic River estuary, Niantic, Connecticut. Final report phases I and II, physical aspects of the Niantic River estuary. Rep. No. RDCGA 18. U.S. Coast Guard Academy, New London, CT. 78 pp.

Kuhl, G.M., and K.N. Mueller. 1988. Fine mesh vertical traveling screens impingement survival study. Pages 69-103 *in* Prairie Island Nuclear Generating Plant environmental monitoring program 1988 annual report.

LMS (Lawler, Matusky & Skelly Engineers). 1985. Fish protective intake test facility: angled screen diversion study. Prepared for Empire State Electric Energy Research Corporation.

LMS (Lawler, Matusky & Skelly Engineers). 1987. Brayton Point Station Unit No. 4 angled screen intake biological evaluation program. Prepared for New England Power Company.

LMS (Lawler, Matusky & Skelly Engineers). 1989. Intake technologies: research status. Electric Power Research Institute, Palo Alto. EPRI GS-6293. Project 2214-4 final report.

Matousek, J.A., T.E. Pease, J. Holsapple, and R.C. Roberts. 1988. Biological evaluation of angles screen test facility. J. Hyd. Eng. 114b:641-650.

McGroddy, P.M., S. Petrich, and L.E. Larson. 1981. Fouling and clogging evaluation of fine-mesh screens for offshore intakes in the marine environment. Pages 5-21 *in* P.B. Dorn and J.T.

Johnson, eds. Advanced intake technology for power plant cooling water systems.

MMES (Martin Marietta Environmental Systems). 1986. Technical review and evaluation of thermal effects studies and cooling water intake structure demonstration of impact for the Salem Nuclear Generating Station. Final Report. Prepared for New Jersey Department of Environmental Protection, Division of Water Resources.

Normandeau Associates Inc. 1991. Seabrook Station. 1990 environmental studies in the Hampton-Seabrook area. Prepared for Public Service of New Hampshire, New Hampshire Yankee Division. 479 pp.

Normandeau Associates Inc. 1992. Seabrook environmental studies, 1991. A characterization of environmental conditions in the Hampton-Seabrook area during the operation of Seabrook Station. Tech. Rep. XXIII-I. Prepared for North Atlantic Energy Service Corporation.

NUSCO (Northeast Utilities Service Company). Undated. Millstone Nuclear Power Station Unit 3. Environmental report - construction permit stage. Vol. 1. Sections 7.2 and 10.

NUSCO. 1987a. Winter flounder studies. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Summary of studies prior to Unit 3 operation. 151 pp.

NUSCO. 1987b. Fish ecology. *In* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Summary of studies prior to Unit 3 operation. 102 pp.

NUSCO. 1988. Fish ecology studies. Pages 255-307 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Three-unit operational studies, 1986-1987.

NUSCO. 1992a. Winter flounder studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992b. Fish ecology studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992c. Niantic Bay current studies. Pages 111-156 *in* Monitoring the marine

environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

PSE&G (Public Service Electric and Gas). 1984. Salem Generating Station 316 (b) demonstration. Public Service Electric and Gas Company, Newark, NJ. (Not seen, cited *in* MMES 1986).

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder *Pseudopleuronectes americanus* (Walbaum). Bull. Bingham Oceanogr. Coll. 18(1):1-78.

Otto, R.G., T.I. Hiebert, and V.R. Kranz. 1981. The effectiveness of a remote, profile-wire screen intake module in reducing the entrainment of fish eggs and larvae. Pages 47-56 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

Robinson, R.E. and M.L. Kitchen. 1981. Construction and operation of an environmentally permitted once-through cooling system for a 770 MW fossil fueled power plant. Pages 65-71 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

SWEC (Stone and Webster Engineering Corporation). 1984. Advance intake technologies study. Electric Power Research Institute, Palo Alto. EPRI CS-3644. Project 2214-2 final report.

Taft, E.P. III, R. Berger, L. Larsen, J.G. Holsapple, and L.W. Eberley. 1981. Laboratory evaluation of larval fish impingement and diversion systems. Pages 138-158 *in* P.B. Dorn and J.T. Johnson, eds. Advanced intake technology for power plant cooling water systems.

Weisberg, S.B., F.S. Stoup, and A.F. Holland. 1986. Tests of biofouling control technologies for use with fine-mesh screens in an estuarine environment. Mar. Tech. Soc. J. 20:37-43. (Not seen, cited *in* Weisberg et al. 1987).

Weisberg, S.B., W.H. Burton, F. Jacobs, and E.A. Ross. 1987. Reductions in ichthyoplankton entrainment with fine-mesh, wedge-wire screens. N. Amer. J. Fish. Man. 7:386-393.

Zeitoun, I.H., J. A. Gulvas, and D.B. Roarabaugh. 1981. Effectiveness of fine mesh cylindrical wedge-wire screens in reducing entrainment of Lake Michigan ichthyoplankton. Can. J. Fish. Aquat. Sci. 38:120-125.

3

REPLENISHMENT OF WINTER FLOUNDER AS A MITIGATION ALTERNATIVE

3.1 INTRODUCTION

There has been some precedent in using hatchery augmentation to improve a fish stock affected by the operation of power plants. As part of the settlement agreement among the utilities, federal and state regulators, and intervenors in the case involving Hudson River power plants and open-cycle cooling (Barnthouse et al. 1988a), one provision called for the construction and operation of a hatchery for striped bass (*Morone saxatilis*). This hatchery was to produce about 600,000 young-of-the-year striped bass averaging 76 mm in length for stocking in the Hudson River each year (Barnthouse et al. 1988b). The feasibility of this approach, however, was based on the long history of the culture of striped bass and a 3-year study in 1973-75 during which 318,585 young striped bass were stocked into the Hudson River during a pilot project (McLaren et al. 1988). These fish were marked by fin clipping and coded wire nose tags prior to release and were found to have survival equal to or significantly better than wild fish of the same age. Production of these fish was a large undertaking and required capturing and spawning adult fish from the Hudson River and incubating and hatching eggs at the Verplanck, NY hatchery. Small larvae were then air-shipped to federal, state, and private hatcheries in Florida, Oklahoma, or North Carolina, where after acclimation in troughs, fish were stocked into freshwater rearing ponds or tanks. Following a period of fast summer development and growth to 75 to 150 mm in length, the fish were shipped back to New York for stocking.

3.2 HATCHERY PRODUCTION OF WINTER FLOUNDER

Hatchery culture of winter flounder would necessarily differ in many respects from that for striped bass, trout or salmon, which can be readily reared in freshwater using artificial diets. Flatfishes have not been cultured as extensively or as successfully. White and Stickney (1973b) investigated the conditions necessary for successful aquaculture of summer (*Paralichtys dentatus*) and southern flounders (*Pa. lethostigma*). Although they concluded that it was feasible to rear some flatfishes under controlled conditions, they noted that basic and specific environmental and nutritional requirements were not known for most species. Based on a number of references given in White and Stickney (1973a), requirements for the culture of European plaice (*Pleuronectes platessa*, a congener of the winter flounder) have apparently been investigated to some degree in Norway and Great Britain. The Japanese have experimented with rearing the common flounder (*Pl. yokohamae*), another congener of winter flounder, for the purposes of releasing young into coastal waters to increase fishery catches (Kuronuma and Fukusho 1984). They reported that over 2 million metamorphosed young (ca. 18 mm) were harvested after 54 days of rearing. Fish were fed rotifers, wild zooplankton, brine shrimp nauplii, and minced sandlance. Although survival rate (69.7%) was considered high, they reported 14.4% of the fish were deformed or abnormal to some degree; actual survival rate of normal fish was 55.3%.

The Japanese flounder (*Pa. olivaceus*), which is related to and has life history characteristics similar to the summer flounder, has been cultured and stocked in the waters off the northern island of Hokkaido since 1983 (Sproul and Tominaga 1992). Japanese flounder were spawned at a mariculture facility and larvae were raised there through metamorphosis. In late spring, juveniles from 15 to 40 mm in length were transferred to eight stations along the coast for additional growth before release. Approximately one million juveniles have been released since the inception of this program, with targeted annual production of 100,000 juveniles per year. Using a mathematical model that considered a number of biological and economic costs and benefits, Sproul and Tominaga (1992) reported a positive net economic benefit from this fishery enhancement stocking program. However, a number of uniquely Japanese features were relevant to this situation, including highly restricted access to a tightly controlled commercial fishery, the fact that this species has the highest value of any Japanese fish landed (particularly live specimens), strong government support for the technical and social aspects of this program, and the non-consideration of the construction costs of the mariculture facility, which was also used to produce other species. They noted that the factors most strongly influencing

their economic model were the survival rate of young after release and the annual costs of capital (i.e., interest rates) necessary to run the project.

In southern California, an extensive evaluation was made to determine the feasibility of culturing and stocking California halibut (*Pa. californicus*), which like the winter flounder, has been severely overexploited in recent years. The California halibut has a number of life history traits similar to those of the winter flounder, except it has a pelagic egg. Young California halibut settle in or migrate to bays shortly after settlement and fish remain in relatively shallow water for 2 to 3 years. Hobbs et al. (1990) developed a model to evaluate the bioeconomics of producing and stocking California halibut by the Ocean Resources Enhancement Program (OREP). The model included many parameters, including biological (e.g., age-specific rates of growth and mortality), production (e.g., costs of food, labor, and electricity), and fisheries-related (e.g., value per kg of fish caught). The model was more sensitive to change in certain parameters than others, such as the rate of growth of young in culture. And, as seen with many other models, the size and rate at which fish were taken in the commercial fishery were critical in determining ultimate yield. If cultured fish grew at a near-natural rate (0.25 mm/d), the cost per recruit was about $1.50. This gave a predicted value of $5.00 per fish caught and a net economic benefit of $3.00 per fish (assuming each fish was worth $4.00/kg). However, neither natural growth rates nor optimal release size (17 cm) could be achieved after 290 days of culture. Best available growth rates and sizes reached in culture resulted in a cost per fish of $18.00, which was not economically viable. They also noted potentially negative effects on genetic variability of the wild stock if sufficient numbers of cultured fish were released. Gadomski (1992) summarized the biological aspects for the 5-year OREP project. Adult broodstock successfully spawned naturally in large (20,000 L) tanks and larvae were successfully reared in a variety of smaller (to 300 L) tanks. However, survival declined following metamorphosis and settlement. Early metamorphosed larvae were fed brine shrimp, which may not have been an adequate diet. She concluded that because of the low survival during the juvenile stage, a hatchery operation designed to release large numbers of juveniles was not yet feasible for the California halibut.

According to several researchers (Perlmutter 1947; Topp 1965; White and Stickney 1973a; Klein-MacPhee 1978), winter flounder were apparently cultured in the late 1800s through at least the early 1940s because it was thought that the release of larvae would increase adult population size. Perlmutter (1947) reported catch records of fish taken for hatchery spawning that were available from the U.S. Fish and Wildlife Marine Hatcheries at Boothbay

Harbor, ME for 1910-40 and at Woods Hole, MA for 1919-41. Apparently these operations ceased sometime in the early 1940s. Klein-MacPhee (1978) noted that the effectiveness of this winter flounder stocking program was never established. No scientific or technical papers were cited in several extensive bibliographies of winter flounder (Topp 1965; White and Stickney 1973a; Klein-MacPhee 1978) regarding the success or failure of this work, other than several very early papers (Rathbun 1893; Brice 1898; Bumpus 1898a, 1898b, 1900; Mead 1909) on winter flounder culture techniques.

More recently, winter flounder have been spawned in the laboratory and successfully raised through metamorphosis at the National Marine Fisheries Service (NMFS) Laboratory at Milford, CT (R. Goldberg and J. Whitman, NMFS, Milford, CT, pers. comm.) and at the University of Rhode Island (URI) Marine Ecosystem Research Laboratory (MERL) located at Narragansett, RI (G. Klein-MacPhee, URI, pers. comm.). At MERL, larvae were successfully raised through metamorphosis in 15 m^3 mesocosms, which are set up to mimic natural conditions as much as possible. Eggs were placed into the mesocosms for rearing and larvae fed on natural phyto- and zooplankton in the tanks. Survival rates of 40 to 60% were found from egg through metamorphosis. In some experiments, metamorphosed young were fed chopped clams, but there has been no experience in retaining or rearing more than an insignificant number of metamorphosed young.

At the NMFS-Milford Laboratory, laboratory-spawned larvae were held in 28-L containers submerged in a larger water bath. Eggs were incubated under gentle flow or semi-static (water changed every other week) conditions. Larvae were fed cultured rotifers (which required cultured phytoplankton for their sustenance) through metamorphosis and demersal young were then fed fresh or frozen brine shrimp. After metamorphosis the growth rate decreased substantially, perhaps due to improper nutrition (R. Goldberg, NMFS, Milford, CT, pers. comm.). However, it was not an objective of the research being conducted to keep many of these fish much beyond this stage. Mortality rate of about 50% was found after 4 weeks of rearing larvae and about 90% after 6 months of culture. The number of larvae successfully raised through metamorphosis was "in the thousands" (J. Whitman, NMFS, Milford, CT, pers. comm.).

Genetic issues must also be considered before advocating fish stocking to supplement natural reproduction. Holt (1992) noted that there has been much debate recently over the stocking of hatchery-reared young to offset declining populations and increase fishery yields. Life history

0001- 0001838

traits and genetics should be important considerations for fish culture programs and the natural genetic diversity and variation of wild fish should be maintained as much as possible. A detailed discussion of the advantages, disadvantages, and effects of stocking fish with respect to a natural population genetics are complex and beyond the scope of this work; important issues involving genetic effects of stocking were discussed in detail by Ryman and Utter (1987), Kapuscinski and Philippi (1988), and Hilborn (1992). Briefly, traits that enhance growth, survival, and reproduction in the wild may be different from those selected for in a hatchery (Kapuscinski and Philippi 1988). Thus, fish should be raised and selected in hatcheries that are more representative of natural conditions instead of those that are more suited for culture. Kapuscinski and Philippi (1988) also recommended that long-term monitoring be undertaken to investigate the success of hatchery-reared fish in natural environments.

An example of possible dangers of stock enhancement to indigenous stocks of wild fish was given by Secor et al. (1992). In one year at a South Carolina striped bass hatchery, only six females accounted for 50% of all larval production. In another year, one female produced 92% of all young stocked. Extensive use of a few large females by hatcheries could decrease effective population number (N_e); N_e should be large enough to avoid inbreeding. Deleterious effects of genetic bottlenecks and inbreeding in striped bass populations remain unknown, but the striped bass (like the winter flounder) is an iteroparous fish with relatively long life span and highly variable recruitment. Recommended levels of N_e for broodstock used in fishery recovery programs are 200 to 424 females (Kincaid 1976; Tave 1986). Therefore, for fish like striped bass and winter flounder, a prudent strategy would be to spawn many more smaller females than a few larger ones to achieve similar egg production (Secor et al. 1992).

What degree of production would be necessary to supplement Niantic River winter flounder to mitigate larval entrainment? Based on a number of assumptions, some approximate calculations can be made. The stochastic population dynamics modeling found elsewhere in this report showed that a 50% reduction in entrainment mortality would result in an 8.6% increase in Niantic River female spawner biomass. Therefore, if entrainment were eliminated altogether or completely mitigated by a stocking enhancement program, an approximate 17% increase in biomass could be expected. If an average weight of 1 lb per female spawner is assumed, biomass and fish numbers become equivalent. Note that the calculations that follow below may be reduced proportionately to achieve more limited goals for the mitigation of entrainment.

An average age composition was calculated for recent (1984-90) spawning stocks of Niantic River female winter flounder (NUSCO 1992a: Table 38). This age composition was determined at about the time of spawning (i.e., mid-February). About another 24,000 fish are necessary to increase the number of age-1 (and older) females by 17%. Even though a sex ratio near unity may be more likely for smaller fish, a sex ratio of 1.32 females for every male was assumed for these calculations (NUSCO 1992a: Table 11). This means that an additional 31,680 age-1 winter flounder of both sexes would be needed to increase female numbers by 17%. Because young-of-the-year (age-0) winter flounder grow little during mid- and late summer (NUSCO 1992a: Figure 30), there would be no advantage in holding hatchery-reared fish beyond July. Thus, the mortality of age-0 winter flounder must be considered to determine the number of fish to be stocked in July to attain the desired increase in numbers for the following February. The average long-term monthly survival rate of young winter flounder is about 54.4% (NUSCO 1992b: Table 8; mean of values for stations LR and WA). This figure is equivalent to a daily instantaneous mortality rate (Z) of 0.02 for the 285-day period from early May (time of metamorphosis) to mid-February (age-1), or a total cumulative Z of 5.708. To achieve a goal of 31,680 additional age-1 juveniles in February, 3.2 million young would have to be stocked in early July, if Z is as estimated. To obtain this number of young, 9.5 million newly metamorphosed fish would be required in early May, assuming that mortality rate for cultured fish was the same as for wild fish. However, for several reasons, this calculated daily rate of mortality may be too high for the entire 285-day period. First, mortality of young probably decreases following their movement out of shallow inshore waters in early fall. Their exposure to avian and fish predators likely decreases because of reduced availability, a decrease in seasonal warm-water predators (e.g., summer flounder), and a decrease in temperature (and perhaps density) -dependent diseases such as *Glugea stephani*. Therefore, Z for a 135-day period from mid-October through February was reduced by about 40% to an estimated 0.012 on a daily basis. The value of Z was kept at 0.02 for the preceding 150 days. Using the revised estimate of Z, nearly 1 million fish would have to be stocked in July that would have resulted from 3.36 million metamorphosed young available in May, or about 35% of the previous estimate. Although it is possible that survival of young in a hatchery could be greater than that of wild fish, this is unknown for winter flounder and was therefore ignored in the calculations.

Unlike striped bass, trout, or many other fishes that can be raised in culture in high densities, the winter flounder is a demersal flatfish that may require considerably more space for rearing. Flatfish require large benthic surfaces, which may place constraints on the size and

shape of rearing tanks (Hobbs et al. 1990). Examination of young-of-the-year winter flounder abundance in the Niantic River showed that, in general, when densities of more than 50 to 100 fish per 100 m^2 of bottom were found, mortality appeared to be highest (NUSCO 1992a: Figures 27 and 28). Thus, a maximum density of 1 fish per m^2 apparently resulted in highest production in natural waters. For an estimate of hatchery production, however, it was assumed that young could be crowded to at least ten times this density in a rearing facility because of artificial feeding and predator control. This would necessitate rearing ponds or tanks totaling about 336,000 m^2 of bottom (33.6 ha, or about 83 acres). To put this area into perspective, note that it is about 10% of the surface area of the Niantic River or more than 1.5 times the surface area of Gorton Pond (Frink and Norvell 1984), located near MNPS in Niantic, CT. Only a fraction of this rearing area would be available at MNPS or likely even found at reasonable economic costs in other locations along the Connecticut coast.

To determine the number of female winter flounder needed to produce 3.36 million metamorphosed young, a Z of 2.75 from hatching to 7 mm in size (about metamorphosis) was used (NUSCO 1992a: Table 18). This mortality rate is equivalent to a daily mortality of about 4.5%, which was similar to that reported by Black et al. (1988), but less than the estimates of 13%/d by Buckley et al. (1991a) and 7-9%/d by Laurence (1977). Thus, about 52.6 million newly hatched winter flounder larvae would be required. With an average viable hatch of about 74% and an egg fertility rate of 91% in the laboratory (Buckley et al. 1991b), about 78 million eggs would be needed. Assuming a mean fecundity of about 560,000 eggs per Niantic River female winter flounder, this would be the total production of about 140 female spawners. The number of gravid female winter flounder collected in intensive annual surveys of spawning winter flounder in the Niantic River from 1983 through 1992 has ranged from 123 to 563. Thus, from about one-quarter to all gravid females encountered during recent years of this sampling would have to be removed for hatchery spawning, unless additional effort was made to collect other fish. This, of course, would eliminate these fish from spawning naturally in the Niantic River. This also assumes that fish from other winter flounder stocks would not be used to supplement Niantic River spawners.

The success of a winter flounder stocking program in ultimately increasing yield is unknown. Saila et al. (1965) evaluated the theoretical biomass of juvenile winter flounder necessary to sustain an equilibrium yield of 2 million lbs for the Rhode Island Sound fishery. They determined that the stock weight of newly metamorphosed larvae necessary to sustain the empirical average yield under average rates of mortality was 6,500 kg, or 18 billion

individuals. Even releasing 10 million larvae to this fishery would only add 0.06 to 1% to the equilibrium yield if mortality and growth of stocked larvae were similar to those of wild fish. Saila et al. (1965) next assumed that winter flounder could be reared artificially for about 150 days after hatching before release. The standing stock of 5-month old juveniles calculated under average values of growth and mortality represented a biomass equal to 56% of the calculated equilibrium yield. This occurred because extremely rapid growth during early life history stages provided for biomass increases which were greater than the amount removed by natural mortality. Therefore, the biomass of young winter flounder necessary to significantly augment natural stocks would have to be very high. They suggested that increasing basic productivity of nursery areas or controlled pond culture would have a higher probability of success for improving the fishery than the release of even large numbers of juveniles.

Other aspects of large-scale hatchery production, such as food requirements, predator and disease control, and water quality, remain to be considered in detail. Winter flounder larvae need live food, such as rotifers. These organisms, in turn, would require large-scale production of phytoplankton. This can result in considerable expense and labor (Holt 1992). Little is known about the nutritional requirements of metamorphosed young, but they eat a large variety of invertebrates (Klein-MacPhee 1978). Readily cultured invertebrates such as brine shrimp may not be ideal food for juvenile winter flounder, but it may be possible to feed young winter flounder minced clams or fish. Bergh et al. (1992) summarized effects of bacterial and viral diseases and physical factors on the development of Atlantic halibut (*Hippoglossus hippoglossus*) eggs and larvae in culture. They noted that early life stage mortalities remain a major factor in limiting the commercial success of halibut aquaculture. Iida (1989) and Muroga (1992) reported mass mortalities of larval and juvenile Japanese flounder in rearing ponds caused by viral diseases. The need for potentially large rearing areas also may limit the ability to control some avian predators, diseases and parasites, and to ensure good water quality for growth and development.

The success or failure of a stocking program should be evaluated by marking or tagging fish produced in a culture facility and determining their contribution to the wild population. This could be accomplished by tagging fish or using an inheritable genetic marker (Holt 1992). Determining the fraction of marked juveniles taken in research trawls or their contribution to commercial fishing landings after fish are recruited should be a measure of the worth of a stocking enhancement program. This would require the development of a suitable means of marking juvenile winter flounder, such as the use of a coded wire tag. Stocked Japanese

flounder were marked using more traditional fishery biology methods and included cutting fins, injecting latex dye, and use of anchor tags (Sproul and Tominaga 1992). However, these particular methods may have limited effectiveness. A significant percentage (13-95%) of cultured flounders also may display abnormal pigmentation (believed to be caused by inadequate nutrition during rearing), which can serve as a natural tag (Kuronuma and Fukusho 1984; Sproul and Tominaga 1992).

In summary, the hatchery production of young winter flounder may not be an applicable or practical method of mitigating larval winter flounder entrainment at MNPS. Although there has been some history of winter flounder culture in New England, no evidence was ever presented as to its success in augmenting natural reproduction. Some success has been achieved by governmental agencies in stocking flounders in Japan, but a long-term project investigating the culture of California halibut concluded that it was not economically viable. Unlike striped bass, salmon, or trout, winter flounder cannot be raised at high densities in freshwater ponds or tanks. To release enough young to achieve reasonable success in mitigating larval entrainment would require considerable resources, including large space requirements in a coastal area. Even then, the ultimate increase in yield to the fisheries would be questionable. The operation of a culture facility would require the removal of a large fraction, if not all, of the gravid female winter flounder collected each winter in the Niantic River during annual spawning surveys. This would be necessary to produce the large numbers of larvae needed to offset the high natural mortality of young as well as to maintain genetic diversity of cultured fish. A hatchery would require the development of many new techniques for spawning, rearing, and mass marking of winter flounder. A stocking program may have limited success unless large numbers of young could be released. Because of the uncertainties of fish replenishment, this report should be regarded as a preliminary evaluation, albeit with a negative recommendation. Therefore, no engineering, design, cost, or other more detailed feasibility studies have been undertaken at this time.

3.3 REFERENCES

Barnthouse, L.W., R.J. Klauda, D.S. Vaughan, and R.L. Kendall (eds.). 1988a. Science, law, and Hudson River power plants: a case study in environmental impact assessment. Am. Fish. Soc. Monogr. 4. 347 pp.

Barnthouse, L.W., J. Boreman, T.L. Englert, W.L. Kirk, and E.G. Horn. 1988b. Hudson River settlement agreement: technical rationale and cost considerations. Pages 267-273 *in* L.W. Barnthouse, R.J. Klauda, D.S. Vaughan, and R.L. Kendall (eds.). Science, law, and Hudson River power plants: a case study in environmental impact assessment. Am. Fish. Soc. Monogr. 4.

Bergh, Ø, G. H. Hansen, I. Huse, and A. Jelmert. 1992. Studies on diseases of cultured juvenile Atlantic halibut. Pages 1-5 *in* R.S. Svrjcek (ed.). Control of disease in aquaculture. NOAA Tech. Rep. NMFS 111.

Black, D.E., D.K. Phelps, and R.L. Lapan. 1988. The effects of inherited contamination on egg and larval winter flounder, *Pseudopleuronectes americanus*. Mar. Envir. Res. 25:45-62.

Brice, J.J. 1898. The flatfish or winter flounder. *In* A manual of fish-culture, based on the methods of the United States Commission of Fish and Fisheries. Rep. U.S. Comm. Fish., for 1897, 23 (appendix):215-218, plate 59. (Not seen, cited *in* Topp 1965).

Buckley, L.J., A.S. Smigielski, T.A. Halavik, E.M. Caldarone, B.R. Burns, and G.C. Laurence. 1991a. Winter flounder *Pseudopleuronectes americanus* reproductive success. I. Among-location varability in size and survival of larvae reared in the laboratory. Mar. Ecol. Prog. Ser. 74:117-124.

Buckley, L.J., A.S. Smigielski, T.A. Halavik, E.M. Caldarone, B.R. Burns, and G.C. Laurence. 1991b. Winter flounder *Pseudopleuronectes americanus* reproductive success. II. Effects of spawning time and female size on size, composition and viability of eggs and larvae. Mar. Ecol. Prog. Ser. 74:125-135.

Bumpus, H.C. 1898a. The breeding of animals at Woods Hole during the month of March, 1898. Science, N.S. 7(171):485-487. (Not seen, cited *in* Topp 1965).

Bumpus, H.C. 1898b. On the identification of fish artificially hatched. Amer. Nat. 32:407-412. (Not seen, cited *in* Topp 1965).

Gadomski, D.M. 1992. (Abstr.). The use of larval fish culture in fisheries management: the California halibut *Paralichthys californicus* as an example. 16th annual larval fish conference, June 16-20, University of Rhode Island, Kingston, RI.

Hilborn, R. 1992. Hatcheries and the future of salmon in the Northwest. Fisheries (Bethesda) 17(1):5-20.

Hobbs, R.C., L.W. Botsford, and R.G. Kope. 1990. Bioeconomic evaluation of the culture/ stocking concept for California halibut. Pages 417-449 *in* C.W. Haugen, ed. The California halibut, *Paralichthys californicus*, resource and fisheries. Calif. Fish and Game Fish. Bull. 174.

Holt, G.J. 1992. (Abstr.). Can larviculture play a role in alleviating population and habitat losses? 16th annual larval fish conference, June 16-20, University of Rhode Island, Kingston, RI.

Iida, Y., K. Masumura, T. Nakai, M. Sorimachi, and H. Matsuda. 1989. A viral disease occurred in larvae and juveniles of Japanese flounder, *Paralichthys olivaceus*. Aquatic Animal Health 1:7-12. (Not seen, cited *in* Yoshimizu and Kimura 1992).

Kapuscinski, A.R., and D.P. Philippi. 1988. Fisheries genetics: issues and priorities for research and policy development. Fisheries (Bethesda) 13(6):4-10.

Kincaid, H.L. 1976. Effects of inbreeding on rainbow trout populations. Trans. Am. Fish. Soc. 105:273-280.

Klein-Mac Phee, G. 1978. Synopsis of biological data for the winter flounder, *Pseudopleuronectes americanus* (Walbaum). NOAA Tech. Rep. NMFS Circ. 414. 43 pp.

Kuronuma, K., and K. Fukusho. 1984. Rearing of marine fish larvae in Japan. IDRC-TS47e. International Development Research Centre, Ottawa, ON, Canada. 94 pp.

Laurence, G.C. 1977. A bioenergetic model for the analysis of feeding and survival potential of winter flounder, *Pseudopleuronectes americanus*, larvae during the period from hatching through metamorphosis. Fish. Bull., U.S. 75:529-546.

Mead, A.D. 1909. A method of fish culture and of transporting live fishes. Pages 79-106 *in* 39th Annu. Rep. Comm. Inland Fish. Rhode Island. (Not seen, cited *in* Klein-MacPhee 1978).

McLaren, J.B., J.R. Young, T.B. Hoff, I.R. Savidge, and W.L. Kirk. 1988. Feasibility of stocking age-0 striped bass in the Hudson River. Pages 286-291 *in* L.W. Barnthouse, R.J. Klauda, D.S. Vaughan, and R.L. Kendall (eds.). Science, law, and Hudson River power plants: a case study in environmental impact assessment. Am. Fish. Soc. Monogr. 4.

Muroga, K. 1992. Bacterial and viral diseases of marine fish during seed production. Pages 57-61 *in* R.S. Svrjcek (ed.). Control of disease in aquaculture. NOAA Tech. Rep. NMFS 111.

NUSCO (Northeast Utilities Service Company). 1992a. Winter flounder studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992b. 1992 abundance indices for winter flounder. Enclosure 1 to letter D05905 dated October 28, 1992 from J.F. Opeka, NUSCO, to T, Keeney, Commissioner, CT DEP. 18 pp.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bull. Bingham Oceanogr. Coll. 11:1-92.

Rathbun, R. 1893. Report upon the inquiry respecting food-fishes and the fishing grounds. Rep. U.S. Comm. Fish., for 1889 to 1891, 17:97-171. (Not seen, cited *in* Topp 1965).

Ryman, N., and F. Utter (eds.). 1987. Population genetics and fishery management. University of Washington Press, Seattle. 420 pp.

Saila, S.B., D.H. Horton, and R.J. Berry. 1965. Estimates of the theoretical biomass of juvenile winter flounder, *Pseudopleuronectes americanus* (Walbaum) required for a fishery in Rhode Island. J. Fish. Res. Board Can. 22:945-954.

Secor, D.H., J.M. Dean, T.A. Curtis, and F.W. Sessions. 1992. Effect of female size and propagation methods on larval production at a South Carolina striped bass (*Morone saxatilis*) hatchery. Can. J. Fish. Aquat. Sci. 49:1778-1787.

Sproul, J.T., and O. Tominaga. 1992. An economic review of the Japanese flounder stock enhancement project in Ishikari Bay, Hokkaido. Bull. Mar. Sci. 50:75-88.

Tave, D. 1986. Genetics for fish hatchery managers. AVI Publishers, Westport, CT. 305 pp. (Not seen, cited *in* Secor et al. 1992).

Topp, R.W. 1965. An annotated bibliography of the winter flounder, *Pseudopleuronectes americanus* (Walbaum). Mass. Div. Mar. Fish., Mass. Coop. Fish. Unit Paper No. 1. 30 pp.

White, D.B., and R.R. Stickney. 1973a. A bibliography of flatfish (Pleuronectiformes) research with partial annotation. Georgia Mar. Sci. Center Tech. Rep. Ser. No. 73-6. 77 pp.

White, D.B., and R.R. Stickney. 1973b. A manual of flatfish rearing. Georgia Mar. Sci. Center Tech. Rep. Ser. No. 73-7. 31 pp.

Yoshimizu, M., and T. Kimura. 1992. Viral infections of cultured fish in Japan. Pages 43-47 *in* R.S. Svrjcek (ed.). Control of disease in aquaculture. NOAA Tech. Rep. NMFS 111.

4

SELECTION OF DATES USED FOR THE EVALUATION OF SHUTDOWNS AS A MITIGATION ALTERNATIVE

4.1 METHODOLOGY

One method to reduce the entrainment of larval winter flounder at MNPS is to selectively shut down one or more units to reduce condenser cooling-water demand. At MNPS, the densities of larval winter flounder in the cooling water vary throughout the larval season, each unit has a different capacity for cooling water, and Units 2 and 3 have NPDES permit requirements that some circulating-water pumps remain in operation during shutdowns for certain operations. Thus, potential reductions in entrainment can vary according to how these factors interact. Because of the cooling-water flow at Units 2 and 3 during shutdowns, a 100% reduction in entrainment cannot be achieved even if all units did not produce power during the entire winter flounder larval season. Based on flow alone, the maximum reduction would be about 69% (Table 4-1). If a 25% reduction in entrainment is selected as a goal for mitigation using shutdowns, this targeted reduction cannot be achieved either with a season-long shutdown for Unit 1 alone (about 23% of total MNPS cooling-water flow) or with Unit 2 alone (about 15%). A shutdown of Unit 3 over the entire season, however, could result in a reduction in entrainment of approximately 32%.

TABLE 4-1. Fractional cooling-water flow for MNPS Units 1 through 3 and mode of operation during shutdowns.

Unit	Fraction of total MNPS flow	Circulating-water pumps run during shutdowns	Fraction of total MNPS flow during shutdowns
1	0.23	0 of 4	0
2	0.29	2 of 4	0.15
3	0.48	2 of 6	0.16
MNPS total	1.00		0.31

To determine optimal times for shutdowns, the distribution of larval winter flounder over time in entrainment collections was examined. This distribution is skewed because densities increase relatively rapidly to a maximum and then slowly decline (NUSCO 1992). A cumulative density over time from this type of distribution results in a sigmoid-shaped curve and the time of peak abundance coincides with the inflection point. The Gompertz function (Draper and Smith 1981) was used to directly describe the cumulative abundance distribution of winter flounder larvae over time and determine the date of peak abundance (NUSCO 1992: Equation 2). To describe the average long-term entrainment of winter flounder larvae at MNPS, the following procedure was used. Daily entrainment densities were estimated from 16 years (1976-91) of data and were expressed as a percentage of the total annual density. These daily percentages were determined by fitting the Gompertz function to cumulative weekly percentages. Therefore, the α parameter of this function was constrained to 100%, because α corresponds to the maximum or asymptotic cumulative density. A total of 347 cumulative weekly percentages during the occurrence of larval winter flounder was used to fit the equation using nonlinear regression methods (SAS Institute Inc. 1985). Average daily percentages, as opposed to cumulative percentages, were calculated from first derivative of the Gompertz function with respect to time (NUSCO 1992: Equation 3), except that here the parameter α' of this function was constrained to 100%. Output used for the selection of days for shutdowns consisted of the date and percentage of the annual entrainment density at MNPS and is shown graphically on **Figure 4-1**. Once the long-term average cumulative percent-distribution over time was determined for entrained winter flounder larvae, dates could be chosen to predict average annual reduction in entrainment when flow reductions were also considered. As noted above, the density distribution of larvae over time is asymmetrical. Typically, entrainment of winter flounder first occurs at very low levels beginning in mid-February, rises slowly until early April and then increases rapidly until a maximum (under average annual conditions) is reached by April 23. Because of the asymmetry of the daily density distribution, the date on which the cumulative density reaches 50% of the total does not occur until May 1. Daily larval entrainment rates begin to tail off by late May, but some larvae continue to be found in many years until late June or early July. Shutdowns during February and March and for most of June would be much less effective in reducing entrainment mortality then they would be in mid-season. Therefore, the tails (first 1% and last 4%) of the cumulative larval entrainment distribution were eliminated in the consideration of dates for shutdowns. This truncated the larval entrainment season to a 73-day period extending from April 2 through June 13. Considering the potential reduction in flow for each MNPS unit along with the cumulative daily entrainment allowed for the selection of dates for shutdowns within this period and the estimation of total percent reduction in entrainment.

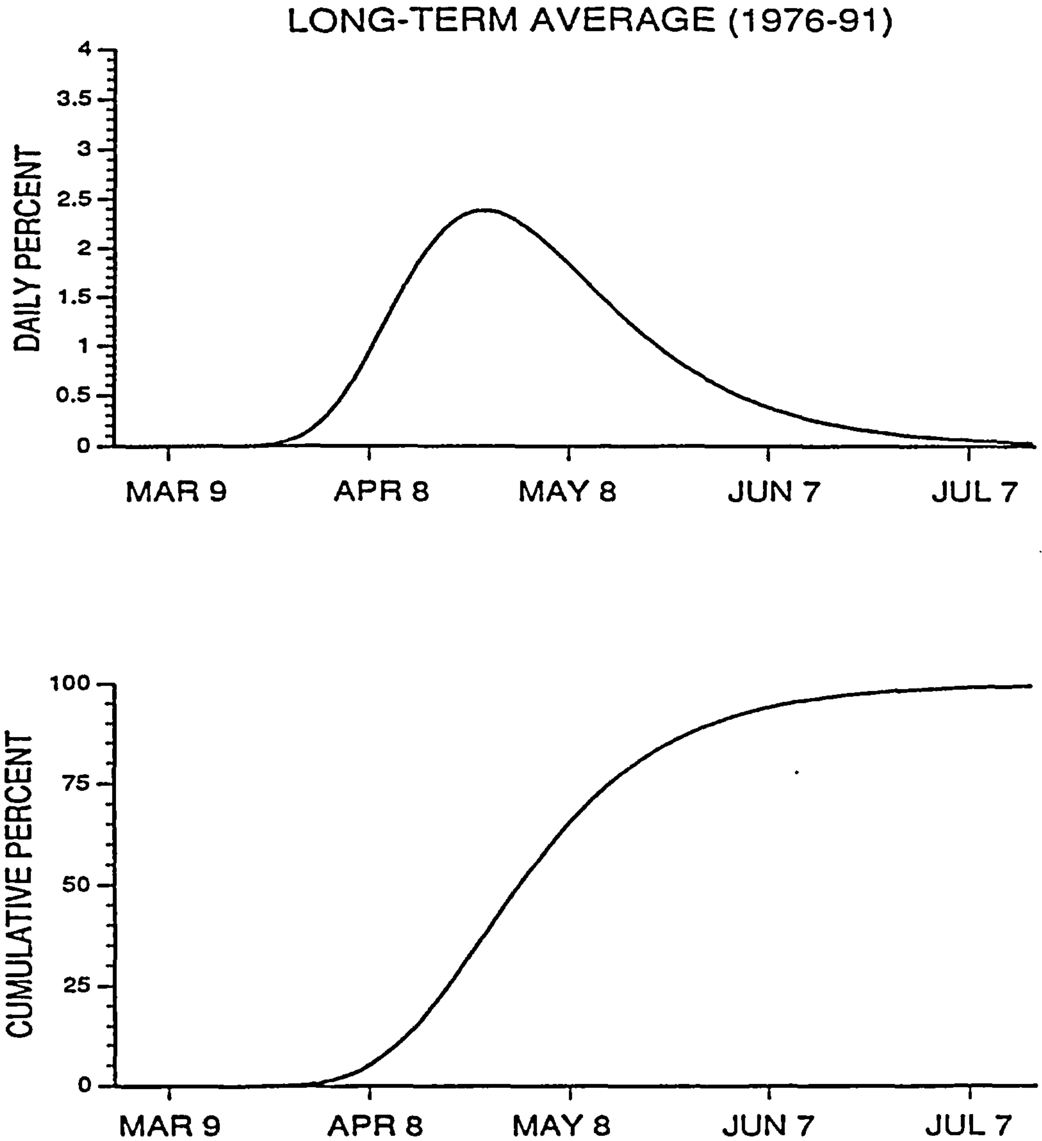


Fig. 4-1. Cumulative percent-distribution (bottom) and daily percentage (top) of winter flounder larval densities available for entrainment through the condenser cooling-water systems of MNPS. Estimates were based on a Gompertz function fitted to larval density data collected during 1976-91 and describe long-term average conditions.

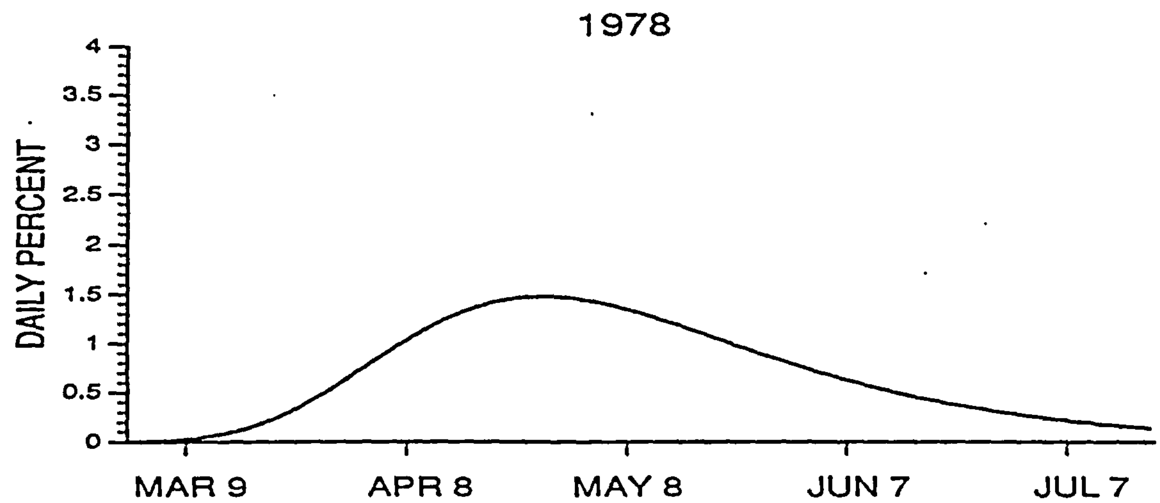
A shutdown of Unit 1 during the April 2-June 13 period would result in about a 22% reduction in total entrainment (**Table 4-2**). However, a shutdown of Unit 2 during the same period would only reduce entrainment by 13% because two circulating-water pumps would remain in operation. If Unit 3 was shutdown for the same number of days, entrainment would be reduced by about 30%. Since this is above the goal for reduction, the 73-day period may be reduced by 14 days (ending on May 30) to achieve the desired reduction of 25%. A similar decrease can be achieved if Units 1 and 2 are shut down for the same 59-day period. Shutting down all three units simultaneously is an unlikely option for operational and economic reasons. Nevertheless, to achieve the desired theoretical reduction in entrainment, a 21-day shutdown from April 22 through May 12 would suffice to reduce present entrainment by 25%.

TABLE 4-2. Summary of dates for selected shutdowns as an alternative to reduce the entrainment of larval winter flounder at MNPS Units 1 through 3 under average annual conditions.

Unit	Dates[a]	Number of days shutdown	Approximate total reduction in entrainment
1	April 2 - June 13	73	22%
2	April 2 - June 13	73	13%
3	April 2 - May 30	59	25%
1 + 2	April 2 - May 30	59	25%
1 + 2 + 3	April 22 - May 12	21	25%

[a] Approximately 1% of total winter flounder larval entrainment occurs from mid-February through April 1 and 4% from mid-June through early July.

Finally, it should be noted again that these dates and reductions were based on an average annual entrainment season that was derived from historic entrainment data. The actual annual distribution of larvae in entrainment collections each year may vary considerably from the annual average due to many biological and environmental factors. Two years (1978 and 1982) in the database represent extreme differences within the 16-year time-series (**Figs. 4-2 and 4-3**). Shutdowns during the same number of days during those two extreme years would result in reductions of entrainment mortality quite different from those described above. Entrainment would have been reduced to a greater extent for the same number of days in 1982 than in 1978. This is because the distribution of larvae peaked more quickly in 1982, which had a much shorter larval season. Generally, shutdowns at any nuclear power station require lengthy lead times for planning and scheduling. No reliable long-term ability to predict entrainment density distributions in a particular year can be foreseen at this time. Thus, a shutdown to mitigate larval entrainment mortality would have to be based on long-term average conditions and only minor modifications could be made to a schedule once it had been set.



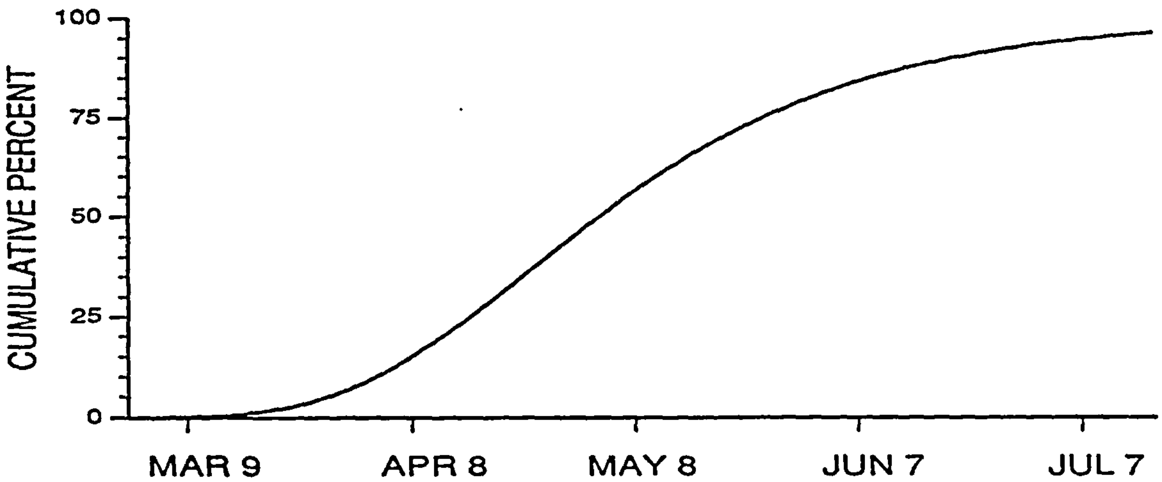


Fig. 4-2. Cumulative percent-distribution (bottom) and daily percentage (top) of winter flounder larvae available for entrainment through the condenser cooling-water systems of MNPS in 1978. Estimates were based on a Gompertz function fitted to larval density data.

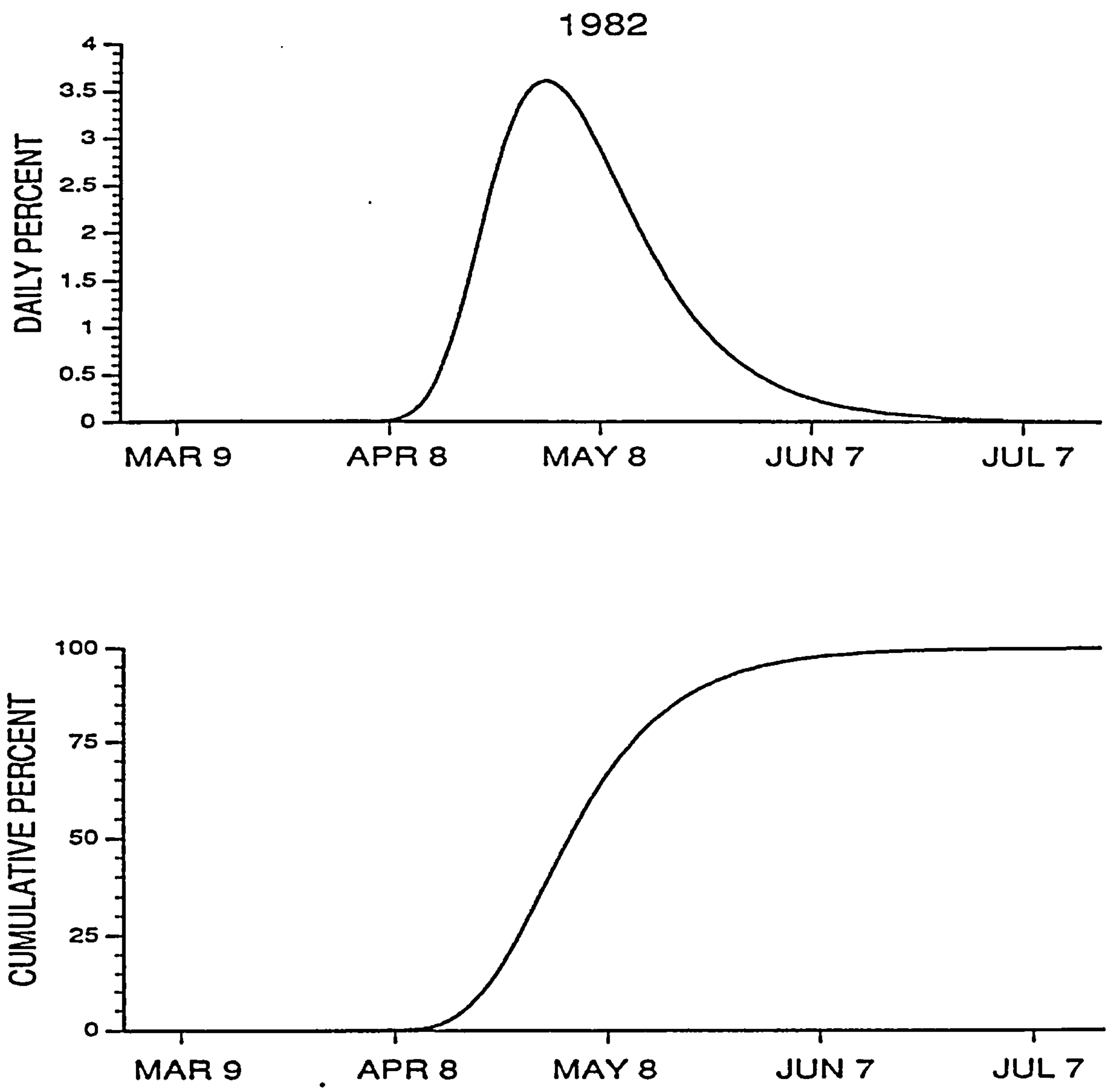


Fig. 4-3. Cumulative percent-distribution (bottom) and daily percentage (top) of winter flounder larvae available for entrainment through the condenser cooling-water systems of MNPS in 1982. Estimates were based on a Gompertz function fitted to larval density data.

4.2 REFERENCES

Draper, N., and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, New York. 709 pp.

NUSCO (Northeast Utilities Service Company). 1992. Winter flounder studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

SAS Institute Inc. 1985. SAS user's guide: statistics. Version 5 edition. SAS Institute Inc., Carey, NC. 956 pp.

5

EFFECTIVENESS OF THE MITIGATION OF LARVAL WINTER FLOUNDER ENTRAINMENT

5.1 INTRODUCTION

The NUSCO stochastic population dynamics model (SPDM) was used to assess the effectiveness of mitigating larval winter flounder entrainment at Millstone Nuclear Power Station (MNPS). Model development and appplications were fully described in NUSCO (1989, 1990, 1992a). A brief discussion of key model parameters and simulation conditions are given below. This is followed by results of the model simulations, which examined the effect of reductions (10, 20, 25, and 50%) in the rate of entrainment projected for various mitigation alternatives.

5.2 WINTER FLOUNDER STOCK AND RECRUITMENT

5.2.1 RICKER STOCK-RECRUITMENT MODEL

The stock-recruitment relationship (SRR) of Ricker (1954, 1975) is the basis of the life-cycle algorithm that drives the SPDM for Niantic River winter flounder. The data used for determining the SRR were derived from the catch-at-age of winter flounder during annual adult spawning surveys in the Niantic River. Because the spawning stock is made up of many year-classes, the true recruitment consists of the reproductive contribution over the life of each individual (Garrod and Jones 1974; Cushing and Horwood 1977). Therefore, the index of annual parental stock size was based on derived egg production and the index of recruits or year-class size was based on calculated egg production accumulated over the life-time of the recruits. This method accounted for variations in year-class strength and in fecundity by size and age. The assumptions and methods used to age Niantic River winter flounder and to calculate a recruitment index expressed as equivalent numbers of female spawners were given in NUSCO (1989, 1990, 1992a).

The Ricker SRR appeared best suited for use with the Niantic River winter flounder stock because the relationship between recruitment and spawning stock indices was a dome-shaped curve with substantial decline in recruitment when the stock was larger than average (NUSCO 1989). In addition, this model has been applied to other New England flounder stocks (Gibson 1989). The α parameter of the Ricker SRR describes the inherent growth potential of the stock because α is the slope of the SRR at the origin (Ricker 1954) and the natural logarithm of that slope, in turn, corresponds to the intrinsic rate of natural increase of the population (Roughgarden 1979). The β parameter is the instantaneous rate at which recruitment declines at large stock sizes due to some form of density-dependent compensatory mortality. Because an inverse relationship was found between winter flounder recruitment and mean water temperature (determined at the intakes of MNPS) during February, the parameters α and β that were fitted initially to the Ricker SRR were re-estimated by adding a temperature-effect component (termed ϕ) to the SRR. Mechanisms that cause greater recruitment in cold years are not known for certain, but February coincides with most spawning, egg development, hatching, and early larval development (NUSCO 1988, 1989). These processes, as well as larval growth, are all temperature-dependent. In addition, the effect of temperature on potential prey or predators of larvae and newly metamorphosed juveniles may be an additional means for control of population abundance. The temperature effect can result in either a decrease or an increase in the number of recruits-per-spawner produced each year because temperature was defined as the deviation of each particular mean February temperature from a long-term (1977-87) average of February water temperatures. When the February mean water temperature is equal to the long-term average, the temperature deviation becomes zero.

5.2.2 ESTIMATION OF SRR PARAMETERS FOR SPDM SIMULATIONS

The current estimate of Ricker's β parameter was 0.0000246 and the estimated value for the temperature effect parameter ϕ was –0.264 (NUSCO 1992a). The α value determined from the three-parameter Ricker SRR was 2.502 with a standard error of 0.40 (NUSCO 1992a). Variation in the parameter estimate of α could be caused by changing exploitation rates in addition to the inherent instability of parameter estimates fitted to small data sets. However, each year of additional data have served to confirm the SRR for Niantic River winter flounder and standard errors of the estimates have been reduced since initial estimates were first reported in NUSCO (1988).

The SRR estimate of α for the Niantic River winter flounder is an underestimate of the true

0001- 0001856

slope at the origin for the unfished and non-impacted stock because the method of calculating annual recruitment included the effects of fishing on winter flounder that were age-2 and older and from the entrainment of larvae. Therefore, the direct estimate of α corresponds to a compensatory reserve diminished by existing entrainment and exploitation rates. The concept of compensatory reserve in fishing stocks and the effect of exploitation on the shape of the reproduction curve when the recruitment index is based on the exploited stock was discussed in NUSCO (1992a). As larval entrainment and fishing rates increase, estimates of recruitment will decrease and so will the estimates of α (i.e., the remaining compensatory reserve).

To assess impacts appropriately, the inherent potential of a stock to increase in the absence of fishing and plant effects must be determined. Crecco and Howell (1990) investigated the possibility of using indirect methods to estimate the true α parameter (i.e., for the virgin stock when $F = 0$). They used four indirect methods (Cushing 1971; Cushing and Harris 1973; Longhurst 1983; Hoenig et al. 1987; Boudreau and Dickie 1989) based on different life history parameters. Because these methods do not depend upon direct estimates of recruitment, they avoid biases caused by changing fishing rates and provide independent means of validating SRR-based estimates. For the SPDM simulations, a Ricker SRR α parameter estimate was derived from a value of 3.74 in biomass units (lbs) reported by Crecco and Howell (1990: Table 2). The large difference between this value of α and the direct regression estimate of α (2.502) reflects the different potential for growth between an unfished and a highly exploited stock of winter flounder. The choice of an unfished stock as the starting point for SPDM simulations has advantages for particular scenarios selected. For example, simulations may include initially moderate fishing rates that are much lower than those affecting the data on which the regression estimate of α was based. The estimates of the other two SRR parameters (β and ϕ) given above, which do not depend upon fishing and entrainment rates, were used in the population simulations as determined from the data.

5.3 STOCHASTIC SIMULATION OF NIANTIC RIVER WINTER FLOUNDER STOCK DYNAMICS

5.3.1 MODELING STRATEGY AND BACKGROUND

An approach to stock assessment that can incorporate environmental variability and all types of mortality, both constant and variable, involves the computer simulation of the fish population

dynamics using a simple model of population renewal with spawning stock feed-back (e.g., a functional SRR). This approach has the advantage of not assuming population equilibrium and the ability to incorporate a great degree of detail into the conditions used to simulate changes in fish populations through time. An additional advantage is that Monte Carlo methods (Rubinstein 1981) can readily provide the stochastic (as opposed to deterministic) framework needed for probabilistic risk assessment (PRA) and for testing hypotheses about the probable size of the stock at some future point in time. Further, Monte Carlo replications can be used to derive the sample distribution function (Stuart and Ord 1987) without assuming a known statistical distribution. This simulation approach was applied in NUSCO (1990) to assess the impact of larval entrainment under a very simple scenario. In NUSCO (1991) various combinations of historic and projected fishing and larval entrainment rates were used to assess more realistically the impact of MNPS operations on local winter flounder. Finally, in NUSCO (1992a) the impact resulting from the impingement of juvenile and adult winter flounder was simulated along with entrainment as an equivalent instantaneous mortality rate that was held constant throughout the MNPS operational period. The basic steps leading to the final impact assessment using this simulation approach included the direct estimation of annual larval entrainment rates at MNPS; mass-balance calculations to estimate the fraction of Niantic River annual flounder production lost through larval entrainment at MNPS; estimation of the equivalent instantaneous mortality rates for females that were attributed to impingement (as derived in NUSCO 1992a); stochastic simulation of the winter flounder stock dynamics to predict stock biomass at selected levels of entrainment and fishing rates; and probabilistic analyses of simulation results leading to a final estimate of the probability of recruitment failure under simulated conditions.

Although the Ricker SRR fitted to the data does not appear explicitly in the SPDM formulation, the mechanisms underlying this form of recruitment are incorporated in a set of equations used to calculate mortality through the first year of life. Beyond that point in the life-cycle simulation (i.e., age-1), the model describes the annual reduction of each year-class through natural mortality and fishing together with aging and reproduction. These processes occur at the beginning of each model time-step of length equal to 1 year. The projection of adult fish populations over time has been implemented in many models by means of Leslie matrix equations (e.g., Hess et al. 1975; Vaughan 1981; Spaulding et al. 1983; Reed et al. 1984; Goodyear and Christensen 1984). In the SPDM, adult winter flounder were projected over time by grouping fish into distinct age-classes and by carrying out the computations needed iteratively over the age index (1 through 15) and over the specified number of years.

5.3.2 MODEL COMPONENTS

The most critical aspects in the formulation of an SRR-based population model are the specific equation and parameters used to calculate total mortality during the first year of life (i.e., from egg through age-1). The equation used for this purpose in the SPDM was derived from Ricker's equilibrium equation for Z_0 (total instantaneous mortality from egg through maturation age) and involved the extension of stock-recruitment theory, which was developed for fish that spawn only once, to iteroparous fish with multiple-aged spawning stocks. The form of the equation as used in the present model was:

$$Z_{0,t} = \log_e(FEC) + \log_e(ASF) - \log_e(\alpha) + n_t - \phi WT_t - Z_{1,2} + \beta P_t$$

where the subscript t denotes the time-step (in this case, a year) and non-subscripted terms remain constant from year to year; α, β, and ϕ are the estimated parameters of the Ricker SRR described above; FEC is the mean fecundity of the stock expressed as the number of female eggs produced by each female spawner; ASF is a scaling factor to adjust α for the effect of a multi-age spawning stock; n_t and WT_t are independent random variates from two specified normal distributions described later; $Z_{1,2}$ is the instantaneous mortality through the immature age-classes; and the last term (βP_t) is the feed-back mechanism simulating stock-dependent compensatory mortality, which varies according to the size of the annual spawning stock P_t. The complete derivation of the above equation was given in NUSCO (1990: appendix to the winter flounder section). The scaling factor ASF is a multiplier that converts age-3 female recruits into the total spawning potential of their year-class. This spawning potential is defined as the cumulative number of mature females from the same year-class surviving to spawn year after year during the lifetime of the fish.

Stochasticity in the winter flounder model has three annual components: a random term that represents uncertainties associated with the estimate of Ricker's α parameter; annual environmental variability in the form of random deviations from the long-term mean February water temperature; and variability in MNPS operation that affects the conditional entrainment mortality rate, which will be discussed below. The first two components of annual variability are incorporated into the calculation of each new year-class via the mortality from egg to age-1 according to the above equation. The term n_t is the random "noise" simulated as independent random variates from a normal distribution with zero mean and variance equal to σ^2. The value of σ was estimated during the model calibration runs as the amount of variance required to generate α values within the 95% confidence interval of the estimate of α used in the model. Similarly, the term ϕWT_t represents the effect of annual environmental variability of

February water temperatures on larval survival. This effect becomes random when the February water temperatures are themselves simulated as independent random variates from a normal distribution with mean and variance equal to the mean and variance of February water temperatures at the MNPS intakes during 1977-87. PRA methodology was used to assess the risk of stock reduction resulting from the effects of entrainment and impingement at MNPS. The probabilities of stock reductions for PRA were derived from Monte Carlo replicates of the time-series of impacted stocks.

5.3.3 MODEL ASSUMPTIONS AND LIMITATIONS

The major assumptions relate to the underlying form of the SRR used and the reliability of the SRR parameter estimates. First, because the model incorporated the Ricker form of SRR, it was assumed that stock-dependent compensation and the postulated effect of water temperature on larval survival applied reasonably well to the Niantic River winter flounder stock. Secondly, it was assumed that the three parameters of the SRR were correctly estimated and that α, in particular, was a reliable estimate. Thirdly, although the population was not assumed to be at steady state, the average fecundity and survival rates for fish age-1 and older were assumed to remain fairly stable over the period corresponding to the time-series data used to estimate the SRR parameters. Although this last assumption can generally be met in the case of fecundity rates and adult natural mortality, fishing mortality rates are much less stable. Changes in exploitation rates from year to year should not cause estimation problems as long as the changes are not systematic (i.e., change in the same direction year after year). Because these assumptions are seldom completely met, early applications of the model (NUSCO 1990) included calibration runs to validate predictions under both deterministic and stochastic modes by comparing model results to recent series of stock abundance data. Additionally, no temperature trend or large-scale environmental changes (e.g., global warming) were assumed to have occurred during the years simulated in a population projection.

5.3.4 MODEL SIMULATION OF MNPS IMPACT

The dynamics of the Niantic River female winter flounder stock were simulated using the SPDM under a real-time scenario beginning in 1960, well before operation of Unit 1, to 2060, which included a recovery period following the projected shutdown date for Unit 3 in 2025 (Table 5-1). All stock projections were given in units of spawning biomass (lbs) of females because overfishing criteria often rely on measurements of spawning biomass and biomass assessments

TABLE 5-1. Cooling-water requirements and dates of operation for MNPS Units 1 through 3, each with an assumed life-span of 40 years.

Unit	Cooling-water flow (m^3/sec)	Fraction of MNPS total flow	Start-up date	First year of entrainment	Projected last year of operation
1	29.18	0.227	November 1970	1971	2010
2	37.62	0.292	December 1975	1976	2015
3	61.91	0.481	April 1986	1986	2025
MNPS total	128.71	1.000			

tend to be more conservative than those based on fish numbers. Simulation output consists, in general, of a time-series of annual stock sizes generated under some specified set of population parameters and other conditions which constitute a scenario. These parameters include the rates of fishing mortality (F) and some additional mortality equivalent to impingement losses (IMP); conditional mortality rates (i.e., fraction of the annual production of winter flounder that was removed as a result of power plant operation) for larval entrainment (ENT); a schedule of changes when any of these rates is not assumed constant; and the length of the time-series in years. The combined mortality of fishing plus impingement was used only during the simulation period (1971-2025) that corresponded to MNPS operation. The population projection results from averaging a number of replicate time-series identically generated except for the random components used to compute annual fish survival rates. It was concluded previously that 100 replicates were sufficient given the amount of variability present in the winter flounder SPDM simulations (NUSCO 1990). Thus, the Monte Carlo sample size was set to 100 and the geometric mean of the replicates was computed.

The conditional mortality rate ENT was calculated under the assumption that all three units used cooling water pumped at maximum capacity (11.1×10^6 m^3/d). The rates of larval entrainment for 1971-91 were based on actual MNPS cooling-water flow during the annual March-May winter flounder larval season (**Table 5-2**); the number of units in operation in a particular year (**Table 5-1**); and a maximum nominal entrainment rate of 13.9% for Niantic River winter flounder larvae during three-unit operation, which was derived from the mass-balance calculation discussed previously in this report. ENT was proportionately reduced to 10.745% in 2011 following the expected shutdown of Unit 1 and to 6.686% in 2016 after the scheduled shutdown of Unit 2.

TABLE 5-2. Annual average cooling-water flow and percent of nominal maximum flow at MNPS Units 1 through 3 during the March-May winter flounder larval entrainment season from 1971 through 1991.

	Unit 1		Unit 2		Unit 3	
Nominal flow at 100% capacity:	29.18 m^3/sec		37.62 m^3/sec		61.91 m^3/sec	
Fraction of total flow:	0.227		0.292		0.481	
Year[a]	March-May average flow in m^3/sec	% of nominal maximum	March-May average flow in m^3/sec	% of nominal maximum	March-May average flow in m^3 sec	% of nominal maximum
1971	-	67.25	-	-	-	-
1972	-	99.40	-	-	-	-
1973	-	33.73	-	-	-	-
1974	-	83.30	-	-	-	-
1975	-	99.40	-	-	-	-
1976	25.39	87.00	29.16	77.53	-	-
1977	27.61	94.60	24.61	65.42	-	-
1978	17.48	59.91	18.91	50.27	-	-
1979	17.18	58.87	21.48	57.10	-	-
1980	27.60	94.57	31.75	84.42	-	-
1981	1.52	5.20	33.98	90.34	-	-
1982	27.60	94.56	32.33	85.95	-	-
1983	26.79	91.82	30.90	82.14	-	-
1984	13.88	47.58	35.83	95.26	-	-
1985	27.86	95.47	16.40	43.60	-	-
1986	27.21	93.25	36.89	98.07	49.82	80.48
1987	29.01	99.40	36.99	98.32	47.12	76.12
1988	28.84	98.81	32.83	87.27	55.58	89.78
1989	13.85	47.46	24.72	65.72	51.33	82.91
1990	27.55	94.39	33.28	88.48	48.71	78.68
1991	10.79	36.98	32.29	85.83	38.65	62.44

[a] No records of cooling-water flow available for 1971-75. Net electrical generation records were used to estimate flow, with values for 1972 and 1975 normalized to the value for 1987 (maximum of the Unit 1 time-series).

Because the ability of a fish stock to withstand additional stress is reduced by fishing mortality (Goodyear 1980), simulations of the long-term entrainment of winter flounder larvae also included effects due to the substantial exploitation of the stock. The annual schedule of nominal fishing rates was developed from recent DEP estimates of exploitation rates and took into account length-limit regulations in effect since 1982 and the future changes proposed by DEP to reduce fishing mortality in Connecticut waters (Tables 5-3 and 5-4). Vulnerability factors by age-class were calculated for the commercial fishery (60% of the total winter flounder catch) based on actual or proposed changes in length limits, the estimated length distribution of Niantic River winter flounder by age-class at mid-year (age + 0.5), the selection curve for a 127-mm trawl mesh codend given by Simpson (1989), and a discard

TABLE 5-3. Eastern Long Island Sound winter flounder length-limit regulations[a] in effect for the commercial and sport fisheries since 1982.

Period	Length limit in inches: Commercial fishery	Sport fishery	Length limit in mm: Commercial fishery	Sport fishery
1982[b]	8	8	203	203
1983 (Jan-May)	8	8	203	203
1983 (Jun-Dec)	11	8	279	203
1984 (Jan-Aug)	11	8	279	203
1984 (Sep-Dec)	10	8	254	203
1985-1986	10	10	254	254
1987 (Jan-Aug)	10	10	254	254
1987 (Sep-Dec)	11	10	279	254
1988-1994	11	10	279	254
≥ 1995[c]	12	10	305	254

[a] P. Howell, CT DEP, Old Lyme, CT, pers. comm.
[b] Prior to 1982 there were no size regulations, but it was assumed that fish between 6 inches (152 mm) and 8 inches (203 mm) were subjected to about one-half of the nominal fishing mortality for each year. Fish larger than 8 inches (about 2.8 years old) were fully recruited to the fishery.
[c] Tentative; will be proposed by DEP for implementation (P. Howell, CT DEP, Old Lyme, CT, pers. comm.).

TABLE 5-4. Vulnerability factors for eastern LIS winter flounder, adjusted for discard mortality of undersized fish vulnerable to the commercial (60% of total landings) and sport (40%) fisheries, according to length-limits in effect for the periods listed[a].

	Corrected fractional fishing rates by age group[b]														
	Commercial					Sport					Total fishery				
Period	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+
≤ 1981	0.03	0.36	0.60	0.60	0.60	0.06	0.24	0.40	0.40	0.40	0.09	0.60	1.00	1.00	1.00
1982	0	0.36	0.60	0.60	0.60	0.06	0.13	0.40	0.40	0.40	0.06	0.49	1.00	1.00	1.00
1983-84	0	0.30	0.60	0.60	0.60	0.06	0.13	0.40	0.40	0.40	0.06	0.43	1.00	1.00	1.00
1985-87	0	0.30	0.60	0.60	0.60	0.06	0.06	0.40	0.40	0.40	0.06	0.36	1.00	1.00	1.00
1988-94	0	0.30	0.45	0.60	0.60	0.06	0.06	0.40	0.40	0.40	0.06	0.36	0.85	1.00	1.00
≥ 1995[c]	0	0.00	0.21	0.42	0.60	0.06	0.06	0.40	0.40	0.40	0.06	0.06	0.61	0.82	1.00

[a] These factors assume discard mortality at half the nominal F rate for age-2 and older fish caught by commercial gear and at 15% of the nominal F rate for all undersized fish caught by anglers (CT DEP estimates; P. Howell, Old Lyme, CT, pers. comm.).
[b] The notation 5+ refers to fish that are age-5 and older.
[c] Based on tentative regulations proposed for implementation by the DEP.

mortality rate of 50% for undersized fish. Estimates for fish taken by the sport fishery (40% of the total) remained unchanged from NUSCO (1992a). The values of F were stepped up from 0.40 in the 1960s to a peak of 0.91 in 1991 (Fig. 5-1), which reflected the recent

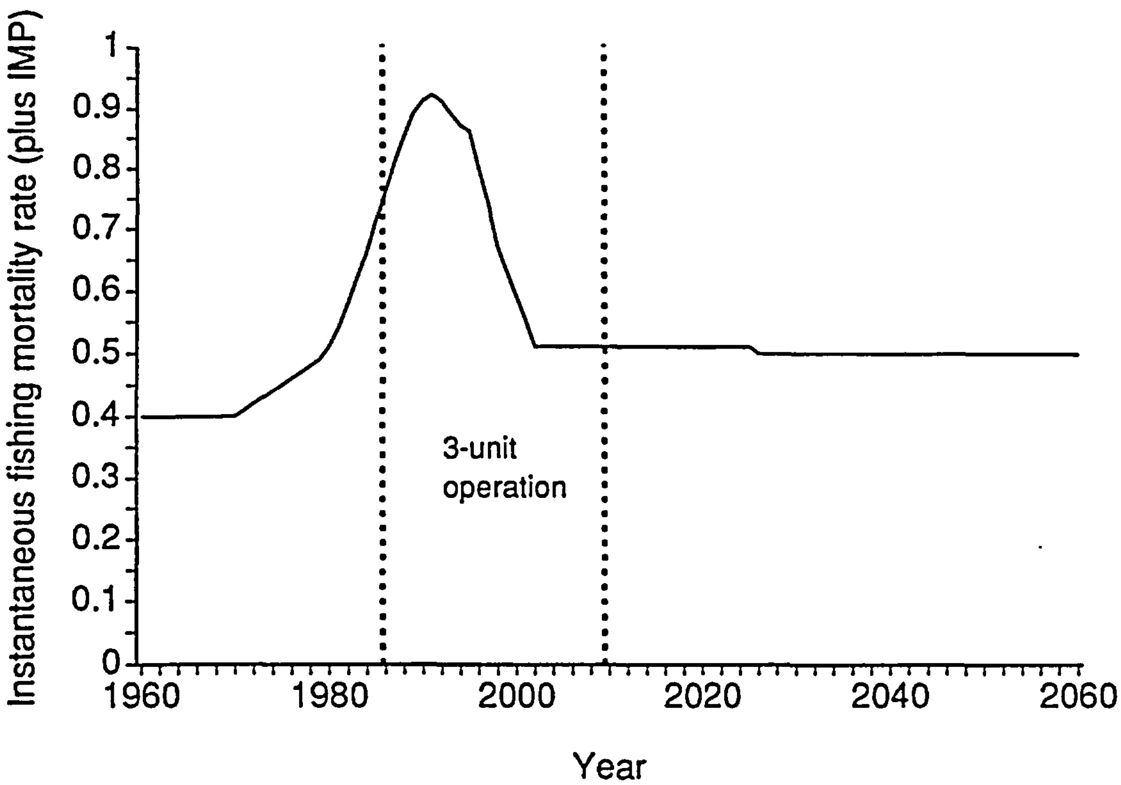


Fig. 5-1. Historic and projected annual mortality rate due to fishing (F) plus a small (0.01) component accounting for impingement mortality (IMP) at MNPS as implemented in the SPDM simulations.

historical increase in fishing and the current high exploitation of winter flounder. Values of F were then reduced to meet a targeted rate of 0.66 in 1998. Although the Atlantic States Marine Fisheries Commission management plan for inshore stocks of winter flounder (Howell et al. 1992) calls for a further reduction in F to about 0.43 during the next decade, a perhaps more realistically attainable value of 0.50 was used in the simulations on the basis of consultations with DEP staff (V. Crecco and P. Howell, DEP Division of Marine Fisheries, Old Lyme, CT, pers. comm.). The effect of the changing fishing rates on partially vulnerable fish is seen in **Figure 5-2**. As a result of more protective regulations, the effect of commercial fishing on ages-1 and 2 has been or will be greatly diminished and many age-3 and 4 fish should be protected as well.

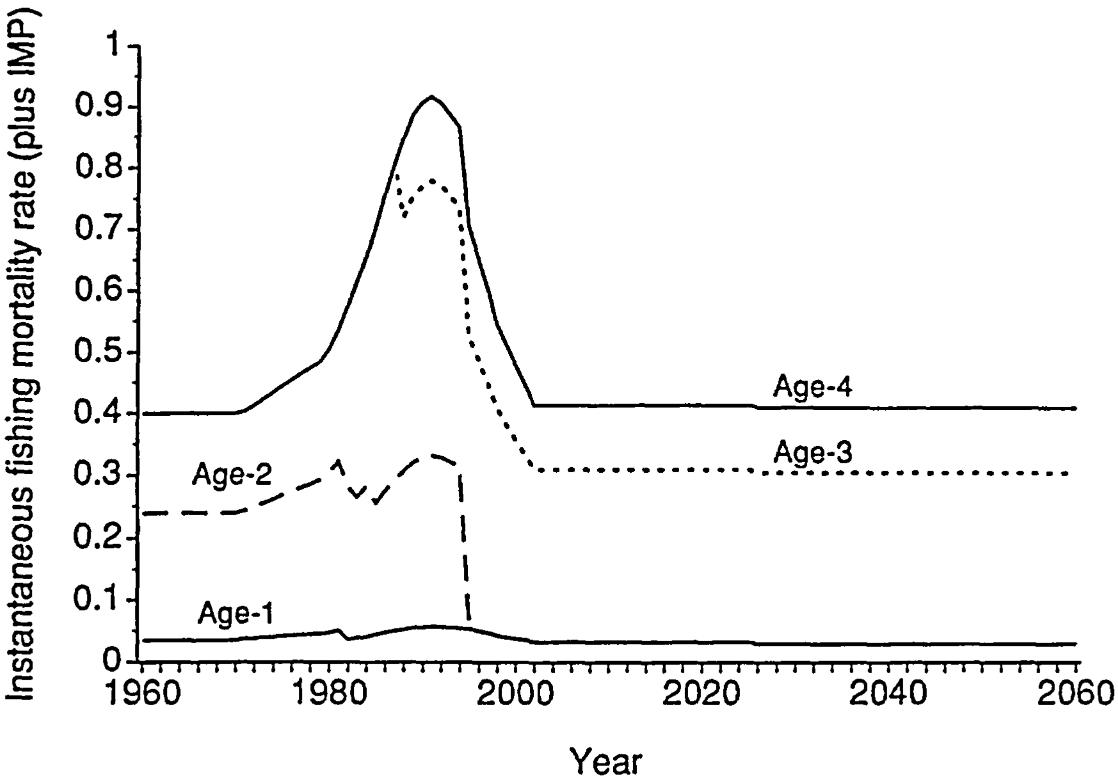


Fig. 5-2. Estimated reductions in F (plus IMP) for age-1 through 4 winter flounder as a result of actual or planned regulations imposed by the CT DEP on the commercial fishery.

The derivation of the equivalent mortality rate IMP was given in NUSCO (1992a) and is an additional small (0.01) component of mortality added to F during the years of MNPS operation. Other data, rates, and inputs to the SPDM are summarized on **Table 5-5** and remain the same as given to DEP in NUSCO (1992b). Among these are the number of age-classes, age-specific rates of maturation, natural mortality, average weight and fecundity at age, the three-parameter SRR estimates, and specifics of the simulations.

A complete simulation consists of several model runs, which provide a set of time-series generated under the same scenario, but with different combinations of F (plus IMP) and ENT. The time-series with fishing plus impingement and plant effects (measured historical entrainment rates through 1991 and maximum nominal entrainment values through 2025) was

TABLE 5-5. Data, rates, and other inputs used with the Niantic River winter flounder population dynamics simulation model.

Model input	Value used or available		
Number of age-classes in population	15		
Earliest age at which all females are mature	6		
Fraction mature, mean wt (lbs), and mean fecundity by age:			
Age-1 females	0	0.011	0
Age-2 females	0	0.125	0
Age-3 females	0.08	0.554	223,735
Age-4 females	0.36	0.811	378,584
Age-5 females	0.92	1.089	568,243
Age-6 females	1.00	1.377	785,897
Age-7 females	1.00	1.645	1,004,776
Age-8 females	1.00	1.873	1,201,125
Age-9 females	1.00	2.057	1,366,951
Age-10 females	1.00	2.203	1,502,557
Age-11 females	1.00	2.304	1,598,597
Age-12 females	1.00	2.390	1,682,208
Age-13 females	1.00	2.461	1,754,800
Age-14 females	1.00	2.516	1,809,000
Age-15 females	1.00	2.552	1,845,800
Age after which annual mortality is constant	3		
Instantaneous mortality rates M and F at age-1	0.50	0 [a]	
Instantaneous mortality rates M and F at age-2	0.35	0	
Instantaneous mortality rates M and F at age-3+	0.35	0	
Initial number of female spawners	76,500[b]		
Mean fecundity of the stock (eggs per female spawner)	871,000[b]		
Ricker's α for the unfished stock	3.74[c]		
β from Ricker's three-parameter SRR	2.466×10^{-5}		
ϕ from Ricker's three-parameter SRR	0.264		
Mean February (1977-87) water temperature (°C)	2.39		
standard deviation	1.17		
minimum temperature	0.36		
maximum temperature	4.02		
Number of spawning cycles (years) to simulate	100		
Number of simulation replicates per run	100		
Fraction of age-0 group entrained at MNPS (i.e., impact)	0.00[d]		

[a] Values are entered here only when mortalities remain constant during all the spawning cycles or years simulated. Zero values direct the model to get a detailed schedule of mortalities from an auxiliary input file set up as a look-up table (see Table 5-6).
[b] Corresponds to the unfished stock at equilibrium.
[c] In units of biomass (lbs); indirectly calculated from life history parameters (see text).
[d] A zero simulates a non-impacted stock; otherwise the conditional mortality due to entrainment is used.

the reference series against which the reductions due to mitigation of entrainment were evaluated; this baseline time-series represented the most likely trajectory of the exploited stock without mitigation of MNPS entrainment rates. Time-series representing the expected stock trajectories corresponding to various reductions (10, 20, 25, and 50%) in present rates of ENT were the mitigation series (Fig. 5-3). These series reflected the effect of projected reductions in entrainment as a result of selected methods of mitigation that are given elsewhere in this report. Conservatively, these reductions in entrainment mortality were simulated to go into effect in 1993, as per NUSCO (1992b). The equivalent instantaneous mortality rates corresponding to ENT for the baseline condition and for the four reductions due to mitigation for 1993-2026 are shown in **Figure 5-4** along with the rates of F + IMP for the same period.

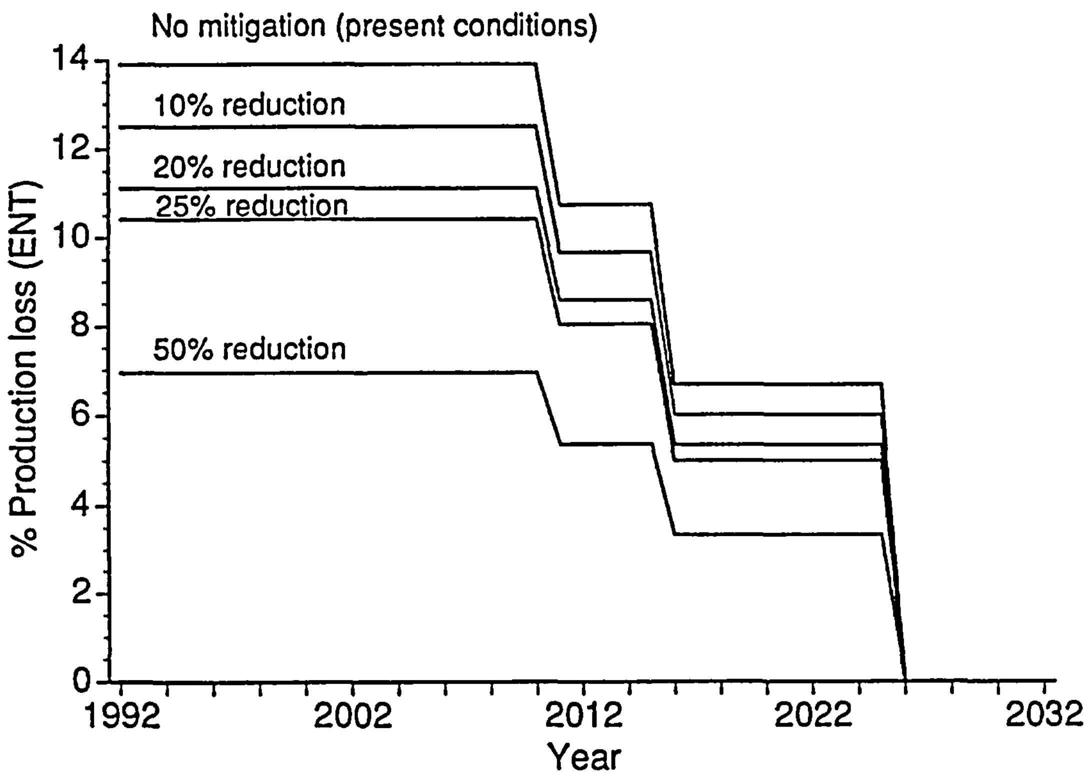


Fig. 5-3. Projected annual production loss (ENT) of Niantic River winter flounder entrained at MNPS under present and expected future MNPS operation without mitigation and with simulated reductions of 10, 20, 25, and 50%.

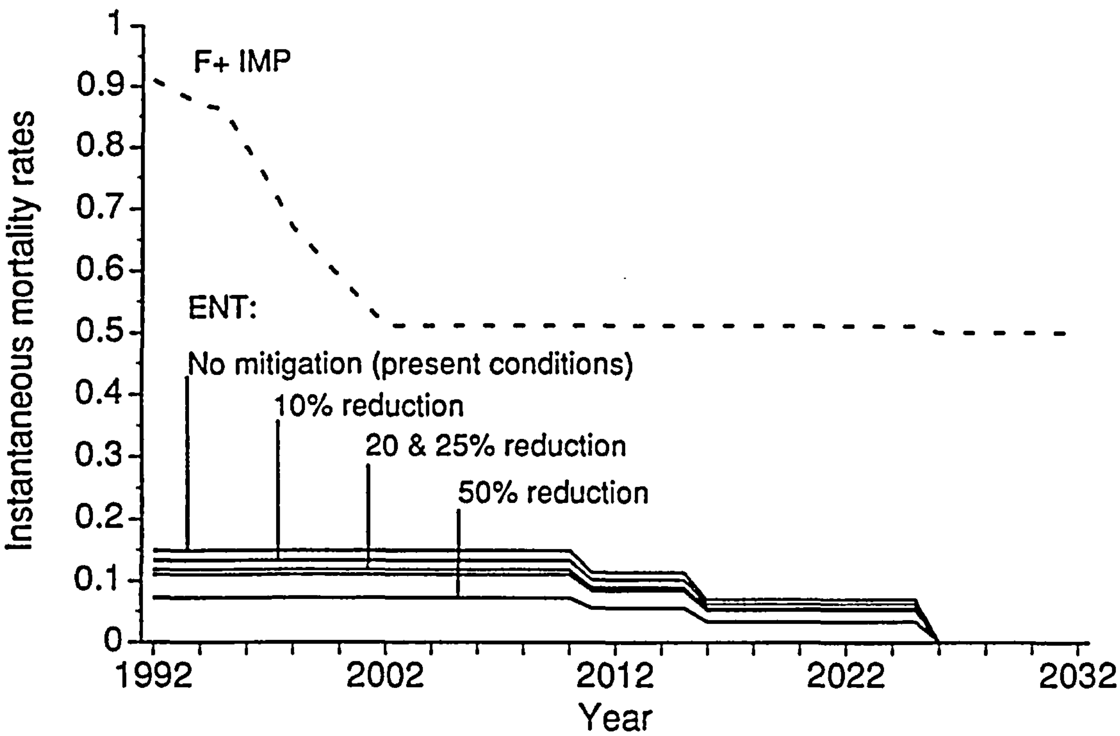


Fig. 5-4. Projected annual mortality rates due to both fishing with impingement (F + IMP) and larval entrainment at MNPS (ENT) as implemented in SPDM simulations. The values for ENT are illustrated for expected future operation without mitigation and with simulated reductions of 10, 20, 25, and 50%.

5.4 ASSESSMENT OF MNPS ENTRAINMENT MITIGATION

5.4.1 SIMULATION RESULTS

The stochastic baseline generated to assess the effectiveness of various levels of mitigation describes the stock variability of Niantic River winter flounder since 1960 and includes fishing, impingement, and currently estimated effects of entrainment at MNPS. This stock projection was used as a standard against which were compared projections that included reductions in entrainment from mitigation. The baseline for Niantic River female winter flounder abundance differs considerably from the one given in NUSCO (1992a) because it not only included plant effects, but much higher initial rates of fishing mortality than those used in

0001- 0001868

the previous simulations (**Table 5-6, Fig. 5-1** of this report; Appendix XIV, Fig. 7 of NUSCO 1992a). According to the simulation schedule (**Table 5-6**), nominal fishing rates started at F = 0.40, remained unchanged through the 1960s, and increased steadily to a maximum rate of 0.91 (subtracting the additional component of 0.01 for IMP) in 1991. Values of F were determined after consultation with DEP Marine Fisheries (V. Crecco and P. Howell, pers. comm.). Impingement mortality was implemented as an equivalent instantaneous mortality rate that was held constant throughout the MNPS operational period (1971-2025). As a result of proposed regulatory changes to the commercial fishery, F was projected to decrease more rapidly through the 1990s to 0.50 in 2002 to remain at that level throughout the rest of the simulation time period. The initial virgin stock size used to start the simulation was about 111,400 lbs (approximately 76,800 female spawners) and the stochastic mean size of the exploited stock by 1960 (under the starting nominal fishing rate of F = 0.40) was about 54,000 lbs (the solid line in **Figs. 5-5 and 5-6**). The simulated baseline responded as expected to the steep increase in fishing mortality by steadily declining to about 22,500 lbs in 1991 and 1992. This level is less than 20% of the initial (unfished) biomass. This reduction in biomass meets the criterion of Howell et al. (1992) for overfishing (stocks reduced to less than 25% of the unfished biomass). If fishing rates remain at levels greater than $F_{0.25}$, then the maintenance of the stock is questionable and spawning stock size may decline further (Howell et al. 1992). Due to variation in the simulations (**Fig. 5-5**), some replicate values showed the stock decreasing to about 15,000 lbs, which is as little as 13% of the unfished female spawning biomass, or MSP (maximum spawning potential) as defined by the Atlantic States Marine Fisheries Commission (Howell et al. 1992).

The simulated stock recovered rapidly beginning in the late 1990s (**Fig. 5-6**), due mainly to the proposed changes in regulations for the commercial fishery. These regulation changes considerably reduced mortality of age-2 and older fish (**Figs. 5-1 and 5-2; Table 5-6**). It was apparent that a reduction in fishing was driving the recovery of the female Niantic River female spawning stock, rather than the concurrent entrainment mitigation. By the time mitigation became effective, the stock was at its peak and no longer overfished nor subjected to a higher probability of collapse. This was expected because the most important difference between fishing with impingement and larval entrainment is that larval entrainment reduces the year-class only once in the early life history of a fish, whereas fishing and impingement remove individuals from each age group every year as long as any fish remain alive.

TABLE 5-6. Schedule of entrainment, and impingement plus fishing mortalities with adjustments for discard mortality, as implemented in the simulation.

Time step	Simulation year	% of year-class reduction based on calculated or theoretical maximum levels of ENT[a]	Nominal F	Fractional F for : Age-1	Age-2	Age-3	Age-4
0	1960	0.000	0.40	0.0360	0.2400	0.4000	0.4000
1	1961	0.000	0.40	0.0360	0.2400	0.400	0.4000
2	1962	0.000	0.40	0.0360	0.2400	0.4000	0.4000
3	1963	0.000	0.40	0.0360	0.2400	0.4000	0.4000
4	1964	0.000	0.40	0.0360	0.2400	0.4000	0.4000
5	1965	0.000	0.40	0.0360	0.2400	0.4000	0.4000
6	1966	0.000	0.40	0.0360	0.2400	0.4000	0.4000
7	1967	0.000	0.40	0.0360	0.2400	0.4000	0.4000
8	1968	0.000	0.40	0.0360	0.2400	0.4000	0.4000
9	1969	0.000	0.40	0.0360	0.2400	0.4000	0.4000
10	1970	0.000	0.40	0.0360	0.2400	0.4000	0.4000
11	1971	2.127	0.41	0.0390	0.2440	0.4040	0.4040
12	1972	3.141	0.42	0.0399	0.2500	0.4140	0.4140
13	1973	1.070	0.43	0.0408	0.2560	0.4240	0.4240
14	1974	2.263	0.44	0.0417	0.2620	0.4340	0.4340
15	1975	3.141	0.45	0.0426	0.2680	0.4440	0.4440
16	1976	5.580	0.46	0.0435	0.2740	0.4540	0.4540
17	1977	5.643	0.47	0.0444	0.2800	0.4640	0.4640
18	1978	3.934	0.48	0.0453	0.2860	0.4740	0.4740
19	1979	4.184	0.49	0.0462	0.2920	0.4840	0.4840
20	1980	6.422	0.51	0.0480	0.3040	0.5040	0.5040
21	1981	3.836	0.54	0.0507	0.3220	0.5340	0.5340
22	1982	6.477	0.58	0.0372	0.2822	0.5740	0.5740
23	1983	6.227	0.62	0.0396	0.2651	0.6140	0.6140
24	1984	5.365	0.66	0.0420	0.2822	0.6540	0.6540
25	1985	4.782	0.71	0.0450	0.2560	0.7040	0.7040
26	1986	12.302	0.76	0.0480	0.2740	0.7540	0.7540
27	1987	12.218	0.81	0.0510	0.2920	0.8040	0.8040
28	1988	12.663	0.85	0.0534	0.3064	0.7180	0.8440
29	1989	9.716	0.89	0.0558	0.3208	0.7520	0.8840
30	1990	11.815	0.91	0.0570	0.3280	0.7690	0.9040
31	1991	8.827	0.92	0.0576	0.3316	0.7775	0.9140
32	1992	13.900	0.91	0.0570	0.3280	0.7690	0.9040
33	1993	13.900	0.89	0.0558	0.3208	0.7520	0.8840
34	1994	13.900	0.87	0.0546	0.3136	0.7350	0.8640
35	1995	13.900	0.86	0.0540	0.0550	0.5225	0.7010
36	1996	13.900	0.80	0.0504	0.0514	0.4859	0.6518
37	1997	13.900	0.74	0.0468	0.0478	0.4493	0.6026
38	1998	13.900	0.67	0.0426	0.0436	0.4066	0.5452
39	1999	13.900	0.63	0.0402	0.0412	0.3822	0.5124
40	2000	13.900	0.59	0.0378	0.0388	0.3578	0.4796
41	2001	13.900	0.55	0.0354	0.0364	0.3334	0.4468
42	2002	13.900	0.51	0.0420	0.0340	0.3090	0.4140
43	2003	13.900	0.51	0.0330	0.0340	0.3090	0.4140
44	2004	13.900	0.51	0.0330	0.0340	0.3090	0.4140
45	2005	13.900	0.51	0.0330	0.0340	0.3090	0.4140
46	2006	13.900	0.51	0.0330	0.0340	0.3090	0.4140
47	2007	13.900	0.51	0.0330	0.0340	0.3090	0.4140
48	2008	13.900	0.51	0.0330	0.0340	0.3090	0.4140
49	2009	13.900	0.51	0.0330	0.0340	0.3090	0.4140
50	2010	13.900	0.51	0.0330	0.0340	0.3090	0.4140
51	2011	10.745	0.51	0.0330	0.0340	0.3090	0.4140

TABLE 5-6. (continued).

Time step	Simulation year	% of year-class reduction based on calculated or theoretical maximum levels of ENT[a]	Nominal F	Fractional F for : Age-1	Age-2	Age-3	Age-4
52	2012	10.745	0.51	0.0330	0.0340	0.3090	0.4140
53	2013	10.745	0.51	0.0330	0.0340	0.3090	0.4140
54	2014	10.745	0.51	0.0330	0.0340	0.3090	0.4140
55	2015	10.745	0.51	0.0330	0.0340	0.3090	0.4140
56	2016	6.686	0.51	0.0330	0.0340	0.3090	0.4140
57	2017	6.686	0.51	0.0330	0.0340	0.3090	0.4140
58	2018	6.686	0.51	0.0330	0.0340	0.3090	0.4140
59	2019	6.686	0.51	0.0330	0.0340	0.3090	0.4140
60	2020	6.686	0.51	0.0330	0.0340	0.3090	0.4140
61	2021	6.686	0.51	0.0330	0.0340	0.3090	0.4140
62	2022	6.686	0.51	0.0330	0.0340	0.3090	0.4140
63	2023	6.686	0.51	0.0330	0.0340	0.3090	0.4140
64	2024	6.686	0.51	0.0330	0.0340	0.3090	0.4140
65	2025	6.686	0.51	0.0330	0.0340	0.3090	0.4140
66	2026	0.000	0.50	0.0300	0.0300	0.3050	0.4100
67	2027	0.000	0.50	0.0300	0.0300	0.3050	0.4100
68	2028	0.000	0.50	0.0300	0.0300	0.3050	0.4100
69	2029	0.000	0.50	0.0300	0.0300	0.3050	0.4100
70	2030	0.000	0.50	0.0300	0.0300	0.3050	0.4100
71	2031	0.000	0.50	0.0300	0.0300	0.3050	0.4100
72	2032	0.000	0.50	0.0300	0.0300	0.3050	0.4100
73	2033	0.000	0.50	0.0300	0.0300	0.3050	0.4100
74	2034	0.000	0.50	0.0300	0.0300	0.3050	0.4100
75	2035	0.000	0.50	0.0300	0.0300	0.3050	0.4100
76	2036	0.000	0.50	0.0300	0.0300	0.3050	0.4100
77	2037	0.000	0.50	0.0300	0.0300	0.3050	0.4100
78	2038	0.000	0.50	0.0300	0.0300	0.3050	0.4100
79	2039	0.000	0.50	0.0300	0.0300	0.3050	0.4100
80	2040	0.000	0.50	0.0300	0.0300	0.3050	0.4100
81	2041	0.000	0.50	0.0300	0.0300	0.3050	0.4100
82	2042	0.000	0.50	0.0300	0.0300	0.3050	0.4100
83	2043	0.000	0.50	0.0300	0.0300	0.3050	0.4100
84	2044	0.000	0.50	0.0300	0.0300	0.3050	0.4100
85	2045	0.000	0.50	0.0300	0.0300	0.3050	0.4100
86	2046	0.000	0.50	0.0300	0.0300	0.3050	0.4100
87	2047	0.000	0.50	0.0300	0.0300	0.3050	0.4100
88	2048	0.000	0.50	0.0300	0.0300	0.3050	0.4100
89	2049	0.000	0.50	0.0300	0.0300	0.3050	0.4100
90	2050	0.000	0.50	0.0300	0.0300	0.3050	0.4100
91	2051	0.000	0.50	0.0300	0.0300	0.3050	0.4100
92	2052	0.000	0.50	0.0300	0.0300	0.3050	0.4100
93	2053	0.000	0.50	0.0300	0.0300	0.3050	0.4100
94	2054	0.000	0.50	0.0300	0.0300	0.3050	0.4100
95	2055	0.000	0.50	0.0300	0.0300	0.3050	0.4100
96	2056	0.000	0.50	0.0300	0.0300	0.3050	0.4100
97	2057	0.000	0.50	0.0300	0.0300	0.3050	0.4100
98	2058	0.000	0.50	0.0300	0.0300	0.3050	0.4100
99	2059	0.000	0.50	0.0300	0.0300	0.3050	0.4100
100	2060	0.000	0.50	0.0300	0.0300	0.3050	0.4100

[a] Values for 1971-91 based on actual percentage of nominal flow at MNPS applied to the 13.9% of year-class reduction due to larval entrainment. Values for 1992-2025 will be simulated by using the level of larval entrainment given for each year in Column 3 of this table.

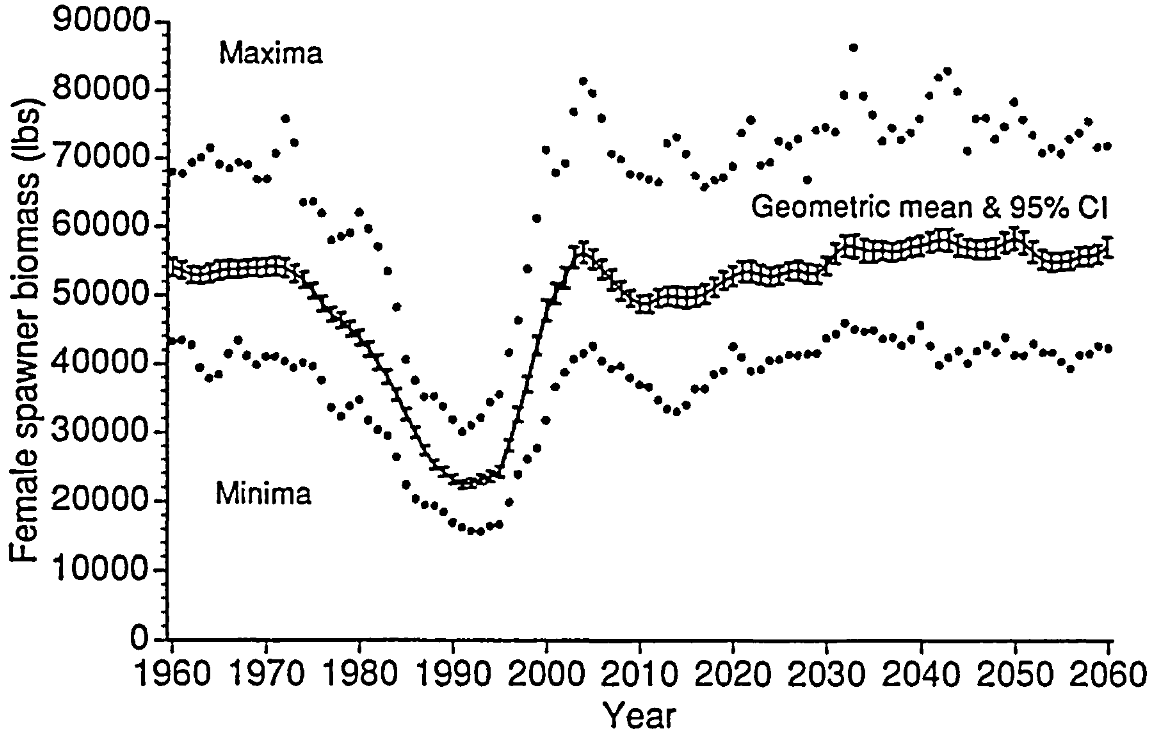


Fig. 5-5. Stochastic variability associated with the projected Niantic River female winter flounder stock expressed as biomass (lbs) for the combined effects of fishing with impingement (F + IMP) and calculated larval entrainment rates (ENT) without simulated mitigation (the baseline illustrated on Figure 5-6). The solid line represents the geometric mean and 95% confidence interval (100 Monte Carlo replications) of the stock size trajectory. The symbols above and below the line correspond to the largest and smallest stocks among the 100 replicates generated for each year.

The dashed lines shown in **Figure 5-6** represent the increased biomass resulting from the simulated implementation of mitigation (10, 20, 25 and 50% reduction in calculated entrainment rates). The section of the figure from the years 2000 to 2035, which is the effective period of mitigation, is shown in greater detail on **Figure 5-7**. Increases in biomass as a result of entrainment mitigation were relatively modest in comparison to gains resulting from reductions in F. As shown on **Figure 5-7**, increases were fairly proportional to the reductions in the projected rate of ENT and gains in biomass became indistinguishable from the baseline about 7 years after the end of MNPS operation in 2025. The maximum gain occurred

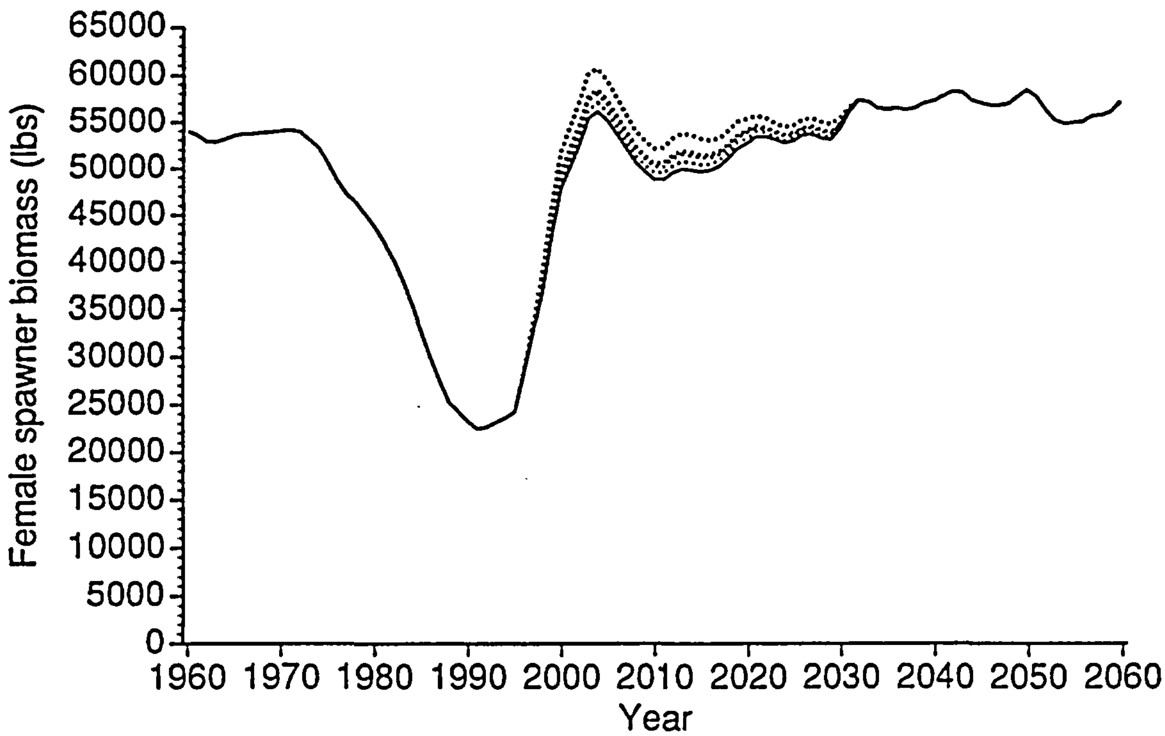


Fig. 5-6. Results of the SPDM simulations showing the combined effects of fishing with impingement (F + IMP) and calculated larval entrainment rates (ENT) without mitigation (baseline; lowermost solid line) on the biomass (lbs) of Niantic River winter flounder female spawners. The dashed lines from bottom to top represent increases in biomass resulting from various simulated methods of mitigation that would reduce ENT by 10, 20, 25, and 50%, respectively. All stock sizes are averages of 100 Monte Carlo replicates.

in 2003, and ranged from about 949 lbs for a 10% reduction in current entrainment to 4,673 lbs for a 50% reduction from mitigation (**Fig. 5-8**). On a percentage basis (**Fig. 5-9**), biomass increases from 1.7% (10% reduction in ENT) to 8.6% (50% reduction). Increases become proportionately smaller after initiation of entrainment mitigation and in the absence of further reductions in fishing.

The baseline and projected increases in biomass shown on **Figures 5-6 through 5-8** are summarized in **Table 5-7**. Mean annual increases in female spawning stock biomass during the 40-year period of effective entrainment mitigation were about 515 lbs for a 10% reduction

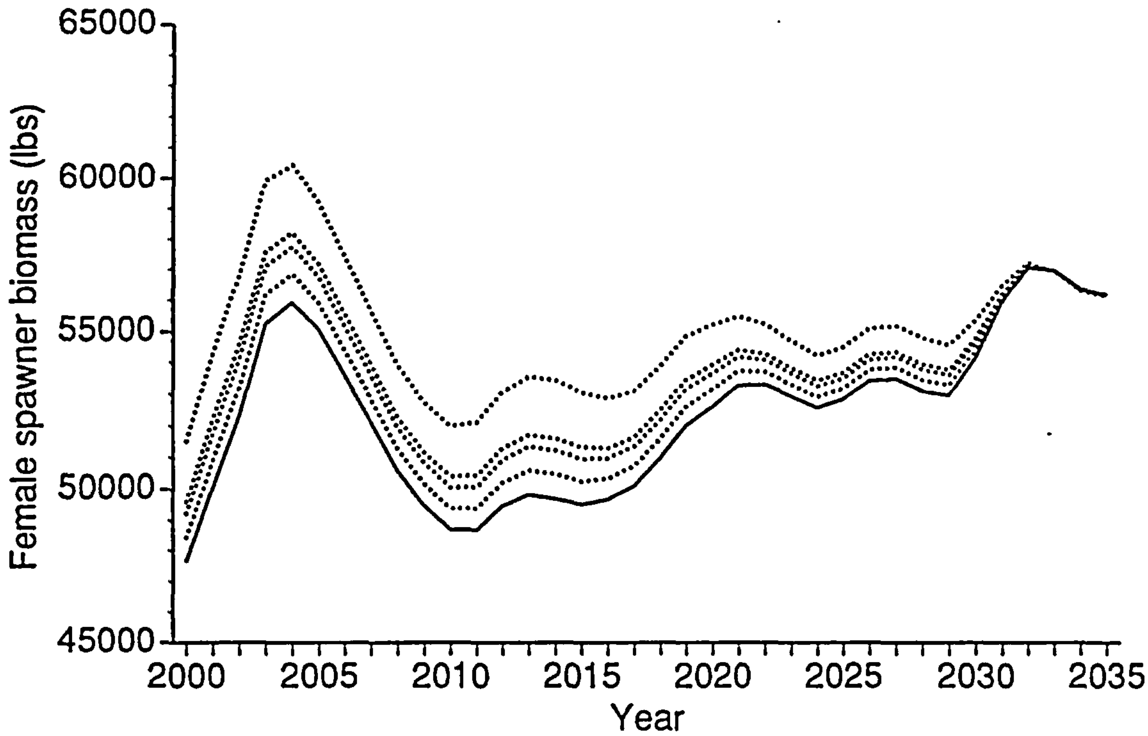


Fig. 5-7. Results (from Figure 5-6) of the SPDM simulations for the years 2000 to 2035 illustrating the largest increases in the biomass (lbs) of Niantic River female winter flounder from the mitigation of larval entrainment at MNPS. The lowermost solid line is the baseline (F + IMP + current ENT) and the dashed lines from bottom to top represent increases in biomass resulting from selected methods of mitigation that would reduce ENT by 10, 20, 25, and 50%, respectively. All stock sizes are averages of 100 Monte Carlo replicates.

in ENT, 1,023 lbs for 20%, 1,274 lbs for 25%, and 2,507 lbs for a 50% reduction. The cumulative gain in biomass for this period ranged from 20,587 to 100,289 lbs. Although these may seem to be significant increases, as shown on **Figure** 5-9 they represent only modest annual (≤ 8.6%) gains in spawning stock biomass.

The simulated mean annual increase in female spawner biomass given above in Table 5-7 that ranged from about 515 to 2,507 lbs, depending upon the level of mitigation, may be compared to recently reported winter flounder landings (Table 5-8). Although the sources of information and geographical areas considered differ for these data, the average annual increases in biomass would likely be a small fraction (< 0.25%) of the combined Connecticut sport and commercial fishing landings. This is because, on average, the Niantic River stock accounts for less than 5% of the Connecticut winter flounder resource (NUSCO 1989). Note that the simulated gains in biomass represent a net increase for the Niantic River stock, as fishing occurred concurrently with entrainment in the model simulations.

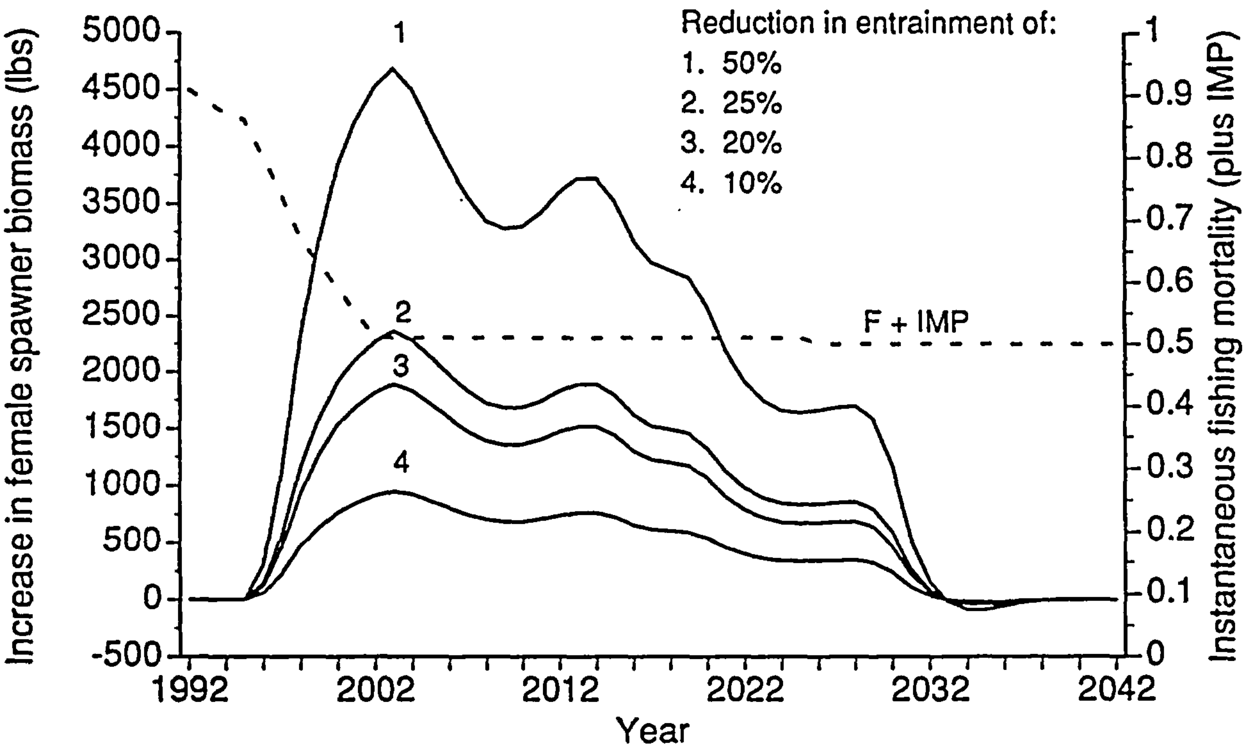


Fig. 5-8. Absolute increase (lbs) in Niantic River female winter flounder spawner biomass resulting from selected methods of mitigation of larval entrainment that would reduce ENT by 10, 20, 25, and 50%. The projected reduction in the annual mortality rate due to fishing (F) plus a small (0.01) component accounting for impingement mortality (IMP) at MNPS is also shown.

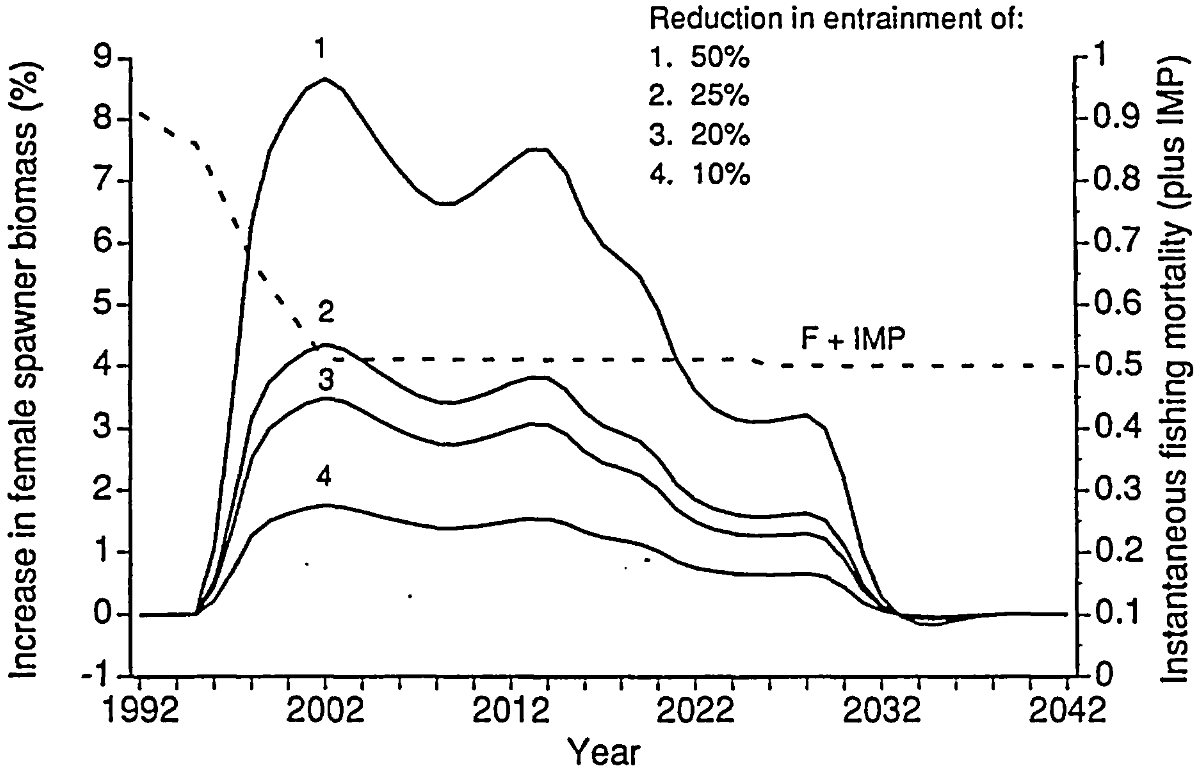


Fig. 5-9. Increased percentage of Niantic River female winter flounder spawner biomass resulting from selected methods of mitigation of larval entrainment that would reduce ENT by 10, 20, 25, and 50%. The projected reduction in the annual mortality rate due to fishing (F) plus a small (0.01) component accounting for impingement mortality (IMP) at MNPS is also shown.

5.4.2 PROBABILISTIC RISK ASSESSMENT (PRA) OF MNPS EFFECTS

Stochastic variability associated with stock projections for combined fishing, impingement, and larval entrainment (**Fig. 5-5**) forms the basis for probabilistic analyses, which take into account not only the mean stock biomass predicted for each year, but also the range of predictions both smaller and larger than the mean. PRA of stock projections were made for six selected points in time (**Table 5-9**). These include 1993, when stock biomass was near its lowest level and entrainment mitigation was simulated to go into effect; 1998, about midway during the period when F was being rapidly reduced; 2003, when gains in biomass were largest; 2013, near the midpoint of entrainment mitigation effects and 12 years after F was reduced to 0.5; 2023, near the end of MNPS operation; and 2033, just after the effective end of MNPS

TABLE 5-7. Projected increases in spawning stock biomass (lbs) of Niantic River female winter flounder without mitigation (i.e. full larval entrainment at MNPS) and with four different levels of entrainment reduction. These projections assume that mitigation begins in 1993 and that concurrent reductions in fishing mortality (F) proposed by the CT DEP and shown below take place as expected.

Year	Nominal F[a]	Stock size (lbs) under full entrainment and F[b]	Gain in biomass (lbs) from a reduction (%) in entrainment mortality due to mitigation: 10%	20%	25%	50%
1993	0.89	23121.4	0.0	0.0	0.0	0.0
1994	0.87	23557.3	0.0	0.0	0.0	0.0
1995	0.86	24234.4	0.0	0.0	0.0	0.0
1996	0.80	28109.8	59.9	119.7	149.6	299.1
1997	0.74	32543.3	227.0	454.0	567.5	1134.8
1998	0.67	36989.6	464.7	929.4	1161.7	2323.4
1999	0.63	42549.1	634.9	1269.9	1587.4	3175.4
2000	0.59	47644.0	766.1	1532.4	1915.7	3832.6
2001	0.55	50056.7	847.9	1695.6	2119.3	4236.5
2002	0.51	52302.1	909.3	1816.1	2268.4	4519.7
2003	0.51	55233.0	949.0	1891.3	2359.8	4673.3
2004	0.51	55925.0	920.3	1829.7	2280.3	4490.7
2005	0.51	55041.0	860.6	1707.0	2124.8	4160.0
2006	0.51	53587.5	799.3	1582.5	1968.0	3835.4
2007	0.51	52106.4	744.2	1471.7	1829.2	3555.1
2008	0.51	50565.2	700.6	1385.1	1721.4	3345.1
2009	0.51	49486.0	683.1	1351.7	1680.5	3273.5
2010	0.51	48700.6	685.1	1357.3	1688.7	3301.0
2011	0.51	48684.6	705.6	1399.6	1742.5	3417.4
2012	0.51	49460.7	739.3	1467.9	1828.4	3595.0
2013	0.51	49824.4	764.4	1518.6	1892.1	3725.2
2014	0.51	49704.8	763.6	1517.1	1890.3	3722.3
2015	0.51	49528.8	724.0	1438.0	1791.2	3522.7
2016	0.51	49677.0	656.5	1302.3	1621.4	3180.0
2017	0.51	50119.5	616.9	1222.7	1521.4	2976.3
2018	0.51	50992.2	603.9	1196.1	1488.0	2906.9
2019	0.51	52005.8	589.5	1167.7	1452.6	2837.6
2020	0.51	52605.7	537.6	1064.7	1324.5	2587.8
2021	0.51	53290.9	454.3	899.5	1118.8	2184.3
2022	0.51	53296.1	399.0	789.9	982.4	1918.4
2023	0.51	52496.3	363.9	720.8	896.6	1752.6
2024	0.51	52584.5	343.0	680.0	846.4	1658.1
2025[c]	0.51	52852.3	336.7	668.5	832.6	1637.2
2026	0.50	53430.0	339.8	675.7	842.3	1662.5
2027	0.50	53501.5	343.7	684.4	853.7	1689.6
2028	0.50	53094.7	345.0	687.5	857.9	1700.7
2029	0.50	52967.7	320.4	638.6	796.8	1580.0
2030	0.50	54159.6	240.4	478.6	596.9	1180.9
2031	0.50	55939.1	111.4	220.7	274.6	536.8
2032[d]	0.50	57067.1	35.6	69.2	85.2	158.5
Mean annual increase in biomass (lbs)			514.7	1022.5	1274.0	2507.2
Cumulative total increase (lbs)			20586.5	40901.5	50958.9	100289.4

[a] Instantaneous rate of fishing mortality plus a small (0.01) component to account for impingement mortality.
[b] Female spawner biomass simulated under given rates of fishing and currently estimated rate of entrainment mortality without mitigation (baseline conditions for this study; see Figure 5-6).
[c] Last year of MNPS operation.
[d] Last year that a reduction in entrainment mortality from mitigation would appreciably affect female stock biomass.

TABLE 5-8. Recently reported Connecticut and Long Island Sound sport and commercial fishing landings (lbs) of winter flounder.

Year	Connecticut landings Commercial[a]	Connecticut landings Sport[a]	Long Island Sound Commercial[a]	Long Island Sound Sport[b]	Eastern Connecticut commercial[c]
1979	749,000	1,669,000	-	-	569,000
1980	491,000	2,204,000	-	-	355,000
1981	568,000	862,000	102,000	-	418,000
1982	425,000	1,618,000	167,000	-	322,000
1983	876,000	829,000	455,000	-	586,000
1984	678,000	849,000	522,000	581,000	649,000
1985	722,000	942,000	601,000	408,000	664,000
1986	670,000	880,000	-	118,000	468,000
1987	618,000	741,000	-	796,000	462,000
1988	515,000	-	-	1,271,000	354,000
1989	-	-	-	710,000	-

[a] Reported in Simpson et al. (1990).
[b] Reported in MacLeod (1990, 1991).
[c] Reported in NUSCO (1989), from CT DEP (unpublished landings data) for DEP statistical areas 1, 6, and 7 (eastern Long Island and Block Island Sounds).

entrainment mitigation. Because mitigation had not yet affected spawning biomass, values for 1993 remained the same under all conditions of entrainment. The analysis indicated that the spawning stock biomass of Niantic River winter flounder would almost certainly ($p = 0.94$) be less than 25% of the unfished, maximum biomass. At this low level of stock abundance, possible recruitment failure becomes a concern (Howell et al. 1992). However, once F was reduced according to the simulation schedule, the probability of low (< 25% of initial biomass) stock levels quickly .ell to 0.02. This occurred under all simulation scenarios, including when larval entrainment continued at present levels, as well as when reductions in entrainment from 10 to 50% were implemented. The probability of critically low stock biomass decreased to zero for all other years, regardless of the magnitude in larval entrainment reduction. As stated previously, the increase in biomass over the years simulated is mostly due to the reduction in fishing mortality, which allowed for a rapid recovery of the Niantic River spawning stock. Furthermore, the gain in biomass from even the largest (50%) reduction in entrainment was relatively small (≤ 8.6%). Given the inherent variability in Niantic River adult female winter flounder from year to year (CV of 51% for egg production of Niantic River female winter flounder reported in NUSCO 1992a, which is a surrogate for biomass), it is unlikely that an increase in stock size of this magnitude could be statistically detected by sampling Niantic River winter flounder abundance.

TABLE 5-9. The mean, minimum, and maximum spawning stock biomass (lbs) of Niantic River female winter flounder at selected years during the SPDM simulations for the baseline without mitigation (i.e. full larval entrainment at MNPS) and with four different levels of entrainment reduction. These projections assume that mitigation begins in 1993 and that concurrent reductions in fishing mortality proposed by the CT DEP take place as planned. The criterion of Howell et al. (1992) that the stock size should not fall below 25% of maximum biomass of female spawners was used to assess the risk of recruitment failure. The statistics and probabilities were based on 100 Monte Carlo replicates of the simulations.

Condition	Year	Female spawner biomass (lbs): Mean	Minimum	Maximum	Probability that the stock would fall to <25% of the maximum biomass
Baseline[a]	1993	23,335	15,666	32,048	0.94
	1998	37,370	26,107	53,588	0.02
	2003	55,686	40,708	76,578	0.00
	2013	50,195	33,456	72,011	0.00
	2023	53,320	39,220	68,903	0.00
	2033	57,523	45,055	86,708	0.00
10% reduction in ENT	1993	23,335	15,666	32,048	0.94
	1998	37,840	26,421	54,287	0.02
	2003	56,641	41,463	77,747	0.00
	2013	50,967	33,901	73,107	0.00
	2023	53,685	39,535	69,363	0.00
	2033	57,521	45,082	85,970	0.00
20% reduction in ENT	1993	23,335	15,666	32,048	0.94
	1998	38,311	26,736	54,986	0.02
	2003	57,588	42,215	78,900	0.00
	2013	51,729	34,340	74,190	0.00
	2023	54,043	39,844	69,836	0.00
	2033	57,517	45,107	85,861	0.00
25% reduction in ENT	1993	23,335	15,666	32,048	0.94
	1998	38,546	26,893	55,335	0.02
	2003	58,060	42,590	79,470	0.00
	2013	52,107	34,558	74,728	0.00
	2023	54,220	39,997	70,064	0.00
	2033	57,514	45,119	85,805	0.00
50% reduction in ENT	1993	23,335	15,666	32,048	0.94
	1998	39,722	27,680	57,082	0.02
	2003	60,389	44,453	82,256	0.00
	2013	53,960	35,627	77,383	0.00
	2023	55,079	40,740	71,177	0.00
	2033	57,494	45,173	85,516	0.00

[a] Combined effect of fishing mortality plus a small (0.01) component to account for impingement mortality at MNPS and calculated larval entrainment rates (ENT) at MNPS without mitigation.

5.5 REFERENCES

Boudreau, P.R., and L.M. Dickie. 1989. Biological model of production based on physiological and ecological scaling of body size. Can. J. Fish. Aquat. Sci. 46:614-623.

Crecco V.A., and P. Howell. 1990. Potential effects of current larval entrainment mortality from the Millstone Nuclear Power Station on the winter flounder, *Pseudopleuronectes americanus*, spawning population in the Niantic River. CT DEP, Bu. Fish., Spec Pub. 37 pp.

Cushing, D.H. 1971. The dependence of recruitment on parent stock in different groups of fish. J. Cons. int. Explor. Mer 33:340-362.

Cushing, D.H, and J.G.K. Harris. 1973. Stock and recruitment and the problem of density dependence. Rapp. P.-v. Reun. Cons. int. Explor. Mer 164:142-155.

Cushing, D.H, and J.W. Horwood. 1977. Development of a model of stock and recruitment. Pages 21-35 *in* J.H. Steele, ed. Fisheries mathematics. Academic Press, New York.

Garrod, D.J., and B.W. Jones. 1974. Stock and recruitment relationships in the Northeast Arctic cod stock and the implications for the management of the stock. J. Cons. int. Explor. Mer 36:35-41.

Gibson, M.R. 1989. Stock-recruitment relationships for winter flounder in the S. New England area and revised fishery reference points. Rhode Island Div. Fish Wildl., Res. Ref. Doc. 89/9. 10 pp + 5 fig.

Goodyear, C.P. 1980. Compensation in fish populations. Pages 253-280 *in* C.H. Hocutt and J.R. Stauffer, eds. Biological monitoring of fish. Lexington Books, Lexington, MA.

Goodyear, C.P, and S.W. Christensen. 1984. Bias-elimination in fish population models with stochastic variation in survival of the young. Trans. Am. Fish. Soc. 113:627-632.

Hess, K.W., M.P. Sissenwine, and S.B. Saila. 1975. Simulating the impact of entrainment of winter flounder larvae. Pages 1-30 *in* S.B. Saila, ed. Fisheries and energy production: a symposium. D.C. Heath and Co., Lexington, MA.

Hoenig, J.M., D.M. Heisey, W.D. Lawing, and H.D. Schupp. 1987. An indirect rapid methods approach to assessment. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2):324-338.

Howell, P., A. Howe, M. Gibson, and S. Ayvazian. 1992. Fishery management plan for inshore stocks of winter flounder. Fisheries management rep. no. 21 of the Atlantic States Marine Fisheries Commission. 138 pp.

Longhurst, A. 1983. Benthic-pelagic coupling and export of organic carbon from a tropical Atlantic continental shelf, Sierra Leone. Est. Coast. Shelf Sci. 17:261-285.

MacLeod, R.E. 1990. Marine angler survey. Pages 1-45 *in* A study of marine recreational fisheries in Connecticut, 1984-1988. Connecticut Department of Environmental Protection, Bureau of Fisheries and Wildlife, Division of Marine Fisheries. F54R final report.

MacLeod, R.E. 1991. Marine angler survey. Pages 1-15 *in* A study of marine fisheries in Connecticut. Connecticut Department of Environmental Protection, Bureau of Fisheries and Wildlife, Division of Marine Fisheries. F54R annual report.

NUSCO (Northeast Utilities Service Company). 1988. Winter flounder studies. Pages 149-224 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Three-unit operational studies, 1986-1987.

NUSCO. 1989. Winter flounder studies. Pages 239-316 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1988.

NUSCO. 1990. Winter flounder studies. Pages 9-77 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1989.

NUSCO. 1991. Winter flounder studies. Pages 9-86 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1990.

NUSCO. 1992a. Winter flounder studies. Pages 7-110 *in* Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station. Annual report 1991.

NUSCO. 1992b. Scope of work for cooling water alternatives feasibility study to reduce larval winter flounder entrainment. Enclosure 1 to letter D05565 dated May 29, 1992 from C.F. Sears, NUSCO, to T. Keeney, Commissioner, CT DEP.

Reed, M., M.L. Spaulding, E. Lorda, H. Walker, and S.B. Saila. 1984. Oil spill fishery impact assessment modeling: the fisheries recruitment problem. Est. Coast. Shelf Sci. 19:591-610.

Ricker, W.E. 1954. Stock and recruitment. J. Fish. Res. Board Can. 11:559-623.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191. 382 pp.

Roughgarden, J. 1979. Evolutionary ecology of single populations. Pages 295-408 *in* The theory of population genetics and evolutionary ecology: an introduction. MacMillan Publishing Company, Inc., New York.

Rubinstein, R.Y. 1981. Simulation and the Monte Carlo method. John Wiley and Sons, New York. 278 pp.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanogr. 6:292-298.

Simpson, D.G. 1989. Codend selection of winter flounder *Pseudopleuronectes americanus*. NOAA Tech. Rep. NMFS 75. 10 pp.

Simpson, D.G., P.T. Howell, and M.W. Johnson. 1990. Marine finfish survey. Pages 47-239 *in* A study of marine recreational fisheries in Connecticut. Connecticut Department of Environmental Protection, Bureau of Fisheries and Wildlife, Division of Marine Fisheries. F54R final report.

Spaulding, M.L., S.B. Saila, E. Lorda, H. Walker, E. Anderson, and J.C. Swanson. 1983. Oil-spill fishery impact assessment model: application to selected Georges Bank fish species. Est. Coast. Shelf Sci. 16:511-541.

Stuart, A., and J.K. Ord. 1987. Kendall's advanced theory of statistics. Vol. I. Distribution theory. Oxford University Press, New York. 604 pp.

Vaughan, D.S. 1981. An age structure model of yellow perch in western Lake Erie. Pages 189-216 *in* D.G. Chapman and V.F. Gallucci, eds. Quantitative population dynamics. International Co-operative Publishing House, Fairland, MD.

6

ENVIRONMENTAL AND BIOLOGICAL SUMMARY

The Niantic River population of winter flounder has been studied in detail by Northeast Utilities Service Company (NUSCO) because each year many of the larvae produced by this stock are entrained through the condenser cooling-water system of Millstone Nuclear Power Station (MNPS). The long-term effects of MNPS operation on this species has been assessed on several occasions for the Connecticut Department of Environmental Protection (DEP) and other regulatory agencies. Because of decreasing abundance of winter flounder throughout much of its range during the past decade, the DEP began increased scrutiny of winter flounder studies at MNPS in the late 1980s. A response to the increased emphasis on winter flounder was the development of the NUSCO stochastic population dynamics model (SPDM) for assessment of long-term effects of MNPS operation. The present entrainment mitigation study resulted from a meeting held in October 1991 between representatives of NUSCO and DEP regarding the feasibility of reducing entrainment. The effectiveness of various methods of mitigating entrainment mortality was to be evaluated through computer simulations using the SPDM.

Adult winter flounder spawn in Connecticut from January through April and local spawning takes place in the mid and upper Niantic River. The demersal eggs hatch in about 15 days and larval development proceeds for about 40 to 60 days through several distinct early life history stages. Total mortality rates of larvae are high and were estimated to be 82.4 to 97.9% for Niantic River winter flounder. Larvae are entrained through the MNPS cooling-water system from February through June, with more than 90% of annual entrainment occurring in April and May. Annual dates of peak larval abundance are highly correlated with water temperature and occur later in colder years. Since 1976, the largest annual entrainment estimate was 219.3 million in 1983. In a study of entrainment survival, only the oldest larvae survived passage through the MNPS condenser cooling-water system and a 96-hour holding period.

Because only a small proportion of entrained larvae are in the oldest stage of development, overall survival of entrained larvae is likely less than 1%.

The number of winter flounder larvae entrained at MNPS depends upon larval densities in Niantic Bay from which the cooling water is withdrawn. The impact of entrainment to the Niantic River stock depends upon the fraction of its annual production lost to entrainment. This fraction is related to the proportion of larvae in the bay that originated from the river, as larvae from other Long Island Sound (LIS) stocks also may enter the bay. However, only indirect rather than direct (e.g., genetic composition of entrained larvae) methods are presently available to quantify the sources of larvae entrained at MNPS. An indirect method known as a mass-balance calculation was used to determine whether the number of winter flounder larvae entering Niantic Bay from the Niantic River alone could account for the number of larvae observed in the bay during the larval season. Mass-balance calculations were based on data from 1984-91 and the patterns found were very consistent from year to year. Generally, a net loss of larvae was indicated from Niantic Bay during the first part of the larval season, but beginning in late March larvae from other areas of LIS were required to support observed larval abundance in Niantic Bay. This pattern agreed with results from an independent special sampling study conducted in 1991.

According to the mass-balance calculations, between 25 and 50% of the winter flounder larvae entrained by MNPS originated in the Niantic River. Since 1984, percentages of the annual production entrained ranged from 6 to 17% (geometric mean of 10.9%). These estimates were based on actual cooling-water flow at MNPS and were recomputed to determine production loss for full (100% capacity) three-unit operations. Annual percentages of Niantic River winter flounder production that would have been entrained since 1984 under simulated full three-unit operation ranged from 8 to 20%, with a geometric mean of 13.9%. This reduction in annual larval production was used in impact assessment simulations with the SPDM.

A natural draft cooling tower constructed for Unit 3 could greatly reduce many of the environmental impacts associated with once-through cooling because of reduced water demand. However, other effects may outweigh any benefits. Land now undeveloped at MNPS and dedicated as a wildlife refuge and public recreation area would be needed for the cooling tower site. Cooling towers located along shorelines have also been responsible for mortalities of migrating birds from collisions, particularly at night or under periods of low visibility. The size of a cooling tower would be significant and it would be a dominating visual intrusion on the coastal

landscape; the structure and vapor plume may be visible for many miles. Noise from the cascading water within the tower also may exceed prevailing standards in nearby residential areas. A wastewater treatment facility may be required for cooling tower blowdown. The high cost of a natural draft cooling tower noted previously in this report would be a significant burden to ratepayers.

An offshore intake site was evaluated for MNPS to specifically reduce the entrainment of Niantic River winter flounder larvae. This location, just outside of a line extending from Millstone Point to Black Point, was chosen on the basis of the hydrodynamics of Niantic Bay in relation to the distribution of Niantic River winter flounder larvae found in the bay. It was assumed that densities of Niantic River winter flounder larvae would be diluted by about one-half and that the offshore intake would provide cooling water for only Unit 3 (about 50% of the total MNPS cooling-water demand). Because overall densities of winter flounder larvae in this area can be high, total entrainment may actually increase when compared to the numbers taken at the present shoreline intake location. Many of these larvae, however, would have drifted in from other source areas. This would shift more of the MNPS-imposed entrainment mortality to stocks other than the one spawning in the Niantic River.

An offshore intake would likely affect the entrainment of other species. For example, entrainment totals for the grubby may decrease, but those for the American sand lance and bay anchovy would likely increase. Adult tautog are more common offshore and tautog and cunner may be attracted to and spawn near the offshore intake structure. Impingement of juvenile and adult fish may also differ between an inshore and offshore intake. Based on the experience of the Seabrook (New Hampshire) Nuclear Generating Station, which has an offshore intake with a velocity cap, fish impingement would probably decrease in comparison to present estimates. However, recently implemented improvements to the fish return system at Unit 3 will likely further reduce present impingement mortality. An offshore intake would likely require a significant increase in the amount of biocide needed to control fouling in the intake structure and the long intake tunnel. A declorination facility may be needed so the discharge does not exceed NPDES permit limits. Finally, like a cooling tower, the offshore intake option is extremely expensive.

Intake screen panels at MNPS could be fitted with fine-mesh screen to impinge and remove larvae before they are entrained through the condenser cooling-water system. Winter flounder larvae were tested in several laboratory and field studies evaluating fine-mesh screens. These

studies showed that entrainment was only prevented by using small (0.355 and 0.5 mm) mesh; nearly all larvae passed through 1.0-mm mesh screens. However, once impinged small larvae were not effectively removed off the screens by the spraywash system evaluated. Larger larvae were removed to a greater extent, but suffered high latent mortality. Survival of other larval fishes at various power plants using fine-mesh screens has been variable. Retention and survival varied widely and was related to the species, size, age, and behavior of larvae. Some drawbacks of fine-mesh screens have included higher debris loading and biofouling. Both of these processes have caused higher impingement mortality, reduced reliability, and the need for increased maintenance. Debris fouling has been an ongoing concern at MNPS and has resulted in numerous plant outages.

The most pertinent study involving fine-mesh screens was at the Brayton Point Generating Station, located on Mount Hope Bay in Massachusetts. Six screens of 1.0-mm mesh were set in an intake canal at an angle of 25° to the intake flow. Organisms that passed along the front of the traveling screens could enter a fish bypass and be returned to the source water body through a pump. Others were entrained through the cooling-water system or were impinged on the fine-mesh screens and washed off into a trough for return. A 3-year study was completed on the effectiveness of this system in which over 50,000 winter flounder larvae were collected and examined and more than 11,000 were held for latent survival studies. Overall, the probability of a winter flounder larva encountering this system and surviving for 72 h was only 6.5%. It was concluded that this system was not effective in mitigating larval winter flounder entrainment. The fine-mesh panels at Brayton Point Station were subsequently removed and replaced by conventional 9.5-mm mesh screens. Other studies also have concluded that fine-mesh screens were generally ineffective in reducing entrainment losses, particularly for larvae less than 10 mm in length. This would include all larval stages of winter flounder.

Some studies have indicated that cylindrical wedgewire screens may be effective in reducing ichthyoplankton entrainment, particularly because of the low intake velocities associated with their use. However, this type of screen has almost exclusively been used for closed-cycle applications using small volumes of intake water. The largest electrical generating station in the United States currently using this type of intake screening requires less than one-third of the cooling-water flow of MNPS Unit 3. Fine-mesh cylindrical wedgewire screens may not be feasible at marine power plants because of excessive fouling, debris loading, and corrosion. Mesh of 1 to 2 mm would probably be required to protect winter flounder larvae. This screening could become clogged daily or even more frequently during high ambient debris

concentrations, possibly compromising plant operation and safety. Because this type of screen may be inappropriate for large power plants at marine sites and because of its unknown effectiveness in reducing larval winter flounder entrainment and impingement, this mitigation alternative may not be practical for MNPS.

Sills, curtain walls, or other devices that restrict intake water flow would likely be ineffective in significantly reducing entrainment mortality of larval winter flounder. Although most older larvae are found closer to the bottom (particularly during the day), they nevertheless remain planktonic; most entrainment of older larvae occurs at night. As long as water volume is not reduced, larvae would continue to be entrained in proportion to their density in the water column, and, thus, ineffective in mitigating entrainment mortalities. Also, any larvae diverted by a sill may be entrained at Unit 1 or 2, especially during an ebb tide. Effectiveness of air bubble curtains in reducing ichthyoplankton entrainment has not been demonstrated and as an unproven technology is an unlikely mitigation alternative.

One method to reduce entrainment without physically changing the plant layout would be to selectively shut down one or more units to reduce cooling-water demand during the larval winter flounder season. Because the densities of larval winter flounder vary throughout the season and because each unit has a different capacity for cooling water and Units 2 and 3 require that some circulating-water pumps remain in operation during shutdowns, potential reductions in entrainment can vary according to how these factors interact. A 25% reduction in entrainment was selected as a goal for mitigation using shutdowns. The optimal dates for shutdowns were determined by examining the distribution of larval winter flounder over time in entrainment collections. Winter flounder larvae have been entrained at MNPS from February through July. However, in general the distribution of entrained larvae is skewed, with densities increasing rapidly to a maximum and then slowly declining. Peak entrainment occurs in April and the cumulative total density reaches 50% on or about May 1. Truncating the entrainment density distribution to remove the long tails resulted in a 73-day (April 2 through June 13) period that included 95% of all larval entrainment. A shutdown of Unit 1 during this period would result in about a 22% reduction in total entrainment and for Unit 3, about a 30% reduction. However, a reduction of only 13% would occur during a Unit 2 shutdown because two circulating-water pumps would remain in operation. To achieve the targeted 25% reduction, Unit 3 would have to be shut down for a 59-day period (April 2 through May 30). A similar decrease could be attained during a simultaneous shutdown of Units 1 and 2 over the same number of days.

The above calculations were based on an average annual entrainment season. The actual distribution of larvae may vary considerably from year to year, and, thus, the effectiveness of shutdowns in mitigating entrainment effects may also vary. No reliable long-term ability to predict entrainment density distributions in any particular year can be foreseen at this time. Therefore, scheduled shutdowns would have to be based on long-term average conditions. As noted in Part I, the cumulative costs for required replacement power for unit shutdowns during the larval winter flounder season make this approach the most expensive of all the entrainment mitigation alternatives considered.

There has been some precedent in using hatchery augmentation to improve a fish stock affected by the operation of power plants (i.e., the Hudson River striped bass). Hatchery production of winter flounder would necessarily differ in many respects from more readily cultured fish, such as striped bass or trout. Several programs were established in the United States and Japan to culture various flatfishes, primarily to improve stocks for fishing. These programs met with limited or no success, except for an instance in Japan, where very high value for the species stocked and tight government and social controls over the fishery exist. Difficulties in rearing young flatfish (e.g., lack of knowledge of specific nutritional requirements; diseases) and high costs made production unfeasible in several instances.

Winter flounder were apparently cultured at two New England marine fish hatcheries from the late 1800s through the early 1940s. However, no indication was ever given of the effectiveness of this work in increasing catches by the fisheries. Because winter flounder have been successfully raised through larval metamorphosis in several laboratories, the requirements for supplementing Niantic River winter flounder reproduction were investigated. Calculations were made on the assumption that hatchery production could completely offset entrainment mortality if an approximate 17% increase in biomass could be achieved. A total of 1 million young would have to be released in July to increase the number of age-1 fish by 17%. This would require the reproductive effort of approximately 140 female spawners, which is about one-quarter to all of the gravid fish collected during annual spawning surveys of Niantic River winter flounder. Removal of these fish would also eliminate them from spawning naturally. Further, the young produced would require rearing ponds or tanks with an estimated surface area of 33.6 ha (83 acres), even if raised at ten times natural densities. An area of this magnitude is not available at MNPS and may not be found at economically reasonable costs elsewhere along the Connecticut coast.

Food requirements, predator and disease control, water quality, and many other aspects of a large-scale hatchery remain to be considered in detail. In addition, genetic issues must be considered before releasing significant numbers of hatchery-reared fish into the wild. Traits that enhance growth, survival, and reproduction in the wild may be different from those selected for in a hatchery. The success of a hatchery stocking program should be monitored by tagging or marking fish produced on culture, which may be difficult for young winter flounder. Because of the uncertainties of mitigating entrainment by the replenishment of fish, no further engineering, design, cost, or more detailed feasibility studies have been undertaken at this time.

Input data to the SPDM used for impact assessment included various basic life-table parameters for Niantic River winter flounder, and estimates of the three-parameter stock-recruitment relationship for Niantic River winter flounder together with February water temperature statistics and a random variability component. Annual conditional mortality rates corresponding to postulated larval entrainment, MNPS operation, mortality attributed to juvenile and adult impingement at MNPS, and fishing rates were adjusted according to historical information and future projections. The annual schedule of fishing mortality rates was provided by the DEP and took into account changes proposed to reduce fishing mortality in Connecticut waters. The female spawning stock was simulated as biomass (lbs) because it is a more conservative measure of potential fish reproduction than the number of spawners.

The output time-series of SPDM simulations with fishing, impingement, and entrainment (measured historical and maximum nominal values through 2025) was the reference series. This baseline time-series represented the most likely trajectory of the exploited Niantic River winter flounder female spawning stock without mitigation of MNPS entrainment. Time-series representing expected stock trajectories corresponding to various reductions (10, 20, 25, and 50%) in rates of entrainment were compared against the baseline to assess the effectiveness of various mitigation alternatives.

The baseline projection showed that an initial theoretical unfished stock of about 111,400 lbs (approximately 76,800 female spawners) decreased to about 54,000 lbs by 1960 assuming moderate exploitation rates corresponding to an instantaneous fishing mortality rate of 0.40. Because of a steep increase in fishing mortality to 0.91 by the early 1990s, the simulated baseline further declined to about 22,500 lbs in 1991 and 1992, which is less than 20% of the initial unfished biomass. The baseline stock recovered rapidly following proposed changes in fishing regulations scheduled to go into effect in the 1990s. The computer simulations showed

that the reduction in fishing was mostly responsible for the recovery of the Niantic River female spawning stock, rather than concurrent entrainment mitigation. Model simulations also showed maximum gains in biomass by the year 2003 that ranged from about 949 lbs for a 10% reduction in entrainment to 4,673 lbs for a 50% reduction. On a percentage basis, these biomass additions represent increases of 1.7 to 8.6%. Cumulative gains in biomass over a 40-year period ranged from 20,587 to 100,289 lbs. Although these values appear to be substantial, they represent only small gains in the annual spawning stock biomass. Annual increases in biomass would likely only represent a small fraction (< 0.25%) of combined Connecticut sport and commercial fishing landings in recent years, because, on average, the Niantic River stock accounts for less than 5% of the Connecticut winter flounder resource.

Probabilistic risk assessment analysis was used to examine the probability that the stock would fall to less than 25% of the maximum spawning biomass at six selected points in time. This value was chosen by the Atlantic States Marine Fisheries Commission as a reference point below which overfishing was indicated and recruitment failure became a possibility. The analysis indicated that in 1993, before reductions in fishing rates and any entrainment mitigation alternatives were put into effect, the spawning stock biomass was almost certainly ($p = 0.94$) less than 25% of the unfished biomass. However, once fishing was reduced, the probability of a critically reduced stock quickly fell to 0.02 by 1998, with or without the implementation of entrainment mitigation alternatives. The probability of critically low stock biomass became zero for all years after 1998. This occurred regardless of the magnitude of larval entrainment reduction because by the time mitigation became effective, the stock was no longer depressed below a critically low size. As the gain in biomass from even the largest (50%) reduction in entrainment mortality was projected to be relatively small (≤ 8.6%), it is doubtful whether projected increases in stock size could be detected on the basis of field-collected data.