→ MC. Pls handle.
Thx.

Consolidated Edison Company of New York, Inc.
4 Irving Place, New York, N.Y. 10003

April 30, 1996

VIA AIRBORNE EXPRESS

Mr. James Gilmore
Regional Chief
Bureau of Marine Habitat Protection
New York State Department of
Environmental Conservation - Region II
47-40 21st Street
Long Island City, New York 11101

Mr. Edward Radle
Division of Fish and Wildlife
New York State Department of
Environmental Conservation
50 Wolf Road - Room 530
Albany, New York 122 33

Re: Ravenswood Station Diagnostic Study Report
DEC File No. R2-2985-90-04

Dear Messrs. Gilmore and Radle:

As required under the terms of the Consent Order in this proceeding, I am enclosing for the Department's review and approval the Diagnostic Study for the intake screens at Con Edison's Ravenswood Generating Station in Queens County, New York.

If you have any questions regarding the report, or would like to meet to discuss the study results, please call me at (212) 460-4837 or Kenneth Marcellus at (212) 460-6059.

Sincerely yours,

Kenneth L. Marcellus

for William L. Kirk, Ph.D.

cc; Paul Gallay, Esq.
Acting Regional Administrator-
DEC Region II

RAVENSWOOD GENERATING STATION
DIAGNOSTIC STUDY REPORT

PREPARED BY CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
PURSUANT TO THE DECEMBER 23, 1993 ORDER ON CONSENT
IN DEC FILE NO. R2-2985-90-04

APRIL 30, 1996

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I. INTRODUCTION

Consolidated Edison Company of New York, Inc. ("Con Edison" or "Company") respectfully submits this report to the New York State Department of Environmental Conservation ("DEC" or Department") pursuant to the terms of the December 23, 1992 Order on Consent ("Consent Order") that it entered into with the Department in DEC File No. R2-2985-90-04. This report presents the results of the diagnostic study that Con Edison was required to conduct under the Consent Order for the purpose of evaluating whether the through-flow intake screens at its Ravenswood Generating Station in Queens County, New York represent best available technology ("BAT") for minimizing adverse environmental impact as mandated by Section 316(b) of the Clean Water Act and the Department's water quality protection rules and regulations in 6 NYCRR Section 704.5.

Con Edison's proposed plan and implementation schedule for the Ravenswood Station Diagnostic Study was approved by the Department on July 27, 1993. As specified by the Department, the report for the Ravenswood Station Diagnostic Study was to contain the following:

(1) a summary of results of impingement and entrainment studies conducted at the station,

(2) a discussion of the short-term remedial actions taken to improve the return of impinged fish and bluecrabs to the East River;

(3) the results of intake water velocity profile studies conducted for the station's through-flow screens; and

(4) a discussion of the options for returning fish impinged on the station's intake screens to the East River.

Each of these required elements is addressed in this report. Section II of the report presents background information regarding the Ravenswood Station ("Station") and its environmental setting. Section III summarizes the results of impingement and entrainment studies that were conducted at the station. This section also discusses the potential levels of post-impingement viability of fish and bluecrabs collected from the Station's traveling water intake screens, and the post-impingement viability levels observed for fish collected from through-flow as well as dual flow screens that have been outfitted with Ristroph-type fish-saving devices at other electric generating stations. Section IV discusses the short-term remedial actions taken to return fish and bluecrabs that are impinged on the Station's water intake screens to the East River. Section V presents results of the intake velocity profile studies that were conducted for the station's conventional through-flow water intake screens. Section VI reviews options for returning impinged fish from the Station's through-flow water intake screens to the East River, and assesses the effects of exposure to heated discharge water on post-impingement viability.

Once this report has been approved by the Department, Con Edison will prepare its Final Action Plan for the Ravenswood Generating Station. In the Final Action Plan, Con Edison will present its proposed plan and implementation schedule for completing any remedial measures needed to ensure that the Station's intake screens comply with the BAT requirement of Clean Water Act Section 316(b) and 6 NYCRR Section 704.5.

II. Ravenswood Generating Station Background

This section describes the Ravenswood Generating Station's once-through condenser cooling water and service water systems and provides background information regarding the East River waterway on which the Station is located and from which it derives its condenser cooling water and service water.

A. Environmental Setting

The Ravenswood Generating Station is located in Queens County, New York, on the east bank of the East River. The station is located between the Queensboro Bridge and the Roosevelt Island Bridge (Figure 1). The East River is a 14 mile long tidal strait connecting New York Harbor and the Long Island Sound, and serves as a major commercial waterway. The shorelines of the waterway in the general vicinity of the Ravenswood Generating Station consist primarily of bulkheads and rock rip-rap. There are no substantive marshes or creeks with unbulkheaded-shorelines within several miles of the Station. Tides flood into the East River from the south (Upper New York Bay) and have a vertical range of approximately 4.5 ft. Channel currents approach 5 ft/sec. Salinity levels range from approximately 15 ppt to 25 ppt (NAI 1994), while temperatures range from a high of approximately 4 deg. C in February to approximately 25 deg. C in August (LMS 1993). Historically, dissolved oxygen levels

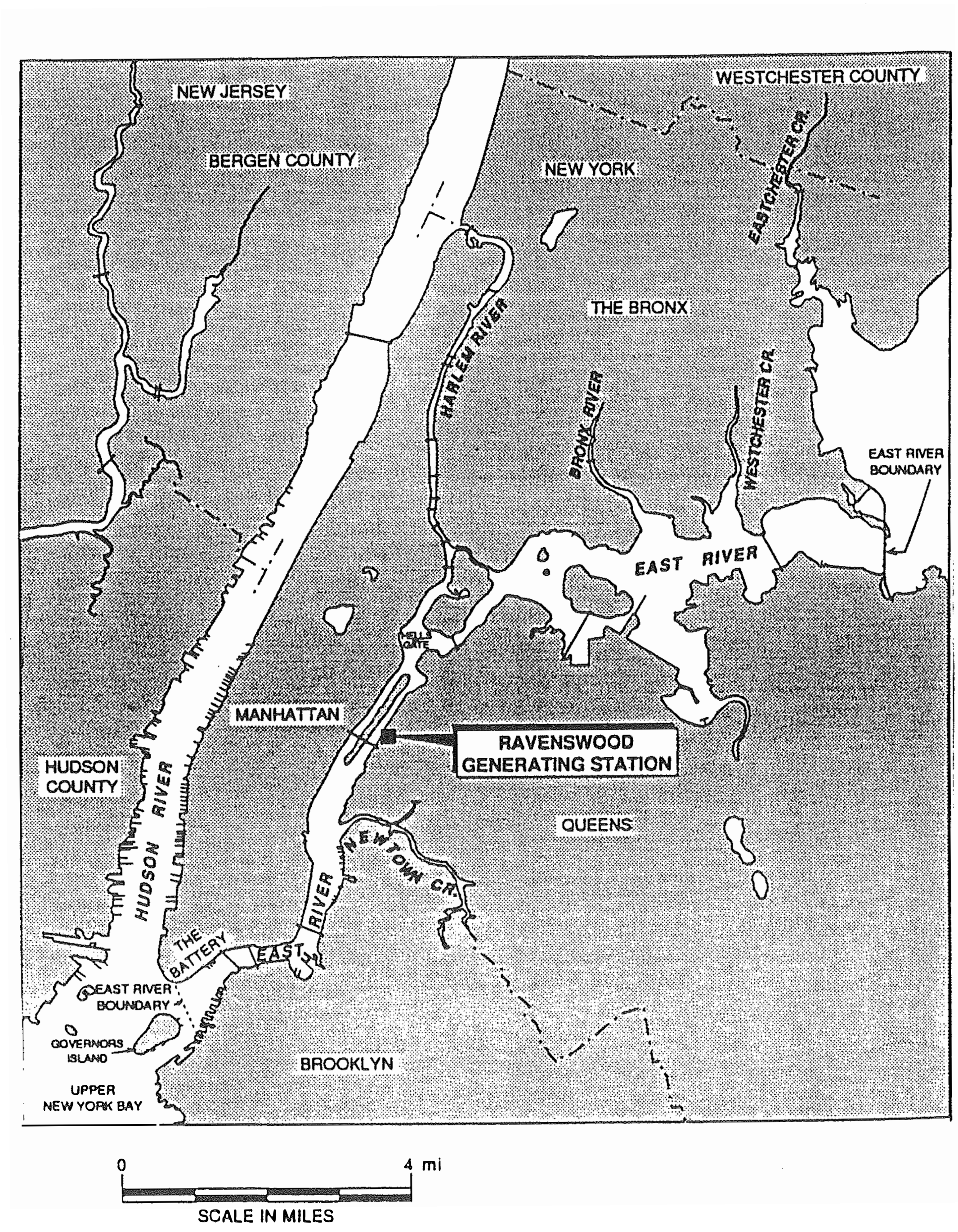

Figure 1. **Location Map for the Ravenswood Generating Station.**
(Source: LMS 1993)

declined to near 0 mg/l during summer months (ISC 1976). However, during the impingement and entrainment studies conducted at the Ravenswood Station between September 1991 - September 1992, and February 1993 -January 1994, summer dissolved oxygen levels remained above 3.0 mg/l in the Station's discharge canal (LMS 1993, NAI 1994).

B. Station Condenser Cooling and Service Water System

The Ravenswood Generating Station consists of three oil/gas fired steam-electric generating units (Nos. 10, 20 and 30) with rated capacities of 400, 400, and 1027 megawatts, respectively. Ravenswood Units 10 and 20 began operating in 1963, while Unit 30 began operating in 1965. After the 1994 summer electrical demand peak period, Ravenswood Units 10 and 20 were placed into a seasonal operation plan under which these units would be operated as needed during June through September, and be placed into reserve shutdown during October through May. This operating plan, which is expected to be followed through 1998, will be continuously monitored and adjusted as needed to meet energy requirements (Con Edison 1995). Unit 30 is scheduled to be operated as a base load plant throughout the period.

Water from the East River is used to cool the generating units' steam condensers (circulating water system) and various small heat exchangers (service water system). Each generating unit has two circulating water pumps. The pumps at Unit 10 are rated at 111,300 gpm each, while those at Unit 20 are rated at 107,000 gpm each. The circulating water pumps at Unit 30 are rated at 268,500 each. There are no interconnections between the circulating water systems for the three units.

The design maximum temperature difference between spent circulating water in the Station's discharge canal and ambient water in the East River is approximately 17.4 deg. F (9.7 deg C) with all three units operating at full power. At Units 10 and 20, the design temperature rise across the condenser is 15.7 deg F (8.7 deg C), while that at Unit 30 is 18.8 deg. F (10.4 deg C) at full power operation.

Each generating unit has two service water pumps, of which only one is in service when its respective unit is operating. The service water pumps for each unit are rated at 8,000 gpm each. The service water pumps are located in sumps adjacent to the circulating water pumps at each unit and are interconnected.

Units 10 and 20 each have four water intake bays that each measure 11.2 ft wide by 17.0 ft deep (Figure 2). Two bays provide water to each circulator. Unit 30 has six intake bays that each measure 11.2 ft. wide by 24.0 ft deep (Figure 3). Three bays provide water to each circulator. The faces of the intake structures are recessed approximately 60 feet inside the bulkhead line at the Station (Figure 4).

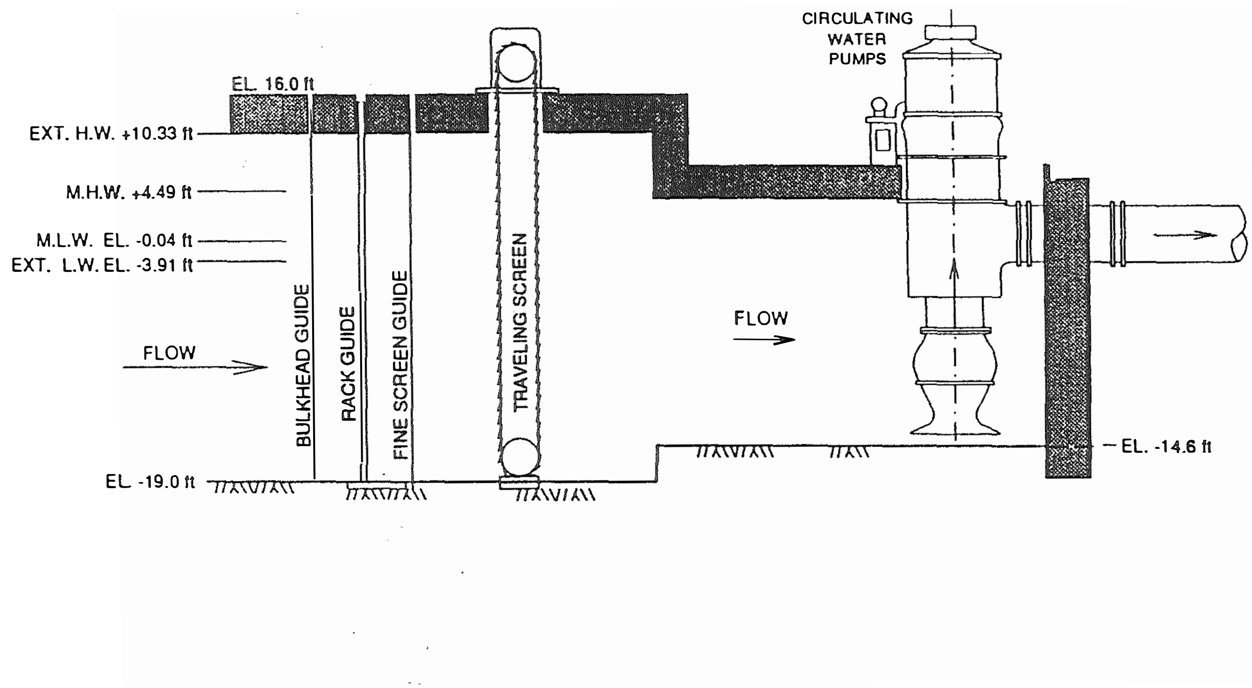

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Figure 2. **Vertical Section of Ravenswood Generating Station Units 10 and 20 Intake bay.** (Source: LMS 1993)

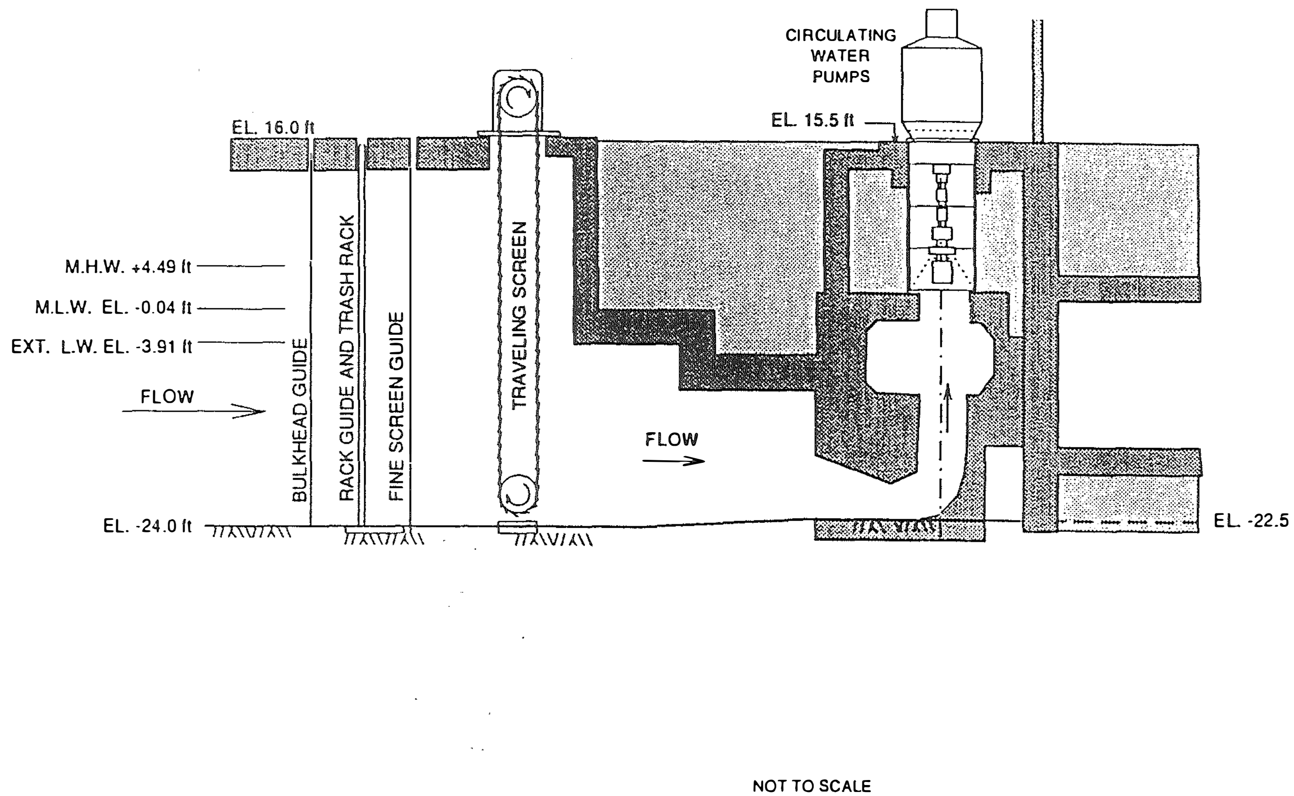

Figure 3. **Vertical Section of Ravenswood Generating Station Unit 30 Intake bay.** (Source: LMS 1993)

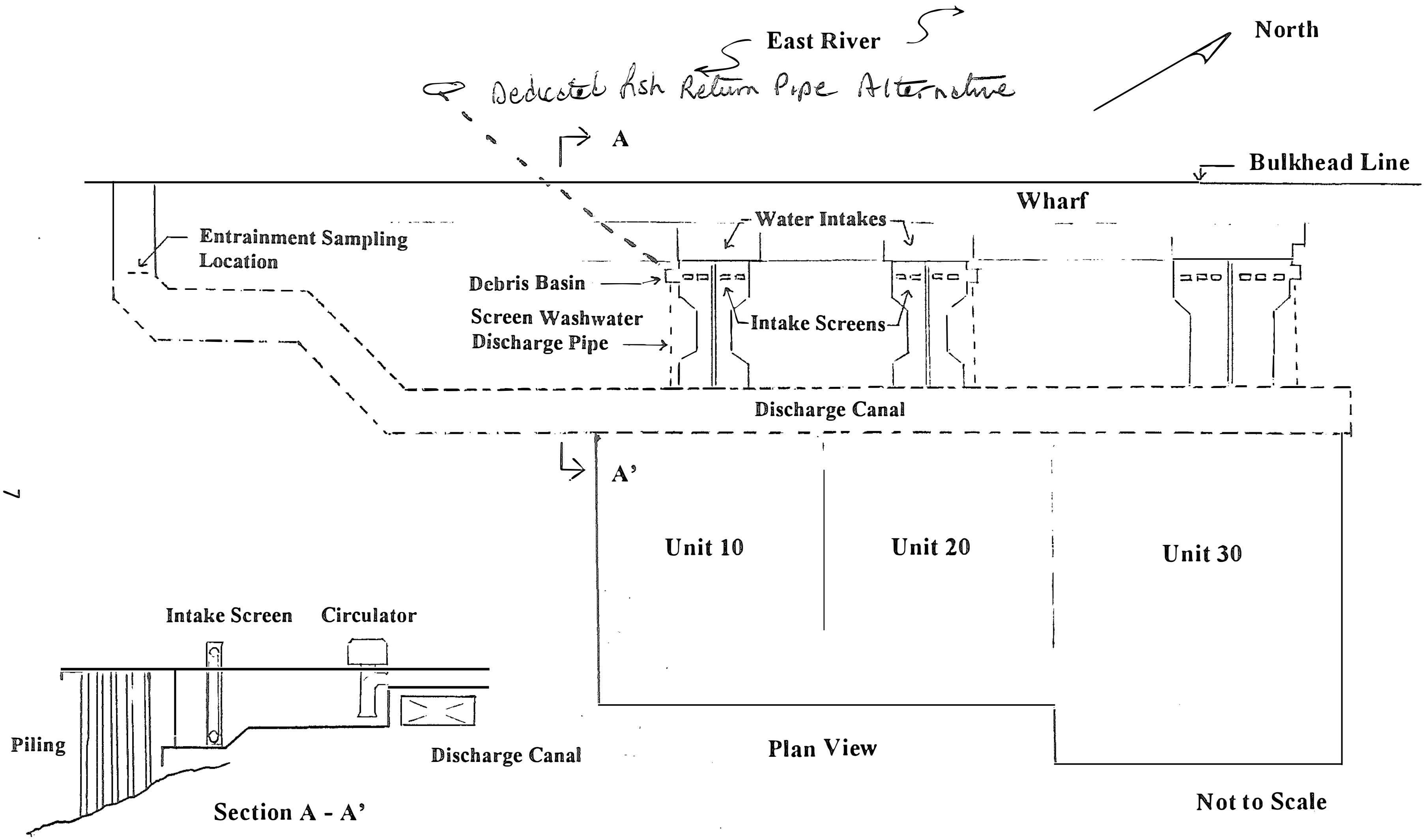

Figure 4. Ravenswood Generating Station Site Plan showing Location of Wharf and Bulkhead Line, Water Intakes, Screen Washwater Discharges, Discharge Canal, and Entrainment Sampling Location.

Wooden debris skimmers are located at the entrance to each intake bay to prevent floating materials from entering the bays. There are no bar screens at any of the three units. When the Stations' three generating units were constructed, the intake bays were equipped with vertical through-flow traveling water screens that were outfitted with 3/8"x3/8" mesh. This type of screen is still installed at the Station. The screens are operated intermittently, approximately 15 minutes every two hours when the associated circulator is in operation. However, when debris loads are heavy, such as periods following heavy rains when domestic refuse is washed into the river through storm sewers, the screens may be operated continuously for short periods until debris loads subside. Debris loading at the Station is relatively light, compared to the Arthur Kill Station in Staten Island. During the impingement studies at the Ravenswood Station, the estimated quantity of debris collected from the screens averaged approximately 22,000 gallons per year. Paper and plastics comprised approximately 22% of the debris, while aquatic vegetation comprised 18%. Bryozoans and tunicates contributed almost 28% of the estimated annual debris accumulations (LMS 1993, NAI 1994.). At the Arthur Kill Generating Station, which is located along a commercial waterway with predominately natural shorelines, the estimated quantity of debris collected from the intake screens during a 13 month study totaled 75,000 gallons. Aquatic vegetation contributed 37%, while paper and plastics contributed 19%, and bryazoans and tunicates contributed 17% (LMS 1993).

High pressure spray systems wash debris from the front (riverward) side of the traveling water screens at each unit into "in-deck" concrete sluices. The sluice at each unit discharges to a debris collection basin. Wash water drains through the baskets and then out through 24 in diameter cast iron pipes to the station's condenser cooling water discharge canal, which in turn, discharges into the East River. Prior to May 1994, debris that was washed from the screens was collected in wire mesh baskets placed within each unit's debris basin. During May and early June 1994, in response to the Consent Order requirement for short-term remedial action at the Ravenswood Station, the debris collection baskets were removed from the basins and spiral-shaped sluice extensions were installed to convey fish and bluecrabs, as well as debris, into the drain pipe of the basin for return to the river. (The sluice extensions are discussed in Section IV, below.)

Each circulating water pump at Units 10 and 20 draws water through two screens. At Unit 30, each pump draws water through three screens. At Unit 10, the design flow through each screen is 55,600 gpm, or 59,600 gpm, if the associated service water pump is operating. At Unit 20, the design flow through each screen is 53,500 gpm or 57,500 gpm, if the associated service water pump is operating. At Unit 30 the design flow through each screen is 89,500 gpm or 92,167 gpm, if the adjacent service water pump is operating (Table 1).

At Units 10 and 20, the calculated intake water velocity for the combined circulating water and service water flow upstream of each screen is 0.7 ft/sec at low tide and 0.6 ft/sec at high tide (Table 1). At Unit 30, the calculated intake water velocity for the combined circulating and service water flow upstream of each screen is 0.8 ft/sec at low tide and 0.6 ft/sec at high tide (Table 1). Velocity profile data for one through-flow screen at Unit 30 were obtained as part of the diagnostic study and are discussed in Section V.

Table 1. Ravenswood Generating Station water intake dimensions and approximated intake flow velocities.

Dimensions								Design Flow (gpm/screen)	
		Intake	Intake	No.	Circulator	Service	No. Screens	Circulator	Circulator +
Unit No.		Width (ft)	Depth (ft)	Circulators	Flow (gpm)	Flow (gpm)*	Per Circ.	Only	Service
10		11.2	17	2	111,300	16,000	2	55,650	59,650
20		11.2	17	2	107,000	16,000	2	53,500	57,500
30		11.2	24	2	268,500	16,000	3	89,500	92,167
					486,800				

* Each Unit has two service water pumps with a combined flow of 16,000 gpm.

Normal service water flow is: 8,000 gpm/unit.

Velocities							Flow/	
		Tide	Tide	Section	Section	Effective	Screen	Approx.
Unit No.		Stage	Level (ft)	Width (ft)	Depth (ft)	Area (ft)	(gpm)	Vel (fps)
10		Low	0.04	11.2	17.0	191	59,650	0.7
		High	4.49	11.2	21.5	241	59,650	0.6
20		Low	0.04	11.2	17.0	191	57,500	0.7
		High	4.49	11.2	21.5	241	57,500	0.5
30		Low	0.04	11.2	24.0	269	92,167	0.8
		High	4.49	11.2	28.5	319	92,167	0.6

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Cooling water from each unit is discharged into a common canal for return to the East River (Figure 4). The discharge canal is approximately 1,200 ft long, 25 ft wide and 15 ft deep. It discharges at the bulkhead line. The water depth at the terminus of the discharge canal is approximately 20 ft. The calculated flow velocity through the canal when all circulating water pumps and one service water pump at each unit are operating is approximately 5.2 ft/sec. When only Unit 10 is in service, the flow velocity is approximately 1.2 ft/sec; with only Unit 20 in service it is approximately 1.1 ft/sec; and when only Unit 30 is in service, it is approximately 2.8 ft/sec.

III. Impingement and Entrainment Studies

This section summarizes the impingement and entrainment monitoring studies that were conducted at the Ravenswood Generating Station from September 1991 through September 1992, and from February 1993 through January 1994. The monitoring studies are discussed in detail in the reports filed with the Department in September 1993 (LMS 1993) and May 1994 (NAI 1994). Accordingly, only a summary of the study procedures and results is presented in this section.

A. Impingement Sampling Procedures

Impingement sampling was conducted at the Ravenswood Generating Station from September 16, 1991 through September 10, 1992, and the February 2, 1993 through January 24, 1994. A total of 52 weekly samples were collected during each of the two study periods. Impingement samples were collected in 5/16 inch square mesh-outfitted baskets suspended at the discharge of each unit's screen washwater sluiceway. The samples were segregated by unit, and exact times that circulating water pumps and service water pumps were either turned on or off were recorded and used to calculate the volume of intake water sampled during each sampling period. Fish and bluecrabs were enumerated for each of four six-hour sampling intervals during each 24 hour sampling period for each unit. Weekly impingement samples were used to estimate the number of fish and bluecrabs impinged annually at the Station.

B. Entrainment Sampling Procedures

Entrainment sampling was conducted at the Station from October 22, 1991 through September 30, 1992, and from February 23, 1993 through January 18, 1994. Weekly sampling was conducted during May through August and every two weeks during other months of the year. A total of 32 entrainment samples were collected during the 1991 - 1992 sampling period, and 33 samples were collected during the 1993 - 1994 sampling period.

Samples were collected from the combined cooling water discharge stream of the station's generating units, downstream of the point where the intake screen washwater sluices empty into the discharge canal. The entrainment sampling point was located approximately 75 ft upstream from the mouth of the discharge canal (Figure 4). Discharge water was pumped from the canal through 4-inch diameter pipes that were positioned to sample water from the surface (-3 ft MLW), mid-depth (-8 ft MLW), and bottom (-13 ft MLW) strata of the canal. The pumped water was filtered through 505-micron cone nets suspended in 110-gallon tanks. Signet in-line velocity meters were used to measure the volume of water filtered for each sample.

Ichthyoplankton were removed from samples and sorted by species into four groups by life stage: egg; yolk sac larvae; post-yolk sac larvae; and juveniles. Weekly and bi-weekly samples were used to estimate the number of ichthyoplankton entrained annually at the station.

C. Impingement Results

1. Fish

During the two 12-month study periods, mid-September 1991 through mid-September 1992 and February 1993 through January 1994, a combined total of 14,358 fish were collected in once per week 24-hour sampling. In the 1991-1992 study, 4,648 fish comprised of 51 species and in the 1993 - 1994 study 9,710 fish comprised of 61 species were collected at units 10, 20 and 30. When adjusted for collection efficiency and scaled to actual plant operating volumes, an estimated 83,311 fish were impinged in 1991-1992 and 82,203 in 1993-1994. Although the total numbers impinged and the numbers of species represented were similar during both studies, there were differences in the relative contributions of the more abundant species to the totals. In 1991-92, the two most abundant species, bay anchovy and blueback herring, contributed 28.1 % and 29.8 %, respectively, with just under an estimated 25,000 individuals each (LMS, 1993). In 1993-94 , winter flounder and grubby were the two most abundant species, contributing 30.7 % and 19.4 % of the total, respectively, with 25,300 and 15,900 individuals estimated to have been impinged (NAI, 1994). The estimated numbers of bay anchovy and blueback herring impinged during this study period were only 2,135, and 1,772, respectively. During both study years, 80% of the species collected were represented by less than 1,000 individuals.

The variability in species abundance in impingement collections between years probably reflects differences in the units' operation during the two periods, as well as differences in year-class strength and the transient nature of most of the species collected. Strong tidal currents and the scarcity of protected areas (shoals, marshes, creeks) in the East River near the Station make residency in this section of the river unattractive for most species.

The number of fish impinged in any time interval is a function of exposure to the cooling water intakes (particularly the volume and/or velocity of cooling water flow) as well as certain behavioral and physiological characteristics. Sampling results averaged across the two study periods generally reflect these sources of variability. Ten species contributed about 82% of the average 12-month total over the two study periods (Table 2). Nine of the ten species were among the most numerous species collected in impingement samples in both years. Total impingement was relatively low in summer and high in winter and early spring (Table 2). Bay anchovy was the major contributor to summer impingement, while various flounders, herrings and the grubby were most abundant in late winter and early spring. Impingement rates (numbers of fish impinged per unit volume of cooling water flow) were also lowest in the summer (Figures 5 and 6). Rates at each of the three units were highest during the winter, which is the season when Units 10 and 20 are scheduled to be in reserve shutdown. The average numbers of fish impinged over the two 12-month study periods were highest at unit 20 (38,030) and lowest at unit 30 (15,299). The differences may be attributable to operating schedule differences, particularly in the fall and winter of 1991 - 1992. Unit 10 did not operate from September 1991 through February 1992, and Unit 30 operated less frequently than did Unit 20 during the study period.

Estimated Numbers of Fish Impinged at Each Ravenswood Unit

	1991 - 1992	1993 - 1994	Average
Unit 10	8,323	22,275	15,299
Unit 20	51,606	24,453	38,030
Unit 30	23,382	35,575	29,479
	83,311	82,303	82,808

Unit-specific impingement rates were examined to determine whether there was evidence that exposure of fish to impingement differed among the units. Since fish abundance in the vicinity of the intakes can differ substantially from day to day, only those days upon which all units were operating (at least one circulating water pump was in service throughout the sampling interval) were used for this comparison. No statistically significant ($p = 0.05$) differences were found (Table 3).

Length frequencies of young-of-the-year fish impinged on the 3/8 inch mesh panels at the Ravenswood Station were determined during the 1991 - 1992 and 1993 - 1994 studies (Table 4). Mean lengths for the ten most frequently impinged fish species ranged from 44 mm for grubby to 102 mm for northern pipefish. Minimum lengths ranged from 23 mm for northern pipefish to 58 mm for silver hake. These can be compared with the lengths of fish impinged on the various finer mesh panels tested at the Arthur Kill Station (Con Edison, 1996) for assessment of size ranges of fish impinged on alternative sizes of screen mesh.

No studies of post impingement survival were conducted at the Ravenswood Station. However, information is available from other stations where conventional through-flow screens, similar to those at Ravenswood, are in place. Studies at several Hudson River

Table 2. Average numbers of ten most abundant fish species impinged at the Ravenswood Generating Station During September 1991 - September 1992 and February 1993 - January 1994.

Estimated Numbers Impinged

Species	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	
Winter Flounder	2,485	1,645	1,188	7,060	178	198	173	215	186	26	8	71	13,433	
Blueback Herring	4,736	957	669	1,042	282	43	31	18	18	37	1,019	4,478	13,330	
Bay Anchovy	313	13	-	534	2,691	483	997	1,894	3,453	960	813	638	12,789	
Grubby	2,055	2,512	1,258	2,266	167	26	23	18	71	-	-	73	8,469	
Silver Hake	101	112	46	69	67	4	-	-	-	332	3,696	327	4,754	
Atlantic Silversides	864	697	639	177	15	-	9	115	458	114	430	931	4,449	
Northern Pipefish	204	237	1,072	1,414	567	176	60	20	27	122	68	70	4,037	
Smallmouth Flounder	144	113	115	1,137	505	60	-	-	-	8	26	336	2,444	
Northern Searobin	6	-	-	200	77	60	28	38	240	526	298	735	2,208	
Lined Seahorse	8	38	225	1,499	274	65	-	-	-	16	52	23	2,200	
Subtotal	10,916	6,324	5,212	15,398	4,823	1,115	1,321	2,318	4,453	2,141	6,410	7,682	68,113	(82%)
All Specie	13,396	7,373	6,389	19,103	6,110	1,818	1,692	2,864	5,233	2,513	7,191	9,127	82,809	
% of Annual Total	16.2	8.9	7.7	23.1	7.4	2.2	2.0	3.5	6.3	3.0	8.7	11.0	100.0	

14%

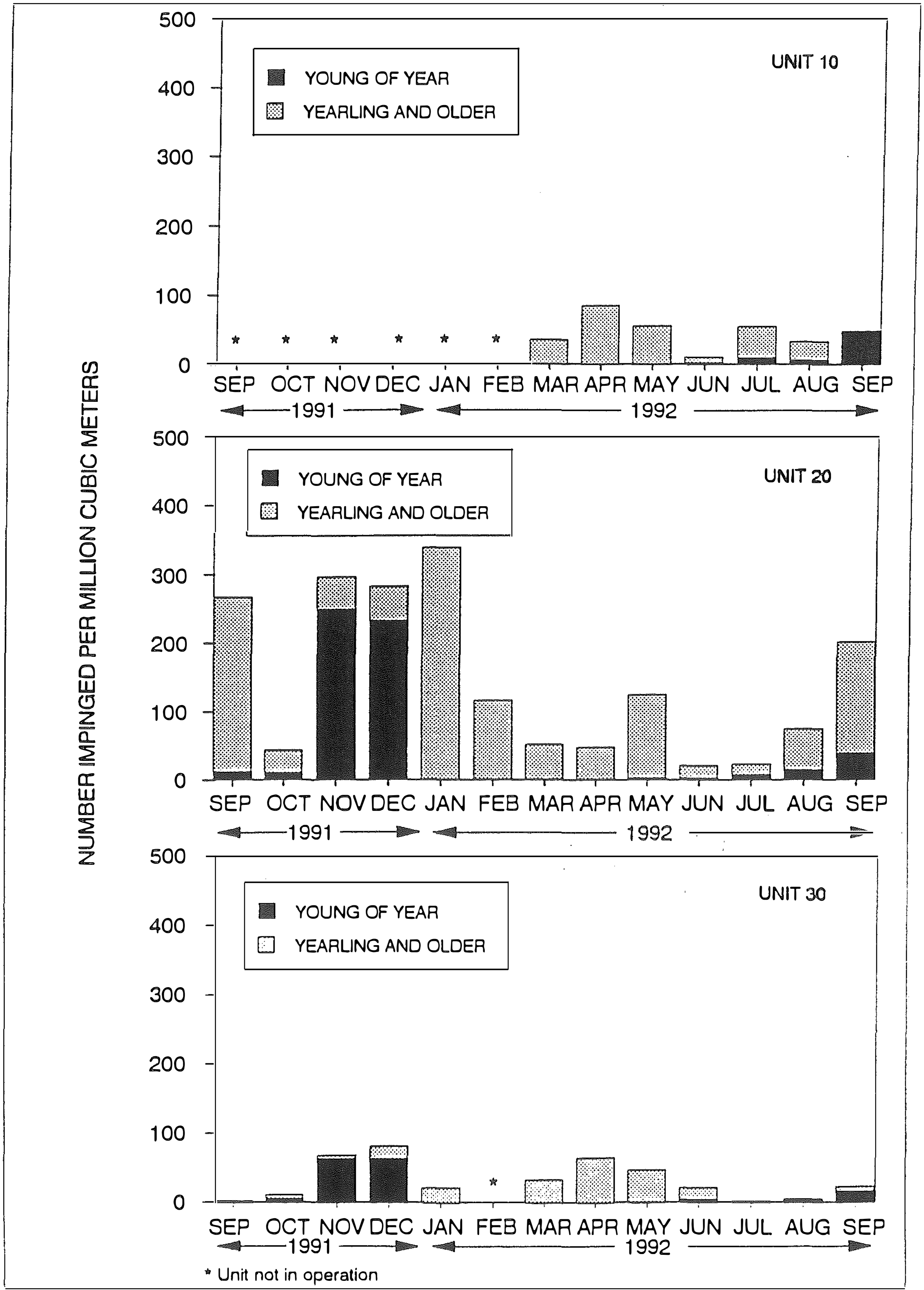

Figure 5. **Average monthly impingement rates of young-of-the-year and yearling and older fish at Ravenswood Units 10, 20, and 30 during September 1991 - September 1992.** (Source: LMS 1993)

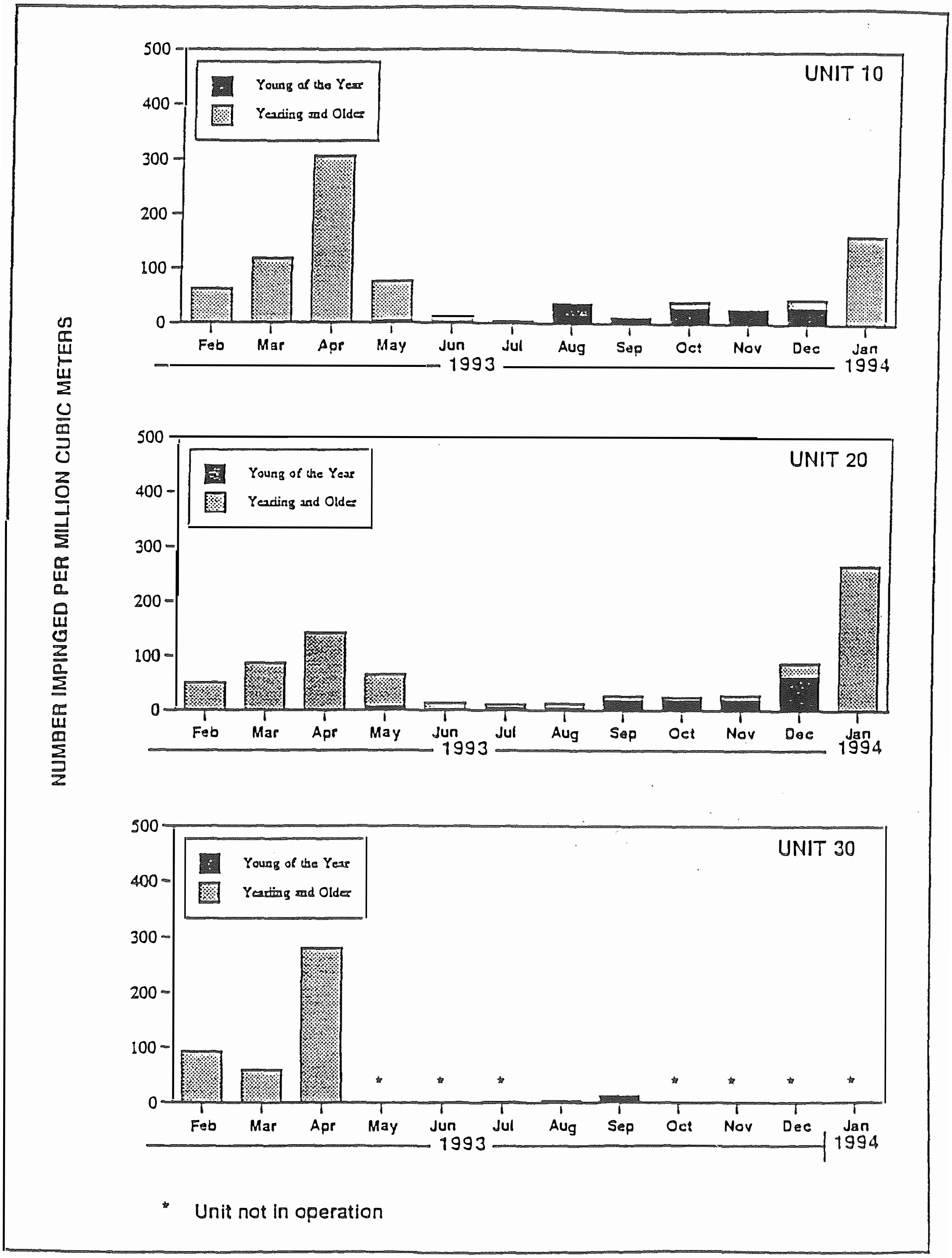

Figure 6. **Average monthly impingement rates of young-of-the-year and yearling and older fish at Ravenswood Units 10, 20, and 30 during February 1993 - January 1994.** (Source: NAI 1994)

Table 3. Average monthly impingement rates (all fish species combined) at Ravenswood Units 10, 20 and 30 during September 1991 - September 1992 and February 1993 - January 1994 *.

	Impingement Rates (Numbers/mcm)		
Month	Unit 10	Unit 20	Unit 30
6/92	20.18	4.97	9.26
7/92	29.94	18.87	9.31
8/92	15.98	33.45	8.35
9/92	5.76	3.43	12.54
2/93	58.03	91.85	100.01
3/93	40.66	75.08	122.6
4/93	92.11	75.06	37.79
6/93	40.97	30.86	5.42
7/93	5.09	12.25	3.32
8/93	5.5	3.28	5.54
9/93	62.37	29.77	5.3
Mean	34.24	34.44	29.04

* Includes only sampling dates on which circulating water pumps at all units were operating.

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Table 4. Lengths of selected species of fish impinged at the Ravenswood Generating Station during study years 1991 - 1992 and 1993 - 1994.

		Total Length (mm)		
Species	Life Stage	Mean	Minimum	Maximum
Bay Anchovy	Y-O-Y	45	35	70
Blueback Herring	Y-O-Y	77	54	98
Silver Hake	Y-O-Y	78	58	100
Atlantic Silverside	Y-O-Y	87	34	100
Winter Flounder	Y-O-Y	56	29	98
Grubby	Y-O-Y	44	38	49
Northern Pipefish	Y-O-Y	102	23	141
Atlantic Herring*	Yearling	48	27	354
Lined Seahorse*	Yearling	79	37	144
Northern Searobin	Yearling	71	34	145

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Stations indicated a wide range of survival rates, differing among species and affected by temperature, salinity and screen rotating frequency (Muessig, et. al. 1988). With continuous rotation, survival ranged from near zero for bay anchovy and some herrings, to approximately 90 % for Atlantic tomcod, killifish, sticklebacks, and hogchokers. Post-impingement viabilities were higher at higher salinities and lower with intermittent screen rotation. Since the screens at Ravenswood are currently operated intermittently except for brief periods when continuous rotation is needed to avoid Station operation interference due to debris loading, survival of the most sensitive species (bay anchovy and Atlantic herring), is probably limited. Other species, such as northern pipefish, seahorse sp., and northern searobin, may be more tolerant of impingement stress, as was observed at the Arthur Kill Generating Station (Con Edison 1996). Studies conducted at the Arthur Kill and Indian Point Stations demonstrated that fish-saving modifications to traveling water screens can result in increases in post-impingement viability rates for at least some of the species impinged at the Ravenswood Station. Post-impingement viability of the 10 most abundant species of fish found in Ravenswood Station impingement collections were evaluated in post-impingement studies at the Arthur Kill Generating Station from February 1994 - July 1995 (Con Edison 1996). Post-impingement viability for 9 of the 10 species was 79% or higher when collected from 1/8" x 1/2" mesh, and 90% or better when collected from 1/4" x 1/2" mesh dual-flow screens outfitted with fish-saving features (Table 5). Post-impingement viability of only 2 of the 10 species found in the Ravenswood impingement collections were evaluated in tests with a through-flow screen outfitted with fish-saving features at the Indian Point Station. Fall-collected bay anchovy post-impingement viability averaged 79%, while that for blueback herring averaged 74%.

2. Bluecrabs

A total of 21,021 blue crabs was collected during impingement sampling in 1991 - 1992 (LMS 1993) and a total of 928 bluecrabs was collected during the 1993 - 1994 study (NAI 1994). When scaled to operating volumes, the numbers of crabs impinged during the two study periods was estimated to be 162,108 and 7,060, respectively. Although the absolute numbers of crabs impinged differed substantially between the two sampling periods, seasonal patterns were generally consistent (Table 6). There was little or no impingement from December through early April, after which numbers increased rapidly to a peak a few months later and then declined somewhat during mid-summer before increasing again in October and November (Figures 7 and 8). On average, about 50% of the total numbers of bluecrabs impinged annually were impinged from June through September.

Bluecrab post-impingement viability was not evaluated at Ravenswood. However, post-impingement viability of bluecrabs impinged on conventional traveling screens at the Indian Point Station was on the order of 80 % (EA, 1991). Bluecrab post-impingement on both conventional- and Ristroph-modified dual flow screens at the Arthur Kill Generating Station was nearly 100% (Con Edison 1996).

Table 5.	Post-impingement viability levels measured at the Arthur Kill Generating Station of ten abundant species impinged at the Ravenswood Generating Station during September 1991 - September 1992 and February 1993 - January 1994.							
				24 Hr. Post-Impingement Viability (MODIFIED SCREENS)				
			Screen No. 24		Scr. No. 23	Screen No. 31		
Species		% Comp.	Mesh = (1/8"x1/2")			Mesh = (1/4"x1/2")		TOTAL SURVIVAL
Winter Flounder		16.2		97	41.3	97	97	15.7
Blueback Herring		16.1		79	14.8	87	96	14.0
Bay Anchovy		15.4		41	0.4	46	52	7.1
Grubby		10.2		100	(n=1) 100.0	100	100	10.2
Silver Hake		5.7		82	15.4	91	100	5.2
Atlantic Silversides		5.4		98	50.0	98	99	5.3
Northern Pipefish		4.9		97	100.0	98	100	4.8
Smallmouth Flounder		2.9		100	(n=1) 0	100	100	2.9
Northern Searobin		2.7		97	82.1	93	90	2.5
Seahorse sp.		2.7		100	100.0	100	100	2.7
c:vabilit.akg				Abundance weighted survival =		85.6%		70.4% survival of total impingement

→ Compose 82.2% of total estimated impingement averaged over both sample years.

Table 6. Estimated average numbers of bluecrabs impinged per year at Ravenswood Units 10, 20 and 30 combined during 1991 - 1992 and 1993 - 1994.

	Month												
	Jan	Feb	Mar	April	May	June	July	Aug	Sept*	Oct	Nov	Dec	Total
Number	75	16	18	667	23,724	11,949	10,564	13,080	4,130	5,819	8,561	2,042	80,645

* Data collected during September 1991 and September 1992 are averaged to facilitate year to year comparisons. Accordingly, the total is slightly smaller than that reported in LMS (1993).

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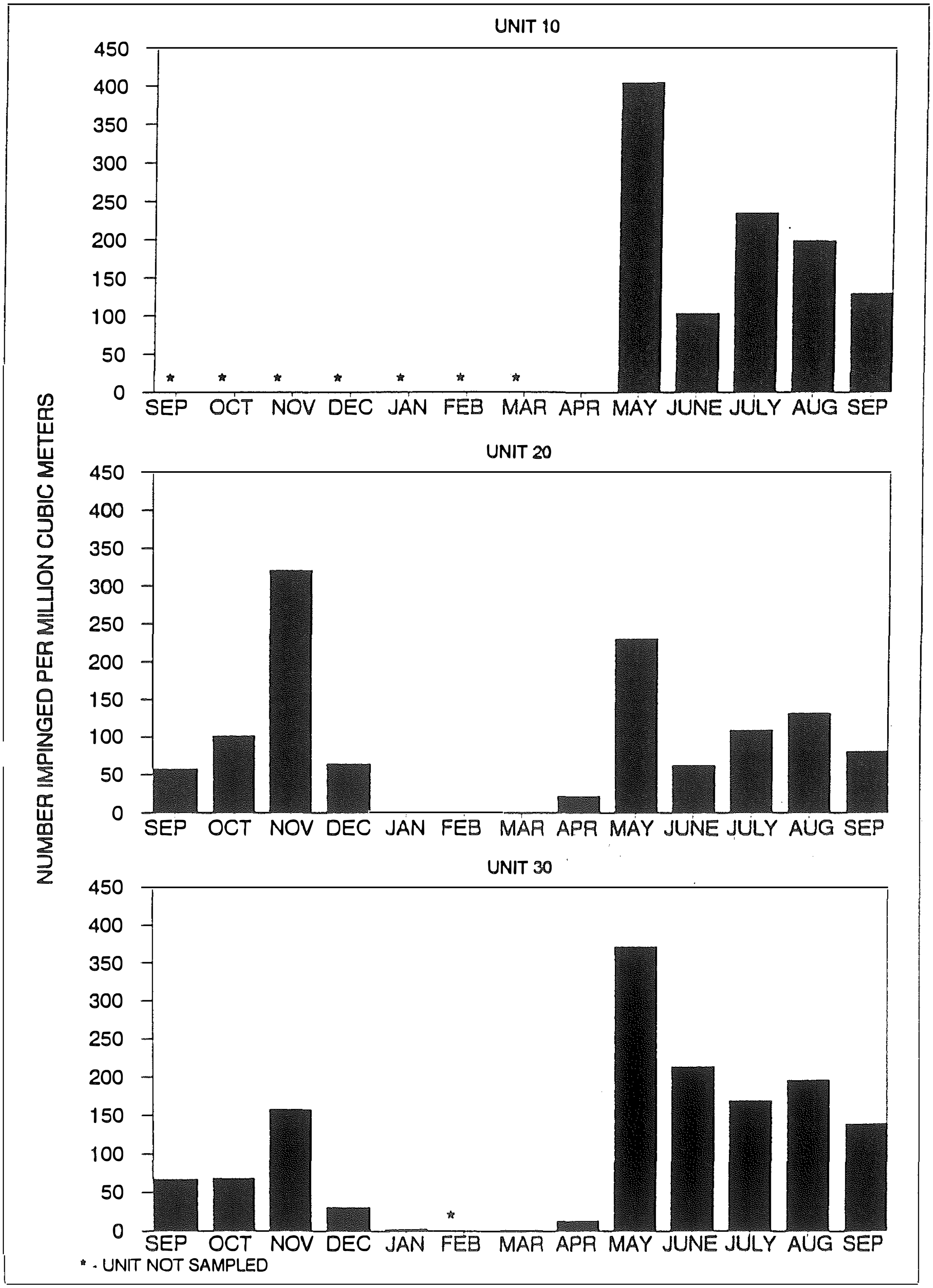

Figure 7. **Average monthly impingement rate of bluecrabs at Ravenswood Units 10, 20 and 30 during September 1991 - September 1992.**
(Source: LMS 1993)

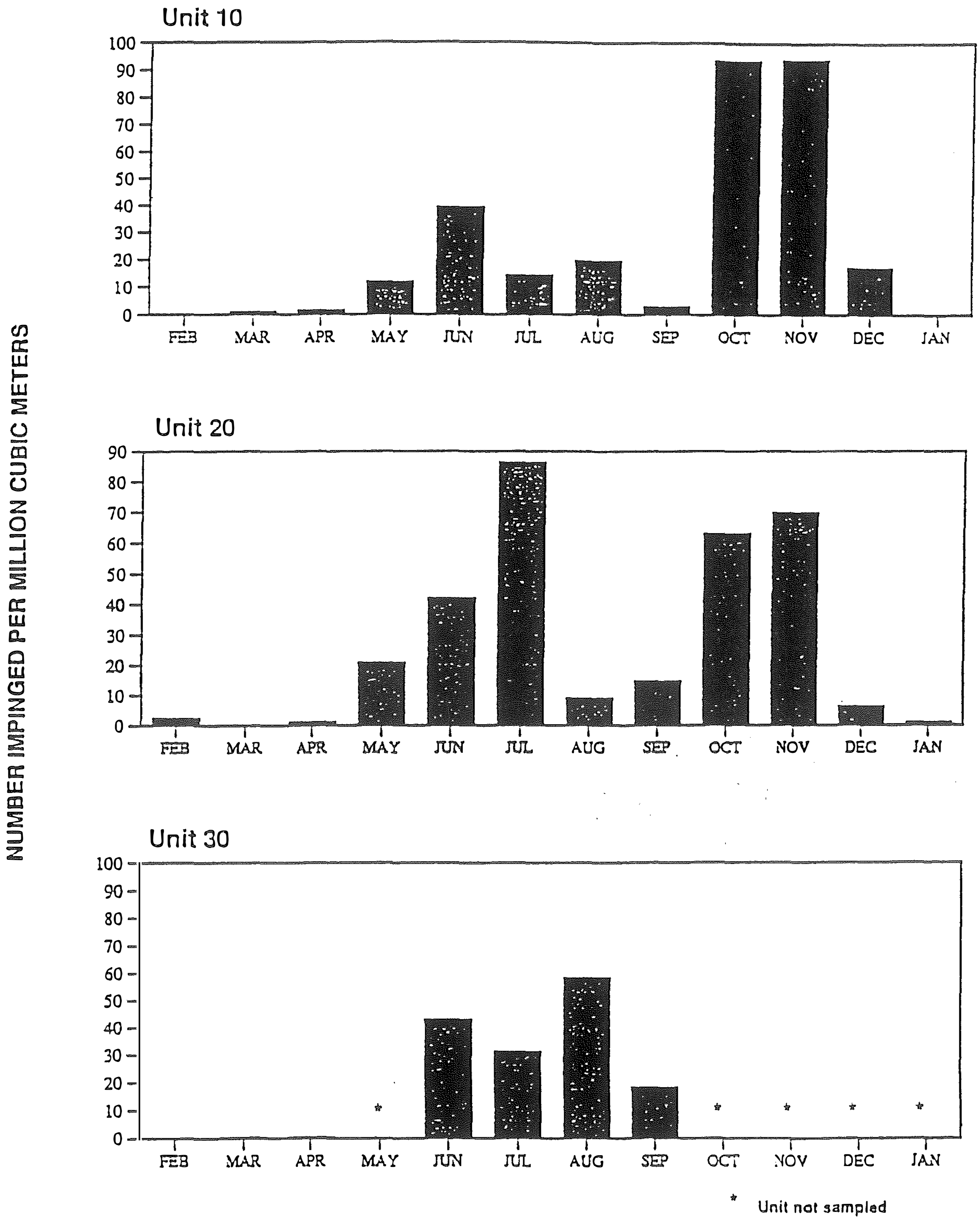

Figure 8. **Average monthly impingement rate of bluecrabs at Ravenswood Units 10, 20 and 30 during February 1993 - January 1994.**
(Source: NAI 1994)

D. Entrainment Results

During the two study intervals, September 1991 - September 1992 and February 1993 - January 1994, a total of 36,692 fish eggs , larvae and juveniles were collected in weekly or bi-monthly 24-hour sampling. In the 1991-1992 study, 11,311 individuals comprised of 25 species (plus four higher taxa) were collected. In the 1993 - 1994 study, 25,651 individuals comprised of 29 species (plus five higher taxa) were collected at units 10, 20, and 30 combined. When scaled to actual plant operating volumes, an estimated 183.7 million fish were entrained in 1991-1992 and 258.5 million were entrained in 1993-1994. There were differences in the relative contributions of the more abundant life stages and species to the totals. In 1991-92, eggs made up 95% of the total numbers of organisms entrained (fourbeard rockling contributed nearly 90% of the eggs entrained; LMS,1993), whereas in 1993 - 1994, eggs made up about 60% of the total numbers entrained (fourbeard rockling contributed approximately 63% of the total numbers of eggs; NAI 1994). The variability between years probably reflects some differences in the units' operation during the two periods, as well as differences in year class strength and the transient nature of many of the species making up the fish community near the Ravenswood Station.

The number of organisms entrained in any time interval is a function of exposure to the cooling water intakes and the characteristics of the intake, particularly the volume of cooling water flow. In making comparisons among intakes or periods of time, both elements need to be considered. Sampling results averaged across the two years of study reflect both sources of variability Five species of fish contributed about 94% of the average 12-month total over the two study periods (Table 7). Four of the five species were among the five most abundant species of fish entrained in both years. Atlantic menhaden was the most numerous species collected in 1991 - 1992, while tautog was the most numerous in 1993 - 1994. Total entrainment was relatively low from November to January, and highest in April (Table 7). Bay anchovy and silver hake were the major contributors to summer entrainment, while fourbeard rockling, winter flounder and the grubby were the most abundant species in late winter and spring. Entrainment rates, (numbers of fish entrained per unit volume of cooling water flow), were lowest in fall and early winter and highest in the early spring. From June through September, when all three units are expected to be operated in the future, the most likely species to be entrained are silver hake and bay anchovy (Table 7).

Entrainment effects are a function of both numbers entrained and post-entrainment viability. Post-entrainment viability of bay anchovy has generally been found to be low (EA 1986). No information has been found on silver hake, but post-entrainment viability of other gadids (cods) has been reported for several Hudson River plants. Post-entrainment viability of eggs, yolk-sac larvae, post-yolk-sac larvae and juveniles are reported to be 100%, 63%, 46.9% and 42.5%, respectively, due to mechanical factors; no thermal mortality was observed at temperatures below 24.2 deg. C (EA 1986). Post-entrainment viability of winter flounder has been reported to be inversely related to delta T and discharge temperature. Viability after 96 hours was about 93% at a delta T of 3.5 deg C and a discharge temperature of 14.8 deg. C, but only about 24% at a delta T of 9.3 deg C and a discharge temperature of 19 deg. C (EA 1986)

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TABLE 3-16 ESTIMATED NUMBER OF EGGS, LARVAE, AND JUVENILES ENTRAINED FROM OCTOBER 1991 TO SEPTEMBER 1992

TAXON	1991 OCT	1991 NOV	1991 DEC	1992 JAN	1992 FEB	1992 MAR	1992 APR	1992 MAY	1992 JUN	1992 JUL	1992 AUG	1992 SEP	TOTAL	STD ERROR	CV	PERCENT
EGGS																
Bay anchovy	0	0	0	0	0	0	0	0	1,978,836	4,013,547	186,339	0	6,178,722	1,718,731	27.8	3.5
Hogchoker	0	0	0	0	0	0	0	7,584	41,584	60,514	88,272	0	197,954	102,251	51.8	0.1
Atlantic menhaden	4,915,720	0	0	0	0	0	0	0	136,614	0	0	0	5,052,334	56,613	1.1	2.9
Weakfish	0	0	0	0	0	0	0	46,937	105,560	0	0	0	152,497	102,031	66.9	0.1
Cyprinidae																
Unidentified	0	0	0	0	0	0	109,170	0	0	0	0	0	109,170	105,468	96.6	0.1
Tautog	0	0	0	0	0	0	0	0	0	7,528	0	0	7,528	7,026	93.3	<0.1
Fourbeard rockling	0	0	0	0	0	3,566,666	141,687,256	11,015,188	0	0	0	0	156,269,110	114,874,130	73.5	89.5
Winter flounder	0	0	0	0	0	606,262	87,336	0	0	0	0	0	693,598	263,713	38.0	0.4
Silver hake	0	0	0	0	0	0	0	0	26,09042	3,109,883	21,798	0	5,740,723	2,618,319	45.6	3.3
Unidentifiable	0	0	0	0	0	0	0	0	8,797	0	0	0	8,797	8,030	91.3	<0.1
Windowpane	0	0	0	0	0	0	0	0	96,763	0	0	0	96,763	88,333	91.3	0.1
Total	4,915,720	0	0	0	0	4,172,928	141,883,762	11,069,709	4,977,196	7,191,472	296,409	0	174,507,196	115,120,928	66.0	
YOLK SAC LARVAE																
Grubby	0	0	0	0	12,409	195,570	0	0	0	0	0	0	207,979	35,111	16.9	96.9
American sand lance	0	0	0	0	0	6,757	0	0	0	0	0	0	6,757	6,528	96.6	3.1
Total	0	0	0	0	12,409	202,327	0	0	0	0	0	0	214,736	41,307	19.2	
POST-YOLK SAC LARVAE																
Bay anchovy	33,669	15,687	0	0	0	0	0	0	0	7,815	821,485	18,484	897,140	499,355	55.7	13.5
Atlantic menhaden	33,669	7,843	0	0	0	0	31,992	0	0	0	0	0	73,504	31,822	43.3	1.1
Northern pipefish	0	0	0	0	0	0	0	0	0	7,815	0	0	7,815	7,293	93.3	0.1
Tautog	0	0	0	0	0	0	31,992	0	0	15,630	0	0	47,622	34,176	71.0	0.7
Striped cusk-eel	0	0	0	0	0	0	151,319	85,90	8,797	0	0	0	168,706	25,254	15.0	2.5
Spot	0	7,580	0	0	0	0	107,651	0	0	0	0	0	115,231	20,948	18.2	1.7
Winter flounder	0	0	0	0	0	0	367,903	1,689,785	357,851	7,957	0	0	2,423,496	619,358	25.6	36.4
Unidentifiable	0	7,843	0	0	0	0	0	0	17,686	0	343,490	55,453	42,4472	313,352	73.8	6.4
Grubby	0	0	0	0	0	54,055	529,380	352,317	0	0	0	0	935,752	495,295	52.9	14.0
Rough silverside	0	0	0	0	0	0	79,979	0	0	0	0	0	79,979	77,267	96.6	1.2
Summer flounder	0	31,110	57,474	106,341	12,269	0	0	0	0	0	0	0	207,194	34,126	16.5	3.1

157.12x10^6 / 2 = 78.56x10^6 (50%) red

26.6 (.10 reduction) = 2.6x10^6 = 80x10^6 red.

50% water red from MAR-MAY = 78.56 x10^6 entrain. Red.
By eliminating entrainment from June-Feb would result in only ≈ 5-7% annual reduction in entrainment (less than EPA's 60% minimum)

TABLE 3-16 ESTIMATED NUMBER OF EGGS, LARVAE, AND JUVENILES ENTRAINED FROM OCTOBER 1991 TO SEPTEMBER 1992

	1991			1992												
TAXON	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	STD ERROR	CV	PERCENT
POST-YOLK SAC LARVAE (Continued)																
Seaboard goby	0	15,160	0	0	0	0	0	0	0	0	0	0	15,160	14,646	96.6	0.2
Windowpane	0	7,843	0	0	0	0	0	0	148,207	0	9,808	0	16,5858	89,069	53.7	2.5
American sand lance	0	0	0	9,677	0	0	174,672	0	0	0	0	0	18,4349	169,009	91.7	2.8
Smallmouth flounder	0	0	0	0	0	0	0	0	0	0	9,808	0	9,808	9,153	93.3	0.1
Gobiidae - gobies	505,040	39,217	23,048	0	0	0	0	0	0	0	253,875	36,969	85,8149	61,193	7.1	12.9
Bothidae unidentified	0	0	0	0	0	0	0	0	4,481	0	0	0	4,481	4,090	91.3	0.1
Cunner	0	0	0	0	0	0	0	0	0	7,957	0	0	7,957	7,426	93.3	0.1
Sciaenidae	0	0	0	0	0	0	0	0	0	7,957	9,808	0	17,765	11,787	66.3	0.3
Blackcheek tonguefish	0	0	0	0	0	0	0	0	0	0	0	18,484	18,484	17,858	96.6	0.3
Total	572,378	132,283	80,522	116,018	12,269	54,055	1,474,888	2,050,692	537,022	55,131	1,448,274	129,390	6,662,922	1,328,322	19.9	
YOUNG OF YEAR																
Bay anchovy	0	7,843	0	0	0	0	0	0	0	0	0	0	7,843	7,577	96.6	0.6
Northern pipefish	0	15,423	0	0	0	0	0	0	8,961	399,620	407,542	0	831,546	94,807	11.4	68.3
Striped cusk-eel	0	0	0	0	0	0	0	25,770	0	0	0	0	25,770	24,050	93.3	2.1
Winter flounder	0	0	0	0	0	0	0	0	39,667	13,478	0	0	53,145	33,453	62.9	4.4
Northern puffer	0	0	0	0	0	0	0	0	0	0	10,899	0	10,899	10,172	93.3	0.9
Summer flounder	0	7,843	0	0	0	0	0	0	0	0	0	0	7,843	7,577	96.6	0.6
Striped searobin	0	0	0	0	0	0	0	0	0	7,957	0	0	7,957	7,426	93.3	0.7
Seaboard goby	0	15,160	0	9,662	0	0	0	0	0	0	15,907	0	40,729	22,852	56.1	3.3
Naked goby	0	0	22,902	0	0	0	0	0	0	0	0	0	22,902	22,151	96.7	1.9
Windowpane	0	0	0	0	0	0	0	0	13,442	15,772	10,019	0	39,233	17,613	44.9	3.2
Northern stargazer	0	0	0	0	0	0	0	0	0	7,815	42,505	0	50,320	29,698	59.0	4.1
Smallmouth flounder	0	0	0	0	0	0	0	0	0	0	10,899	0	10,899	10,172	93.3	0.9
Gobiidae - gobies	67,339	7,843	22,902	9,677	0	0	0	0	0	0	0	0	10,7761	25,213	23.4	8.9
Total	67,339	54,112	45,804	19,339	0	0	0	25,770	62,070	444,642	497,771	0	1,216,847	129,438	10.6	
UNIDENTIFIABLE LIFE STAGE SPECIES																
Unidentifiable	0	0	0	0	0	67,020	328,792	7,584	0	23,445	0	0	426,841	61,728	14.5	37.4
Grubby	0	0	0	0	0	650,604	63,983	0	0	0	0	0	714,587	91,273	12.8	62.6
Total	0	0	0	0	0	717,624	392,775	7,584	0	23,445	0	0	1,141,428	88,412	7.7	

183.73×10^6

Table 7. Average numbers of five most abundant fish species entrained at the Ravenswood Generating Station During September 1991 - September 1992 and February 1993 - January 1994. (Updated 9/27/96)

Estimated Numbers Entrained

Species	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Fourbeard Rockling	0	180,039	2,647,063	113,538,263	12,149,819	21,400	0	0	0	0	0	0	128,536,584
Bay Anchovy	0	0	0	0	0	3,510,826	10,247,073	4,395,206	7,295,126	65,344	40,996	64,095	25,618,666
Winter Flounder	0	3,735,795	8,968,743	3,194,251	846,533	178,926	3,979	0	0	0	0	0	16,928,227
Grubby	0	2,616,760	3,040,931	5,202,027	562,788	-	-	-	-	-	0	0	11,422,506
Silver hake	0	0	0	0	11,040	3,137,910	1,819,127	16,288	0	0	0	0	4,984,365
Subtotal	0	6,532,594	14,656,737	121,934,541	13,570,180	6,849,062	12,070,179	4,411,494	7,295,126	65,344	40,996	64,095	187,490,348
All Species	78,620	6,943,814	14,813,646	123,185,531	13,985,803	9,644,123	14,137,349	5,511,181	7,797,620	3,072,477	155,768	159,343	199,485,275
% of Annual Total	0.0	3.5	7.4	61.8	7.0	4.8	7.1	2.8	3.9	1.5	0.1	0.1	100.0

c:entrain.rav

Table 7. Average numbers of ~~ten~~ (5) five most abundant fish species entrained at the Ravenswood Generating Station During September 1991 - September 1992 and February 1993 - January 1994.

					Estimated Numbers Entrained								
Species	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Fourbeard Rockling	0	180,039	2,647,063	113,538,263	12,149,819	21,400	0	0	0	0	0	0	128,536,584
Bay Anchovy	0	0	0	0	0	3,510,826	10,247,073	4,395,206	7,295,126	65,344	40,996	64,095	25,618,666
Winter Flounder	0	3,735,795	8,968,743	3,194,251	846,533	178,926	3,979	0	0	0	0	0	16,928,227
Grubby	0	2,616,760	3,040,931	5,202,027	562,788	-	-	-	-	-	0	0	11,422,506
Silver hake	0	0	0	0	11,040	3,137,910	1,819,127	16,288	0	0	0	0	4,984,365
Subtotal	0	6,532,594	14,656,737	121,934,541	13,570,180	6,849,062	12,070,179	4,411,494	7,295,126	65,344	40,996	64,095	187,490,348 (94%.6 Total)
All Species	78,620	6,943,814	14,813,646	123,185,531	13,985,803	9,644,123	14,137,349	5,511,181	7,797,620	3,072,477	155,768	159,343	199,325,932
% of Annual Total	0.0	3.5	7.4	61.8	7.0	4.8	7.1	2.8	3.9	1.5	0.1	0.1	100.0
c:entrain.rav													

18.6% (June–Sept)

44.87% × All spp =

35,278 3,115,796 6,647,109 5,473,895 6,275,644 1,378,667 69895 71499

Σ = 72,207,783

% Reduction in flow if Units 10 + 20 on reserve shutdown.

% of total = 72,207,783 / 199,325,932

= 36.3%

Unit-specific entrainment rates were not examined because of the inability to sample discharges from each unit. However, because the intake bays for the three units are close together (all are located within a distance of 300 m) and there are no apparent flow patterns that would suggest that different zones of water withdrawal exist for the individual intakes, the value of unit-specific rates is uncertain. Under these circumstances, cooling water volume is likely to be the primary determinant of entrainment of immobile or slightly-motile organisms.

IV. Short-Term Remedial Action

A. Introduction

The Consent Order required Con Edison, as a short-term remedial action, to modify the existing fish and debris return systems at the Station's intake screen wash water sluices so that impinged fish were more likely to pass through the debris collection chamber and be returned with minimal additional stress to the East River. Con Edison's proposed design and implementation schedule for the modifications was approved by the Department on August 5, 1993. A brief description of the test program and final return system modifications that were installed is presented below.

B. Proposed Modifications and Test Plans

The initial design for the modification proposed for conveying fish and bluecrabs from the debris sluice through the debris basin to the East River consisted of a rectangular-shaped sluice system that followed the inside perimeter of the debris basin to the bottom of the basin, where it discharged into the 24 in. diameter cast iron pipe that drained to the Station's discharge canal. The proposed design also called for devices installed within the washwater sluice to passively remove large pieces of debris from the sluice water, yet allow fish and bluecrabs to be carried along by the flow. The debris was to be transferred to a collection basket that was to be located in the central part of the basin, within the perimeter of the proposed new sluice. Fish and bluecrabs were to be conveyed to the basin's discharge pipe and then on to the discharge canal and East River. Since the final design for the passive system could only be arrived at through field tests, alternative forms of the separator section of the sluice system were fabricated, installed, and tested before construction of the entire sluice system. Testing was performed by releasing upstream of the separator, quantities of debris previously washed from the screens, and then observing the effectiveness of debris separation from the flow and subsequent transfer to a collection basket. Results disclosed that the variable nature of the debris present (wood, sticks, plastic bags) was not amenable to separation from the flow by a passive system. Although large pieces of debris were readily separated from the flow, they often became entangled in extensions of the separator that were intended to shunt the debris to the debris basket. By letter dated April 29, 1994, the Company advised the Department of the status of testing, and announced plans to evaluate the effectiveness of a 2 ft diameter spiral-shaped polyethylene tube to transfer screen washings (fish, bluecrabs, and debris) to the debris basin discharge pipe.

The 2 ft diameter polyethylene tube was installed in the Unit 10 debris basin for initial tests on May 2, 1994. This conduit was designed to receive the flow from the screen wash water sluice at elevation 13.3 ft and convey it through a 270 degree spiral to the cast iron drain pipe at elevation 5.0 ft (Figure 9). Testing was performed by releasing debris collected from the screen into the screen washwater sluice and then inspecting the system for blockages or flow disruptions. All debris was efficiently transported through the polyethylene tube and into the cast iron drain pipe. Flow conditions within the polyethylene tube were similar to conditions observed in full scale tests of a sluice system designed for Indian Point Station Unit No. 2 to convey fish through 5 to 10 ft elevation changes without damage (Con Edison and NYPA 1992). These observations suggested that the polyethylene tube would be highly effective in conveying fish and bluecrabs, as well as debris, that were washed from the intake screens to the debris basin drain pipe. As a result, similar polyethylene tubes were installed at Units 20 on May 24, and at Unit 30 on June 11, 1994.

The Department (Mr. Edward Radle) was notified on June 13, 1994 that the modifications to the return systems were completed at the three units. Following a September 16, 1994 inspection of the modified fish and debris sluices at the Station's three units, DEC concluded in a letter dated October 4, 1994, that the polyethylene spiral tube sluices provided a reasonably smooth transfer of fish through the debris basin without abrupt changes in direction or elevation, and satisfied the short-term remedial construction requirements of the Consent Order. Inspections of the condition and performance of each of the polyethylene spiral tubes in the washwater return systems at Ravenswood Units 10, 20, and 30 were made on October 31, 1994, January 5, 1995 and March 17, 1995. Those inspections and observations in March 1996 disclosed that the systems were in satisfactory condition.

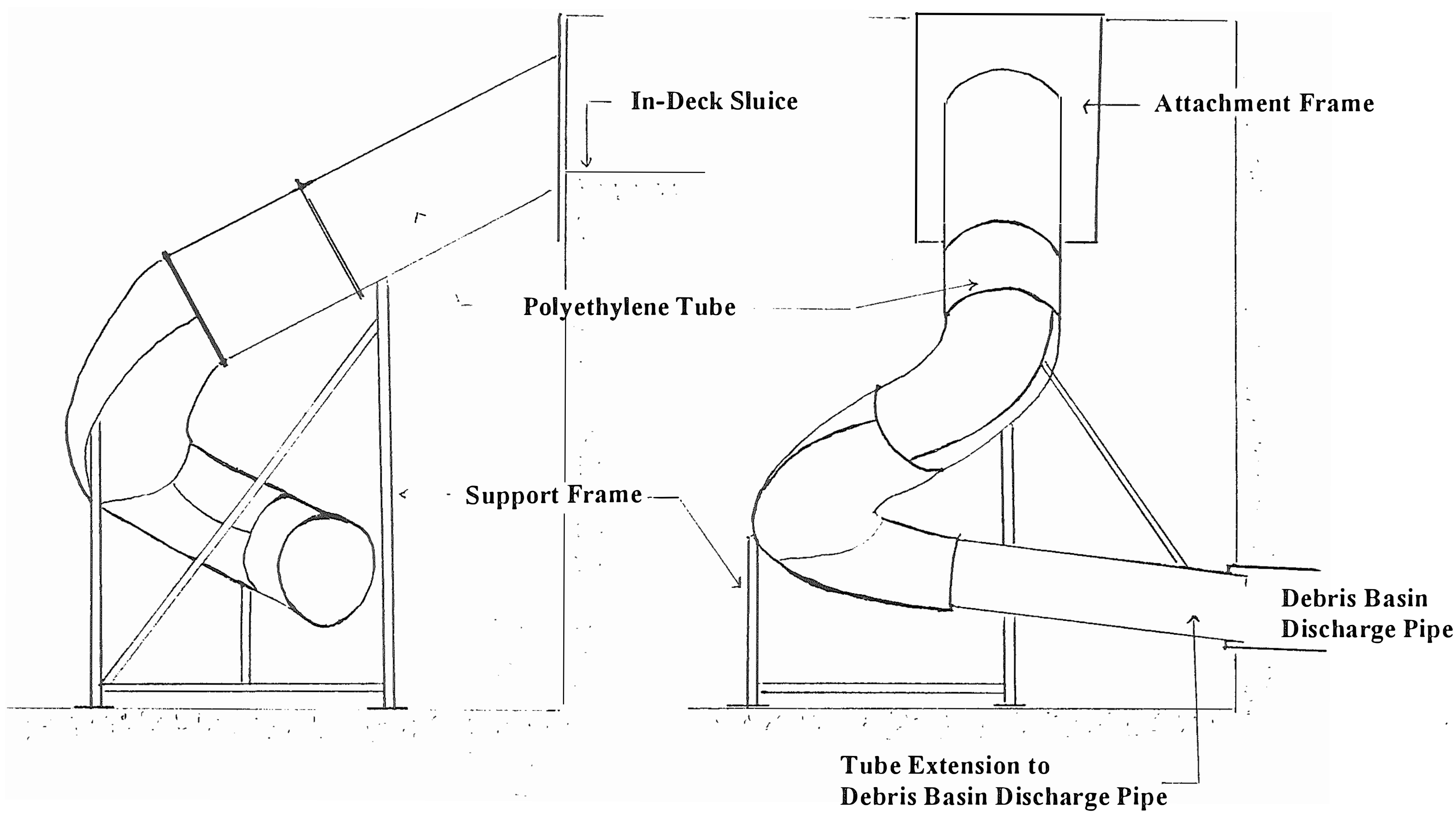

Figure 9. **Vertical sections of polyethylene spiral-tube installed to extend in-deck screen wash water sluices to debris basin drains at Ravenswood Generating Units 10, 20, and 30.**

V. Intake Water Velocity Profile Studies

A. Introduction

To facilitate application of results of post-impingement viability studies at the Arthur Kill Generating Station to the Ravenswood Generating Station, velocity profiles were measured at through-flow screen No. 32 at Ravenswood Unit No. 30 (LMS 1996b; Appendix A). The purpose of the profile measurements was to determine the distribution of the velocity and direction of flow in a cross-sectional plane within the intake bay near the face of the screen, and determine the potential effects of the observed velocities on impinged fish, based on observations at similar intakes at other generating stations.

B. Velocity Study Methods and Materials

Measurements were made at five uniformly distributed horizontal positions (Figure 10) at five depths on a cross-sectional plane located approximately 6 ft upstream[1] of the face of the traveling screen no. 32 at Ravenswood. The 25 velocity profile measurements that were made across the cross-sectional plane were used to characterize the intake bay approach flow. During the velocity profile measurement period, screen repair work was being performed on three of the six traveling screens at Unit 30, including screens Nos. 31 and 33, which were adjacent to test screen bay No. 32. The entrance to the intake bays Nos. 31 and 33 were temporarily screened with fixed fine mesh (3/8 in sq. mesh) panels, and debris loading on these screens appeared to be substantial. Since water flow to the circulator was partially blocked by the debris on the adjacent screens, flow rate through screen No. 32 appeared to have been increased.

Measurements were made with a Marsh-McBirney Model 511 electromagnetic 2-axis water current meter, identical to that used by Fletcher (1994). The instrument was attached to a PVC pipe frame that measured approximately 3 ft. by 11 ft (Figure 11). Pins protruded through the vertical members of the frame and served as guides for raising and lowering the frame within the fine mesh screen slot. The meter was attached to a horizontal arm that was supported by a vertical member of the frame (Figure 11). Adjustments to the length of the arm allowed placement of the meter at any of the five horizontal measurement points. Before velocity profile measurements were made, tests were performed to determine whether stray electrical currents or the metallic mass of the screen would interfere with the electromagnetic flow meter. Electrical current interference was evaluated by adjusting the Marsh-McBirney meter circuitry (LMS 1996b). Metallic mass interference was evaluated by substituting a Price-Pygmy mechanical meter for the Marsh-McBirney electromagnetic meter (LMS 1996b).

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[1] Profile measurements were intended to be taken by attaching the water current meter to screen baskets. However, a debris deflector plate mounted adjacent to the screen precluded this arrangement.

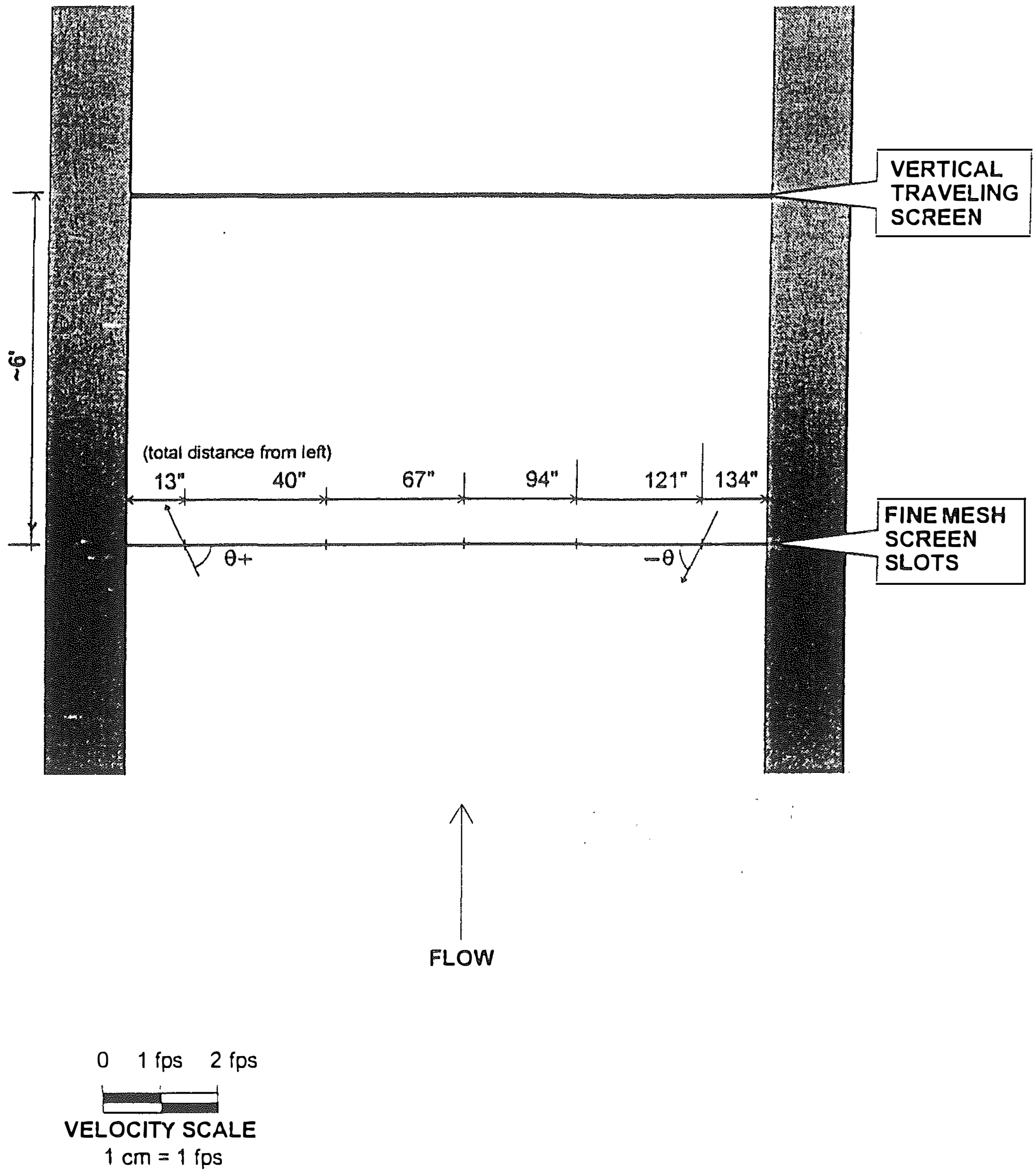

Figure 10. **Velocity measurement locations at Ravenswood Generating Station Intake Bay No. 32.** (Source: LMS 1996b)

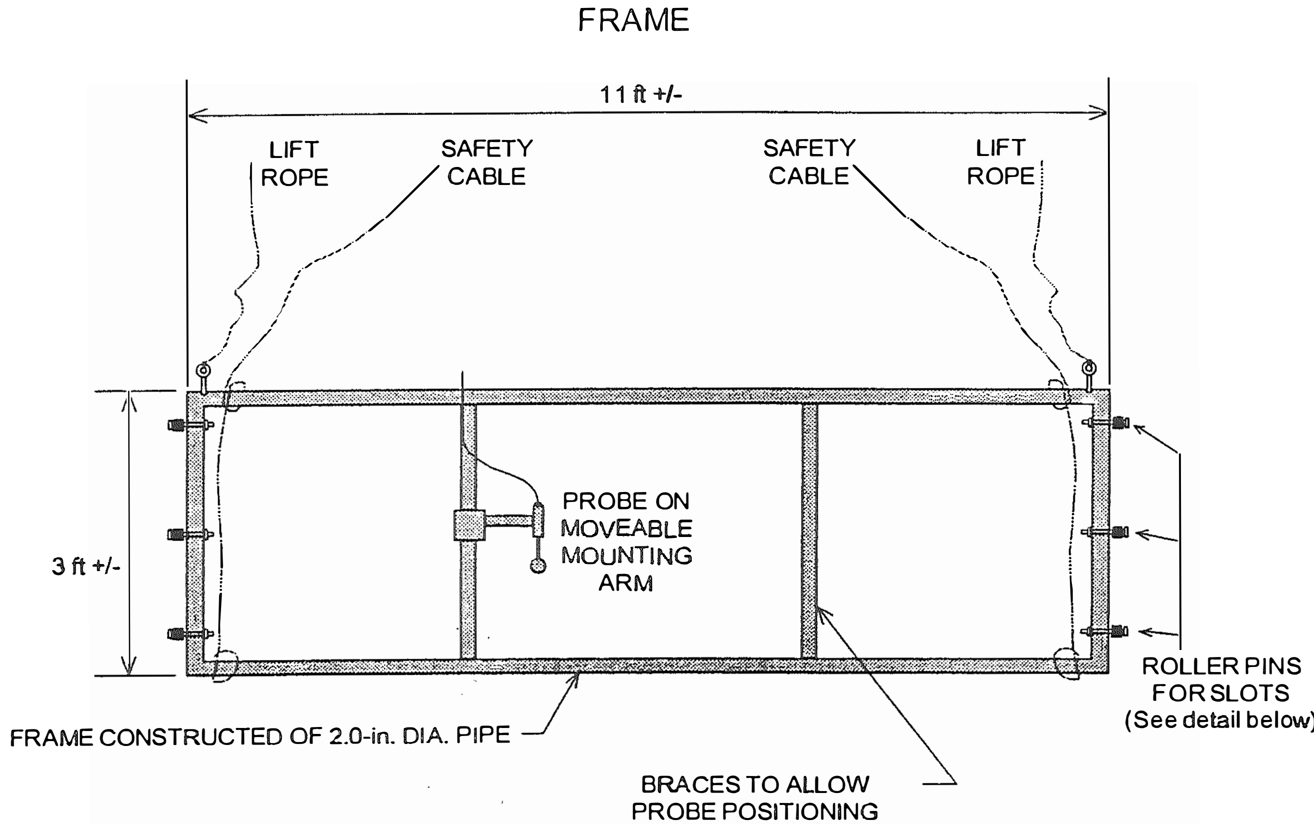

Figure 11. **Water current meter mounting frame used at Ravenswood Generating Station Intake Bay No. 32.** (Source: LMS 1996b)

Three readings of the X,Y components of flow were made at 20 second intervals at each of the 5 horizontal transect and 5 depth positions. In addition, the maximum and minimum meter readings at each coordinate were also recorded to indicate the variability in flow conditions at the measurement point. Velocity vectors (speed and angle) were calculated for each paired set of X, Y components. Resultant values were averaged vertically to generate flow velocity and angle vectors for each horizontal measurement location. In addition a single summary velocity vector was calculated for the entire bay.

C. Study Results

Tests performed to determine the presence of stray electrical currents that might interfere with the electromagnetic water current meter disclosed that none were present. In one instance, electrical welding, which was being performed nearby, caused interference with velocity measurement readings. As a result, readings were not taken when welding was being performed.

Tests were also performed to determine whether the metallic mass of the dual flow screen and associated materials might interfere with the electromagnetic water current meter. Results with the electromagnetic meter were consistent with those obtained with the mechanical meter, which suggested that there were no metallic interferences with the electromagnetic meter (Table 8). Flow profile measurements indicated that vertically-averaged velocities ranged from 0.9 to 1.5 fps, while horizontally averaged velocities ranged from approximately 0.4 to 1.8 fps. The overall cross-sectional average velocity was approximately 1.3 fps (Table 9), which was about 60% greater than expected (Table 1). The increased velocity was believed to be due to accumulations of debris on adjacent intake screens, which were out of service for maintenance, and were not being cleaned on the routine schedule. Blockage of flow at these screens caused more flow to be drawn through test screen no. 32. Vertically-averaged approach flow angles ranged from 59 to 87 degrees, while the horizontally-averaged angles ranged from 100 degrees at the mid-depth level to about 30 degrees near the bottom. The overall average approach angle was 78 degrees. (Figure 12). Deviation from flows that are parallel to the side walls of the channel suggested that approach flows were somewhat irregular, a condition that might have been caused by uneven distribution of flow through the adjacent channels (LMS 1996).

Results of the Ravenswood Unit 30 intake bay No. 32 flow velocities were compared with velocities measured at the Arthur Kill Generating Station. Ravenswood flow velocities at localized areas within the Intake Bay 32 were higher than those observed at the Arthur Kill Station (LMS 1996a), and, given that the cross-sectional area of the through-flow screen would be somewhat less than that for the entire intake bay where the velocities were measured, the screen face velocities would be somewhat higher still. However, since that design basis calculated flow velocities (Table 1) are similar to those at the Arthur Kill Station (Table 10), absent adverse debris loading conditions on adjacent screens, velocity profile measurements at Ravenswood can be reasonably expected to be lower than observed, and similar to those at the Arthur Kill Station.

Table 8. Assessment of potential interferences with electromagnetic water current meter usage in Ravenswood Station Intake Screen Bay No. 32.

Screen No.	Electromagnetic Measurements Rep 1	Rep 2	Average	Mechanical Meter Readings	Percent Difference
32	57	62	59	53	11

Source: LMS 1996b.

c:\meter.rav

Table 9. Ravenswood Generating Station intake water flow velocity and approach angle at Intake Bay No. 32.

	Flow Velocity (fps)					
	Horizontal Position (inches) measured from north intake wall*					Average Velocity
Depth (ft)	13.4	40.2	67.0	93.8	120.6	
14.9	2.0	0.9	1.9	1.1	1.7	1.5
19.0	0.8	1.2	1.2	2.9	2.7	1.8
24.5	0.8	2.1	2.3	2.2	1.0	1.7
30.0	0.3	1.5	1.1	0.3	1.9	1.0
34.0	0.6	0.0	0.5	0.4	0.4	0.4
X	0.9	1.1	1.4	1.4	1.5	
				Intake Bay Average =		1.3

* Intake Bay Width = 11.2 ft.

	Approach Flow Angle (degrees toward mesh)					
	Horizontal Position (inches) measured from north intake wall*					Average Angle
Depth (ft)	13.4	40.2	67.0	93.8	120.6	
14.9	105	99	92	80	75	90
19.0	15	66	72	74	90	63
24.5	82	90	91	109	128	100
30.0	131	92	70	72	84	90
34.0	90	-	69	74	-82	38
				Intake Bay Average =		76

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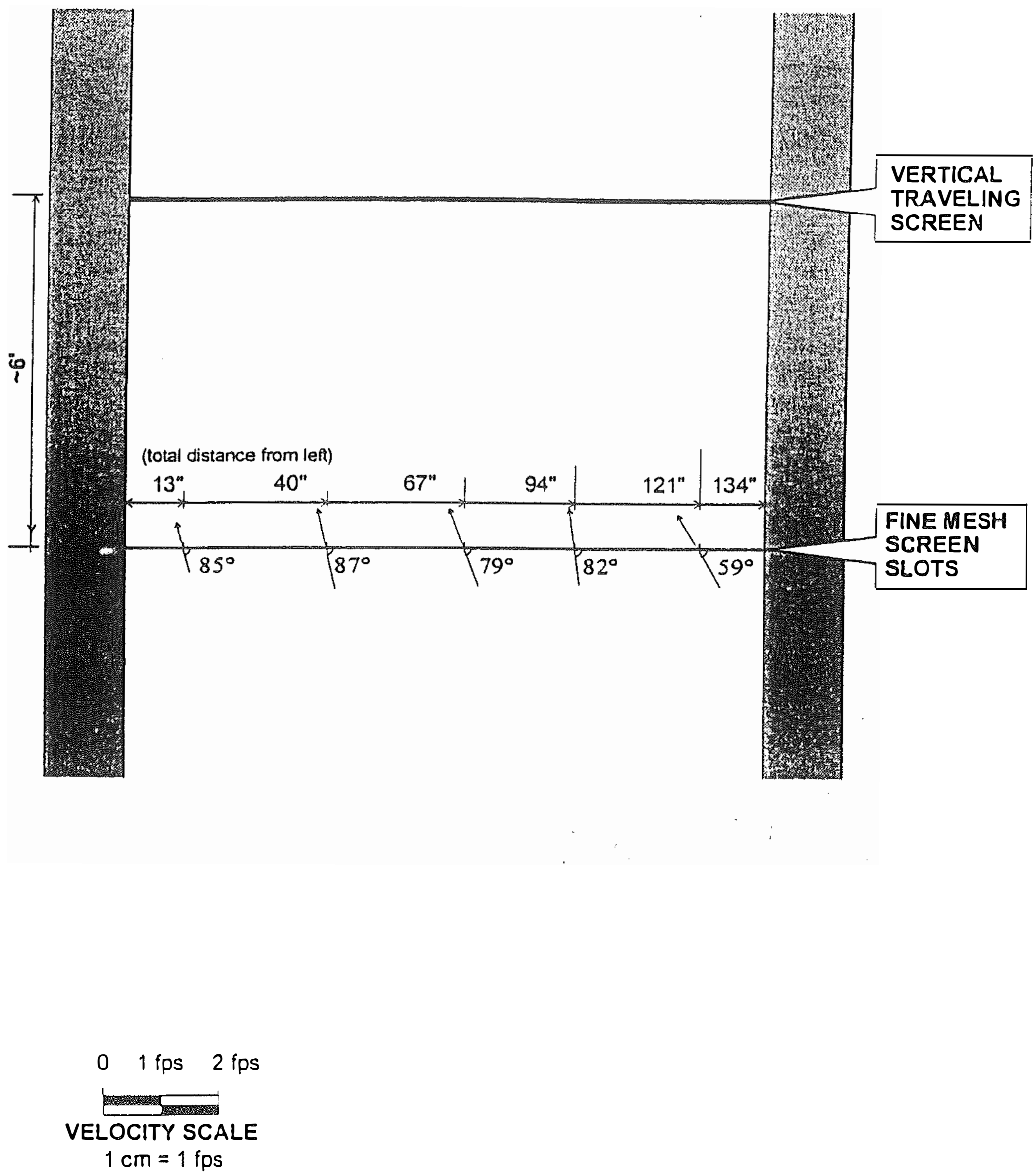

Figure 12. **Vertically averaged water current angles at Ravenswood Generating Station Intake Bay No. 32.** (Source: LMS 1996b)

Table 10.	Arthur Kill Generating Station water intake dimensions and approximated intake flow velocities.							
Dimensions							Design Flow (gpm/screen)	
		Intake	Intake	Circulator	Service	No. Screens	Circulator	Circulator +
Unit No.		Width	Depth	Flow (gpm)	Flow (gpm)	Per Circ.	Only	Service
20		11.2	25	122,000	16,000	2	61,000	69,000
30		11.2	14.5	105,000	25,350	2	52,500	65,175
Velocities								
Unit 20							Flow/	
		Tide	Tide	Section	Section	Effective	Screen	Approx.
Intake Location		Stage	Level (ft)	Width (ft)	Depth (ft)	Area (ft2)	(gpm)	Vel (fps)
Forebay		Low	-0.4	11.2	24.6	276	69,000	0.6
		High	4.7	11.2	29.7	333	69,000	0.5
Screen Portal		Low	-0.4	2.4	24.6	59	69,000	2.6
		High	4.7	2.4	29.7	71	69,000	2.2
Screen Face		Low	-0.4	8	24.6	197	69,000	0.8
		High	4.7	8	29.7	238	69,000	0.6
Unit 30							Flow/	
		Tide	Tide	Section	Section	Effective	Screen	Approx.
Intake Location		Stage	Level (ft)	Width (ft)	Depth (ft)	Area (ft2)	(gpm)	Vel (fps)
Forebay		Low	-0.4	11.2	14.1	158	65,000	0.9
		High	4.7	11.2	19.2	215	65,000	0.7
Screen Portal		Low	-0.4	2.4	14.1	34	65,000	4.3
		High	4.7	2.4	19.2	46	65,000	3.1
Screen Face		Low	-0.4	8	14.1	113	65,000	1.3
		High	4.7	8	19.2	154	65,000	0.9
Note: Machine width is 6' 3"								
c:\akvel.xls								

VI. Options for Returning Fish to the East River

A. Introduction

As part of the diagnostic study effort under the Consent Order, Con Edison considered options for returning fish recovered from the Station's intake screens to the East River. An evaluation of the existing fish and debris return system was reviewed, and alternative routes for installation of a dedicated return system were examined.

B. Existing Sluice and Discharge Canal System

The Station's existing screen washwater discharge sluice system presently provides for the return of fish, bluecrabs, and debris collected from each unit's intake screens to the East River. The system consists of an "in-deck" sluice that receives washwater from each unit's through-flow traveling water intake screens. These sluices, which are positioned along the riverside (frontside) of the screens, are approximately 12" wide and increase in depth from approximately 15" at the upstream end to 30" in depth at their discharge point into the debris basins. The in-deck sluices at Units 10 and 20 are approximately 65 ft long, while the sluice at Unit 30 is approximately 90 ft long. At each unit, sluice water currently discharges into a 24 inch diameter polyethylene tube that spirals downward a vertical distance of approximately 8 ft to the bottom of the debris basin where it discharges into the debris basin drain. The drain pipe entrance is located at the bottom of the east sidewall of the basin, and the pipe extends underground approximately 95 ft eastward to the Station's cooling water discharge canal.

Screen washwater from the Unit 10 screens enters the canal at a point approximately 610 ft upstream from the discharge into the East River (Figure 4). Transit time from the screen wash water discharge sluice through the cast iron pipe to the canal is approximately 1.5 minutes (at an estimated 1 ft/sec). (Similar transit times are estimated for Units 20 and 30 as well). Calculated transit time through the canal from the end of the Unit 10 pipe to the East River ranges from approximately 2.0 to 8.5 minutes, depending on whether all three units or only Unit 10 is operating, respectively.

Screen washwater from the Unit 20 intake screens enters the canal at a point approximately 870 ft upstream from its end (Figure 4). Calculated transit time from the end of the pipe to the East River ranges from approximately 2.8 to 13.2 minutes, depending on whether all three units or only Unit 20 is operating, respectively.

Screen washwater from the Unit 30 intake screens enters the canal at a point approximately 1,150 ft upstream of its end (Figure 4). Calculated transit time from the end of the pipe to the East River ranges from approximately 3.7 to 6.8 minutes, depending on whether all three units or only Unit 30 is operating, respectively.

Water temperatures in the discharge canal reflect plant operating conditions, and may reach design delta Ts for full power operation, which are 15.7 deg F (8.7 deg. C) at Units 10 and 20, and 18.8 deg. F (10.4 deg C) at Unit 30. When all three units are operating at full power, the design delta T in the discharge canal would be approximately 17.4 deg. F (9.7 deg. C), which when combined with the approximate August ambient water temperature (75 deg F), would result in a discharge temperature of 93 deg F. Based on a summary of 1991 - 1995 average maximum discharge temperatures, this level is not routinely reached (Figure 13.) During February when ambient temperature is approximately 38 deg F, full power discharge temperatures (three unit operating at full power) would approach 56 deg F.

Present use of the Station's discharge canal as a return conduit for impinged fish and bluecrabs exposes them briefly to elevated temperatures during transit through the system. If the fish moved passively with the water, they would move through the canal in less than 15 minutes, but active swimming could increase or decrease this time. Since post-impingement viability has been shown to be affected by temperature, both ambient water temperature and any increase (delta T) in water temperature to which fish might be exposed after impingement were considered relative to possible fish return system locations. Approximately 77% of the total annual impingement occurs during the months of November through April (Table 2). Of the major species impinged at the Ravenswood Station, only bay anchovy are impinged most frequently during the other 6 months of the year (May - October). During the 1991 - 1992 and 1993 - 1994 studies, ambient river temperatures during November through April seldom reached 15 deg. C., and the maximum level of about 25 deg. C was reached only during July and August (Figures 14 and 15). Although delta T at full power operation at all three may approach 10 deg C, discharge temperatures during the study periods did not exceed 20 deg C during the colder months, or 32 deg C during the warmer seasons. Thermal tolerance limits have been reported for several of the most abundant fish species impinged at Ravenswood. These data suggest that northern pipefish, winter flounder, and Atlantic silversides, which are impinged mostly during the cooler months, are able to tolerate temperatures and delta Ts characteristic of the Ravenswood Station discharges. Results of post-impingement viability studies with winter flounder and Atlantic silversides collected from a Ristroph-modified screen at the Oyster Creek Nuclear Station during November through January and exposed to discharge temperatures was approximately 90% (EA 1986). Thermal tolerance testing of bay anchovy suggest that at a summer ambient temperature of 24 deg C, a discharge temperature of approximately 30 deg C would be tolerated by most individuals recovered alive from the screens (EA 1978). However, work at the Arthur Kill Generating Station suggested that few bay anchovy would survive long exposure to discharge canal temperatures above 30 deg C following recovery from intake screens (Table 11, Con Edison 1996). Tagatz (1969) indicates that bluecrabs have a 48 hour thermal tolerance of near 96 deg F at an ambient temperature of approximately 75 deg F, and accordingly, would be essentially unaffected by the heated water in the Ravenswood Station's discharge canal.

– what were those disch. temps

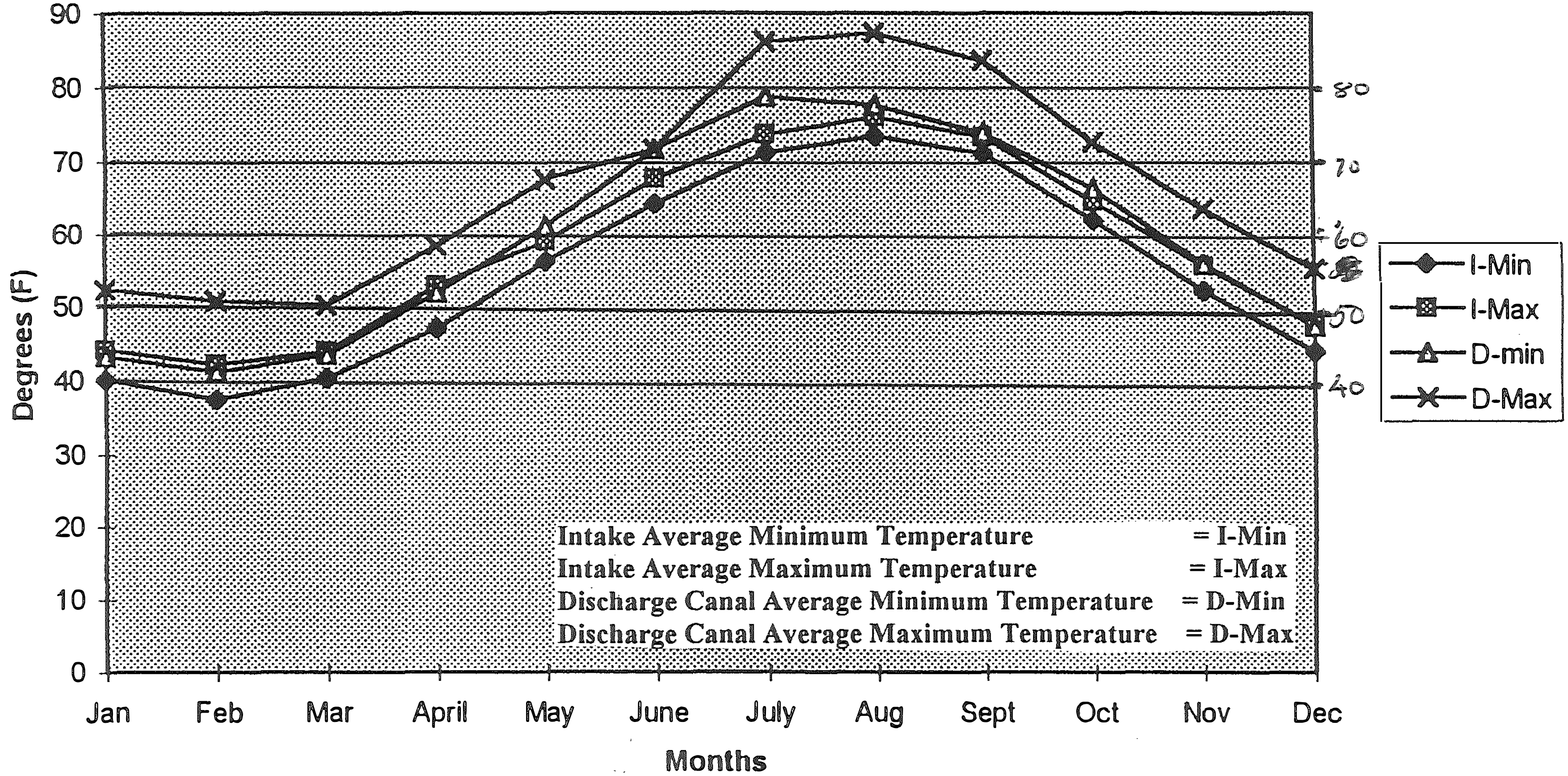

Figure 13. **Average minimum and maximum intake and discharge water temperatures (deg F) at the Ravenswood Generating Station (January 1991 - December 1995).**

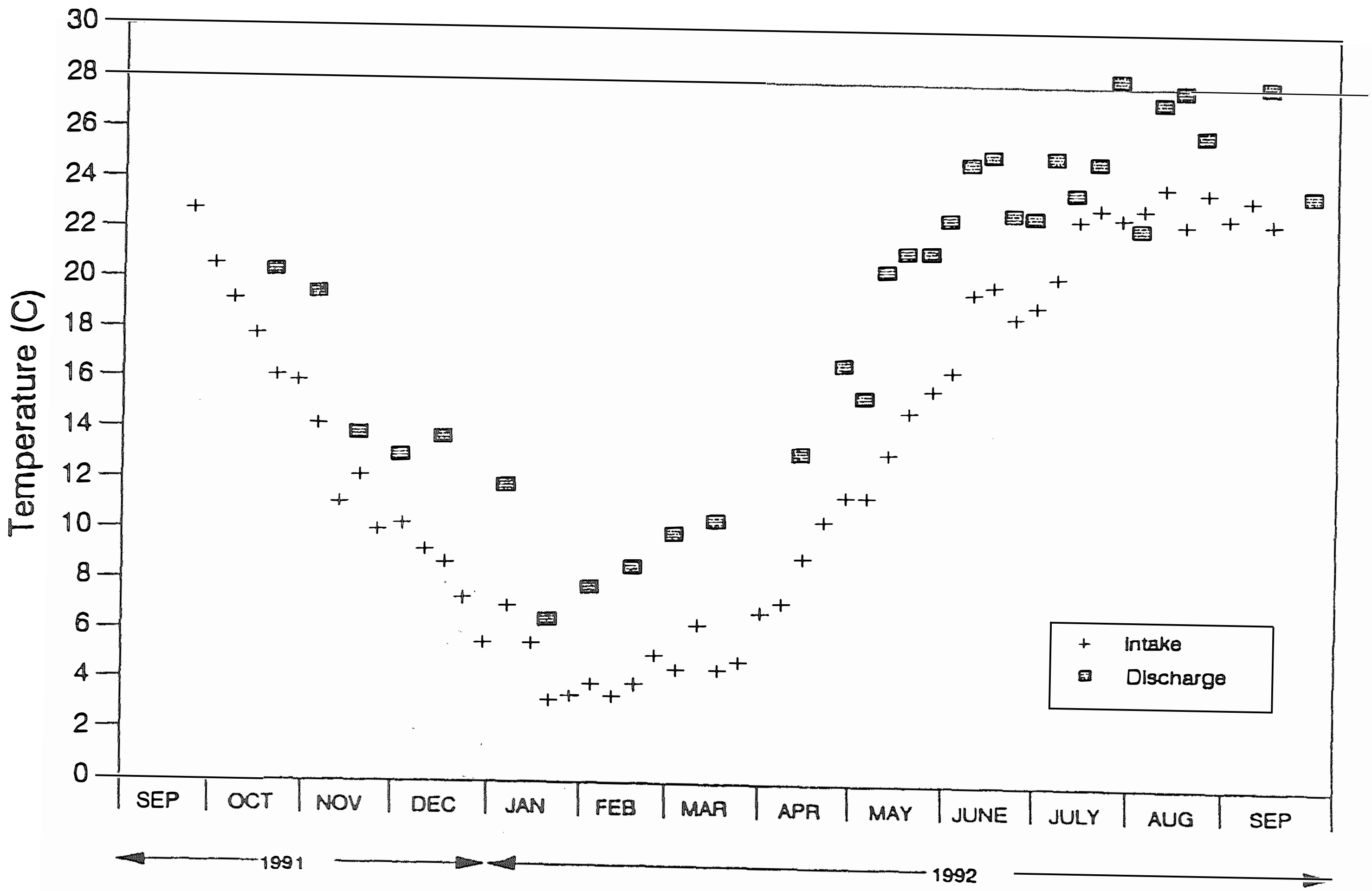

Figure 14. **Average daily intake and discharge water temperatures at Ravenswood Generating Station during September 1991 - September 1992.** (Source: LMS 1993).

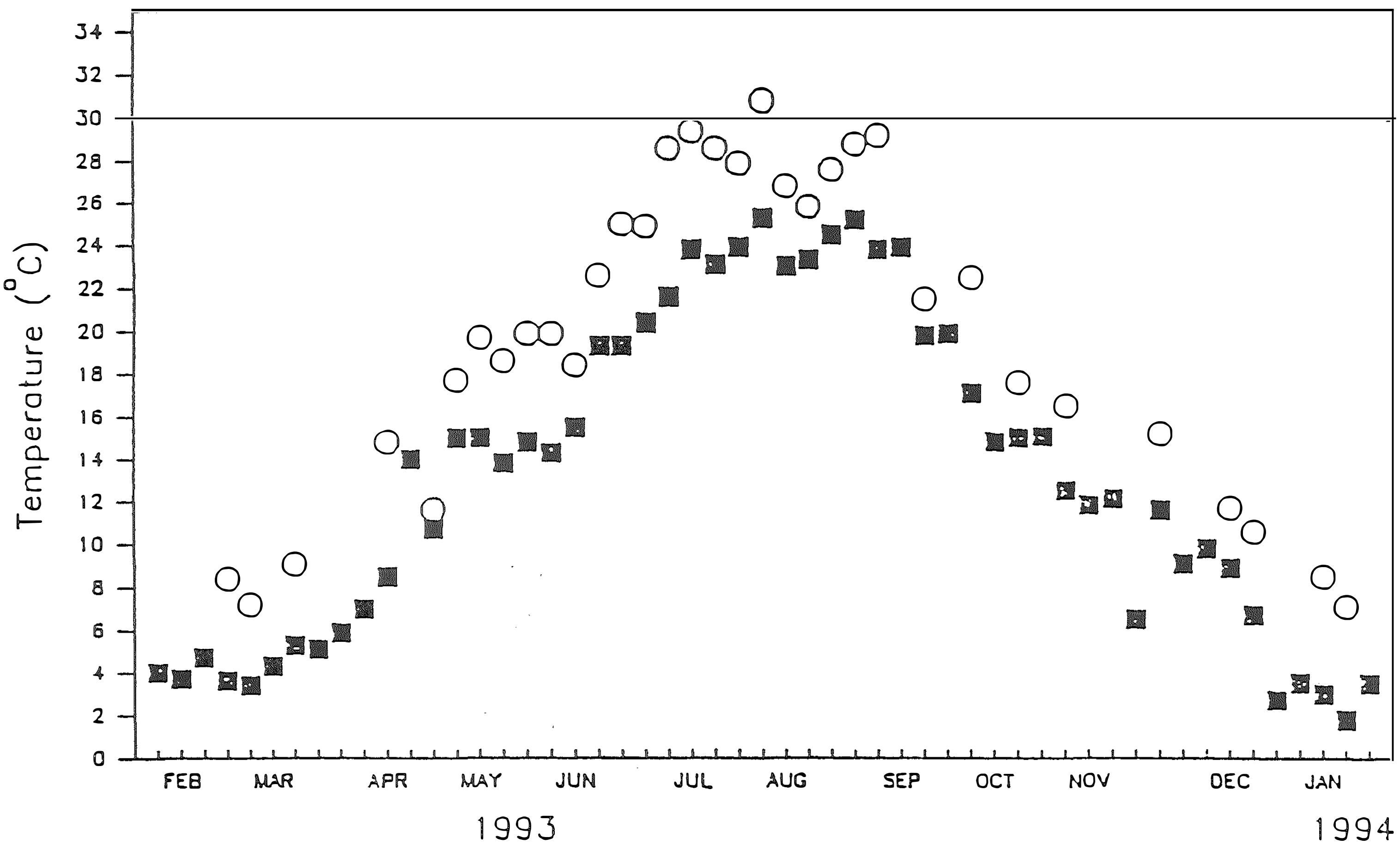

Figure 15. **Average intake and discharge water temperatures at Ravenswood Generating Station during February 1993 - January 1994.**
(Source: NAI 1994).

Table 11. Post-impingement viability of bay anchovy as a function of exposure time to heated discharge canal water at the Arthur Kill Generating Station.

Collection Date: 23-Aug-95 Time: 2000-2200

				Bay Anchovy					
				Ambient Water			Discharge Canal Water		
				No. Fish	180		No. Fish	176	
Hrs After Start of Exposure	Temp Intake	Deg C. Discharge	Delta T Deg. C	No. Dead by time Int.	Cumulative Mortality	Percent Mortality	No. Dead by time Int.	Cumulative Mortality	Percent Mortality
2	28.0	31.0	3.0						
4	27.2	30.2	3.0						
6	28.0	30.0	2.0	46	46	25.6	64	64	36.4
8	27.2	29.8	2.6	12	58	32.2	41	105	59.7
10	28.0	31.6	3.6	3	61	33.9	30	135	76.7
12	28.0	31.6	3.6	17	78	43.3	4	139	79.0
14	28.0	32.5	4.5	16	94	52.2	11	150	85.2
16	28.4	35.0	6.6	9	103	57.2	12	162	92.0
18	28.8	35.0	6.2	10	113	62.8	1	163	92.6
20	28.2	33.0	4.8	0	113	62.8	4	167	94.9
22	28.3	33.4	5.1	25	138	76.7	9	176	100.0
24	28.0	32.2	4.2	0	138	76.7	0	176	100.0
26	27.6	30.2	2.6	0	138	76.7	0	176	100.0

Collection Date: 23-Aug-95 Time: 0100-0300

				Bay Anchovy					
				Ambient Water			Discharge Canal Water		
				No. Fish	76		No. Fish	55	
Hrs After Start of Exposure	Temp Intake	Deg C. Discharge	Delta T Deg. C	No. Dead by time Int.	Cumulative Mortality	Percent Mortality	No. Dead by time Int.	Cumulative Mortality	Percent Mortality
2	28.0	31.0	3.0						
4	27.2	30.2	3.0						
6	28.0	30.0	2.0	-	0	0.0	-	0	0.0
8	27.2	29.8	2.6	0	0	0.0	20	20	36.4
10	28.0	31.6	3.6	13	13	17.1	1	21	38.2
12	28.0	31.6	3.6	0	13	17.1	9	30	54.5
14	28.0	32.5	4.5	0	13	17.1	10	40	72.7
16	28.4	35.0	6.6	0	13	17.1	3	43	78.2
18	28.8	35.0	6.2	0	13	17.1	0	43	78.2
20	28.2	33.0	4.8	0	13	17.1	9	52	94.5
22	28.3	33.4	5.1	14	27	35.5	3	55	100.0
24	28.0	32.2	4.2	0	27	35.5	0	55	100.0
26	27.6	30.2	2.6	0	27	35.5	0	55	100.0

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C. Site Evaluations for a Dedicated Fish Return System

The Ravenswood Station's water intake structures and the adjacent waterfront were examined for alternative routes for dedicated fish and debris return systems, if dedicated routes were decided to be more appropriate than the existing system. Figure 4 illustrates the general location of major facilities along the waterfront at the Ravenswood Station. In general, dedicated fish and debris return systems for the existing through-flow water intake screens would consist of approximately 10 ft extensions of the "in-deck" debris sluices from their points of discharge into the debris basins (currently the polyethylene spiral-shaped tubes) to the westerly wall of the basins. From the westerly wall of each basin, a return pipe might be installed to extend in a westerly direction approximately 60 ft to discharge at a point under and near the waterfront of the Station's unloading wharf. In these locations, the underwater discharge for each of the three fish and debris return sluices would be situated approximately 40 ft riverward of the rock rip-rap shoreline (MLW line) situated behind the piling-supported wharf. The discharges would be located in areas immediately to the south of the intake water approach channel for Units 10, and to the north of the channels for Units 20 and 30. The elevation change for the return system would be approximately 13 ft, as measured from the bottom of the "in-deck" fish and debris sluice to mean low water. This elevation change is similar to that within the design tested for the Indian Point Unit 2 fish return system (Con Edison and NYPA 1992).

Extension of the sluices to discharge points further offshore would be undesirable because the riverbed in front of the wharf where the pipes would have to be placed is occasionally dredged to allow barge access. Return pipes placed in this area would interfere with dredging activities. Also, extension of the return pipes along the waterfront to points either north or south of the Station's water intakes does not appear to offer any substantive advantage over releases near the front edge of the wharf because of the tidal nature of the East River. Fish released through a return pipe that extended north from the intake area might be carried downstream with the ebb tide, while those released south of the intakes might be carried upstream with the flood tide.

Normandeau Associates, Inc. 1994. Ravenswood Impingement and Entrainment Report. New Bedford, New Hampshire.

Tagatz. M.E. 1969. Some Relations of Temperature Acclimation and Salinity to Thermal Tolerances of the Blue Crab, Callinectes sapidus. Trans. Amer. Fish. Soc. 100:713-716.

APPENDIX A

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.

RAVENSWOOD GENERATING STATION VELOCITY STUDIES

Final Report

April 1996

Prepared By:

LAWLER, MATUSKY & SKELLY ENGINEERS LLP
Environmental Science & Engineering Consultants
One Blue Hill Plaza, Pearl River, New York 10965

File: 115-171

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CHAPTER 1
INTRODUCTION

Velocity profiles were measured at one conventional traveling screen (Screen 32) at Unit 30 at the Ravenswood Generating Station. Unit 30 was selected for the velocity profile study because this unit has the highest calculated water approach velocity of the three units at the station (Con Edison). The objective of the measurements was to determine the distribution of velocity, both speed and direction, across the submerged face of the screen. Measurements were obtained by mounting an electromagnetic velocity sensor in a rigid frame which spanned the width of the intake bay. A moveable mounting arm allowed placement of the sensor at any of the selected - horizontal locations. The rigid frame was lowered in the guide slots used for fine mesh screen panels so that velocities could be determined at five different vertical locations within the intake water column.

The velocity measurements were entered into a computer data base and measurements at each location were averaged over time. These averages at each location were subsequently averaged over each vertical transect to produce vertically averaged vector velocities at each of the horizontal locations. Results of the measurements were then displayed in both tabular and schematic form.

The forebay dimensions, unit flow rates, and a velocity range for the Ravenswood Station intake bay are given in Table 1-1.

TABLE 1-1

RAVENSWOOD GENERATING STATION
INTAKE DIMENSIONS AND COMPUTED FOREBAY VELOCITIES[1]

	UNIT 32
Screen Forebay Width (ft)	11.17
Screen Forebay Depth[2] (ft)	24.0
Number of Circulators	2
Circulating Flow (gpm) per Circulator	267,000
Number of Service Water Pumps	2
Service Water (gpm) per Pump	8,000
Number of Screens per Circulator	3
Mean High Tide (ft)	4.5
Mean Low Tide (ft)	0.4
Forebay Velocity (fps) Circulating Flow (calculated) High Tide Sea Level Low Tide	 0.6 0.7 0.7
Forebay Velocity (fps) Circulating and Service (calculated) High Tide Sea Level Low Tide	 0.7 0.8 0.8

[1]Provided by Con Edison

[2]At mean water elevation

CHAPTER 2
METHODS AND MATERIALS

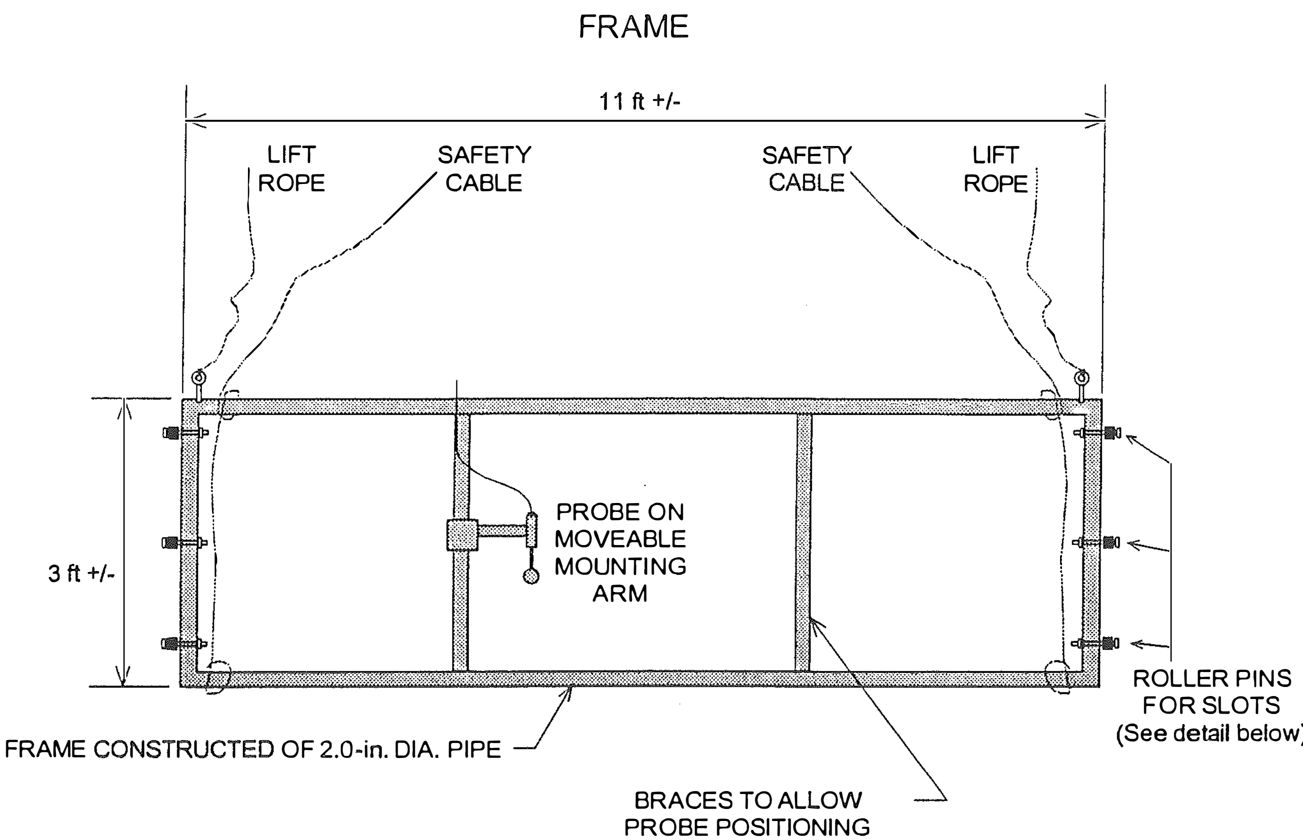
2.1 VELOCITY PROBE MOUNTING SYSTEMS

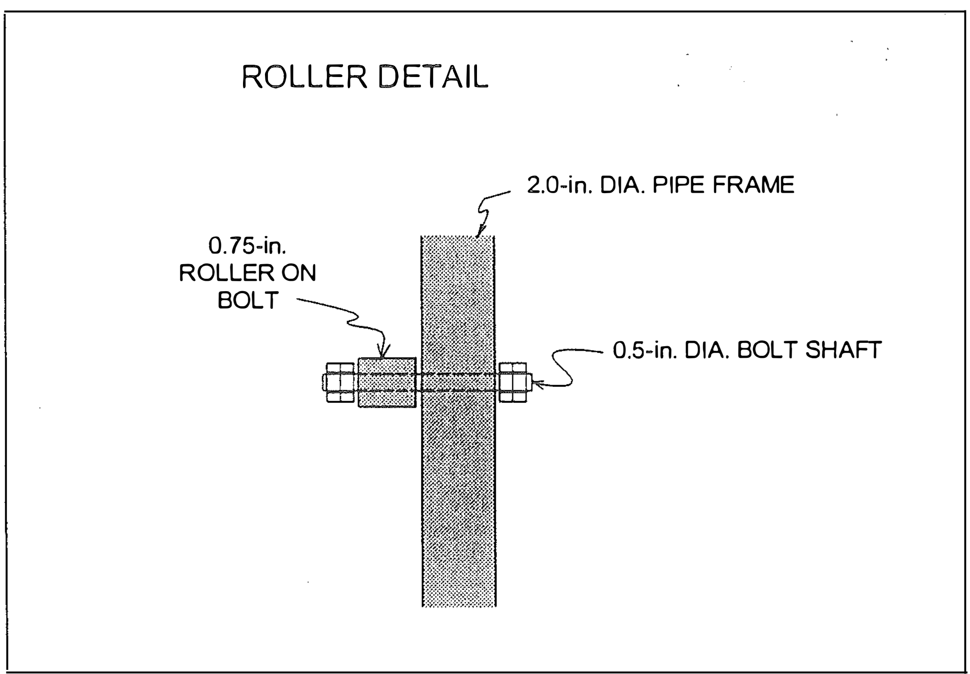
The probe mounting depicted in Figure 2-1 was used to position the velocity probe in front of the traveling screens and hold it in position for measurements. The frame was used at the fine mesh guide slots located approximately 6-ft upstream of the vertical traveling screen face. (The screen's debris seal precluded placing the meter probe on the screen basket frames for velocity measurements.) The frame is constructed of rigid 2.0-inch diameter PVC pipe with internal bracing. The probe was mounted on a bracket which in turn was clamped to the vertical bracing. The bracket could extend the probe to the left or right of the bracing pieces to position the sensor at the preselected horizontal locations for velocity measurement.

The frame width was constructed to be just slightly less than the width of the outside of the guide slots. Rollers were then mounted on bolts which extended 2- to 3-inches beyond the pipe frame width and were designed to travel in the 3-inch deep, 1-inch wide guide slots. Round-headed bolts were used to minimize friction on the slot backs. At the site it was found that the guide slots were considerably narrower than the 1-inch shown on a site engineering drawing. This required removal of the rollers and use of only the bolts projecting into the guide slots.

The frame was 3-ft in height to minimize "racking" or binding in the slots and to allow sufficient clearances for the sensor inside the frame. The frame was raised and lowered by extending ropes to the surface. Several cables were also attached to facilitate recovery if the frame jammed. The probe was set at the appropriate horizontal location and the frame lowered to the required depths. Depth of the frame and sensor was measured by calibrated cable using the deck surface and water surface as reference points.

The 2-axis Marsh McBirney probe was mounted with one axis parallel (X-axis) and one axis perpendicular (Y-axis) to the screen face. Hand levels were used to ensure that the probe was





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RAVENSWOOD MOUNTING FRAME

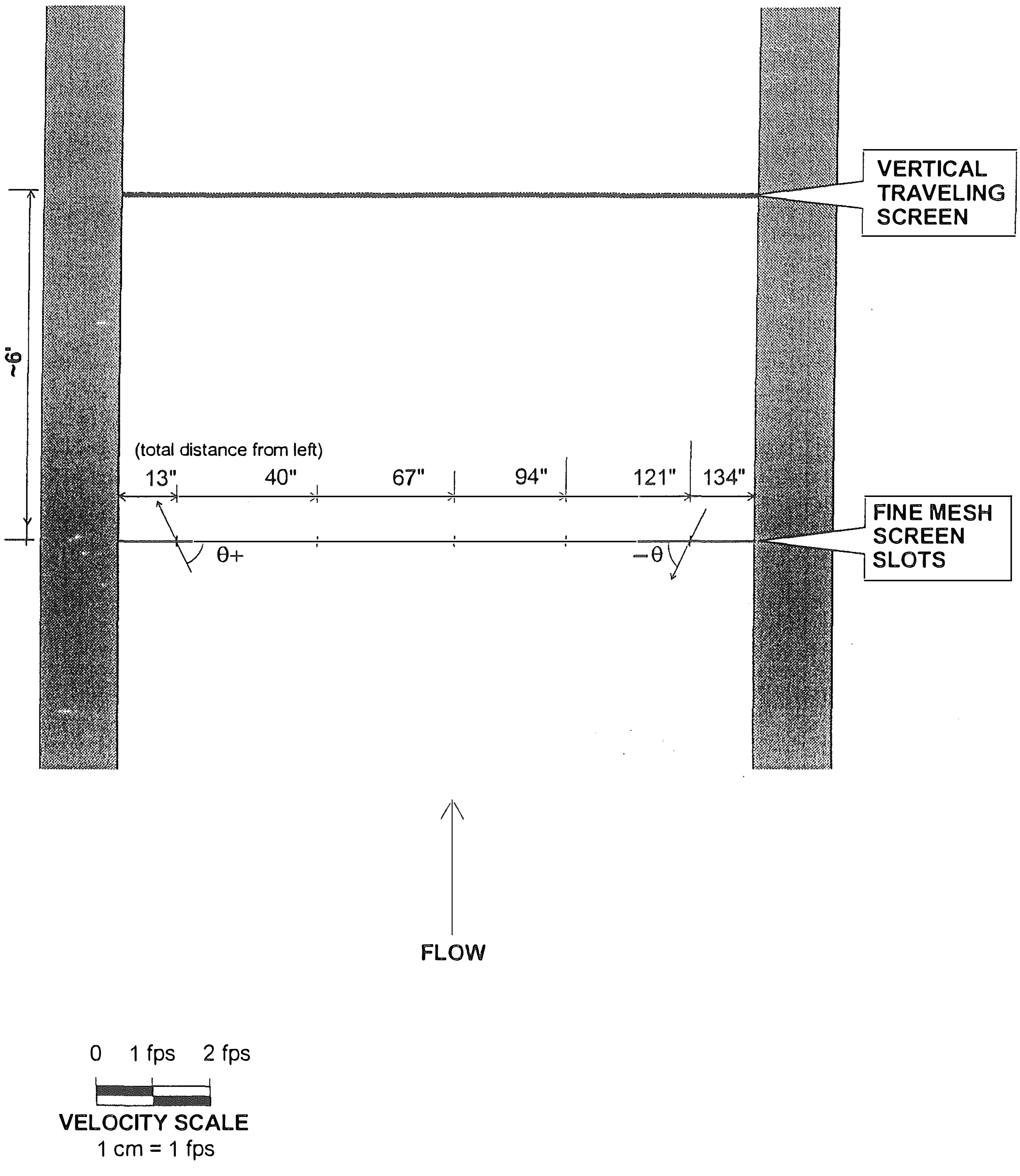
Figure 2-1

oriented correctly in the vertical direction. All probe readings were recorded with the Y-axis directed into and perpendicular to the screen face.

The horizontal locations for each vertical screen transect were determined by measuring from the side of the screen channel. At Ravenswood, the distances of the measurement increments were 13, 40, 67, 94 and 121-inches from the north side of the screen channel (see Figure 2-2). Measurements were made with a tape measure, and the selected positions were achieved by adjusting the length of the probe mounting arm.

As specified by Con Edison, velocities were recorded for five vertical positions on Screen 32. The upper set of velocity measurements at each vertical transect were taken at 1-ft below the water surface, and the lower set of measurements were taken at approximately 5.5-ft above the intake bottom. The lower axis of rotation of the screens is located approximately 4-ft from the bottom, so the lowest measurement point was located 1- to 2-ft above the point where the screen panels rotate around the foot sprocket of the traveling water screen. The vertical interval between the surface and bottom measurement depths was divided into three increments and the velocity measurements were taken at the approximate center of each of the vertical increments. The depths of the three sampling locations between the upper and lower sample positions were calculated based on the anticipated average water depth during the measurement period. This calculation method ensured that the bottom four measurement locations were fixed with respect to the intake lower elevation. The upper measurement position changed with respect to the intake bottom elevation as tide level changed as it was always positioned 1-ft below the water surface.

At the beginning and during each measurement on a screen face, water surface elevation was monitored from the screenwell deck. The distance to the intake bottom was also measured. By taking the difference between the distance to the screenwell bottom and the distance to the water surface at any given time, the actual water depth was calculated. The traveling screen was continuously rotated and washed to assure a clean screen during the measurements.



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Velocity Measurement Locations

CON EDISON COMPANY • RAVENSWOOD GENERATING STATION

Figure 2-2

A set of measurements at a screen was accomplished by first affixing the probe to the mounting frame and positioning the probe properly at a specified horizontal location. The distance to the water surface from the deck was measured by tape measure. The frame was then lowered to position the probe at the first, or 1-ft depth level. A set of velocity measurements was taken and the frame was then lowered to the next depth interval.

This process continued to the final depth interval located approximately 5- to 6-ft above the bottom. The probe was then brought back up above the deck level; the probe mounting was moved to the next horizontal location, and the vertical profile procedure was repeated. This process was repeated at each of the five horizontal locations across the channel. Based on the ability to control the depth of the frame, the probe could generally be vertically located within ±0.75-ft of the desired vertical location.

2.2 *DATA RECORDING*

Data was recorded in the field on preformatted data sheets (see Figure 2-3). Information recorded included standard elements such as date, time, screen location and reference information for both vertical and horizontal locations. A single data sheet was used for each vertical transect.

Once the probe was located at a specific grid point, the meter was allowed to stabilize for approximately 30- to 60-sec. After the meter had stabilized, the meter reading technician monitored the movements of the X-axis and Y-axis component dials simultaneously. At 20-sec increments, readings were simultaneously taken from each of the dials, indicating the X- and the Y-axis components of the velocity. The second technician recorded the readings, a process which allowed the meter monitoring technician to continuously observe the dials. The process was repeated twice at 20-sec intervals, resulting in three readings separated by 20-sec intervals, as specified by the scope of work.

In addition to recording each of the three paired sets of X- and Y-axis readings at the 20-sec intervals, the meter monitoring technician also monitored the maximum and minimum range

FIGURE 2-3

FIELD DATA SHEET

LAWLER, MATUSKY & SKELLY ENGINEERS - CON EDISON INTAKE VELOCITY STUDY

ID No. ____________ Date: ____________ Start Time: ____________ End Time: ____________

Field Crew: ____________ Meter: ____________ Units: ____________ Rep Int: ____________ (sec)

Plant: ____________ Screen No. ____________ Screen Face: ____________ (A/D)

Hori. Ref: ________________________ H units: ____________

Vert. Ref: ________________________ V units: ____________

Water Elevation From Vertical Ref. (ft). Start: ____________ End: ____________

Hor.	Vert.	Rep	X vel	Y vel	X min	X max	Y min	Y max

achieved by both the X- and Y-axis meters. These minimum and maximum values are not necessarily paired values, but are recorded as an additional indication of the degree of variability in each component during the monitoring period.

2.3 INTERFERENCE CHECKS

As specified in the scope of work, tests were done to determine if there were either electrical or magnetic interference affects, which could affect the velocity measurements at each of the screens. A check was made for potential electrical interference by positioning the probe at a submerged location and disconnecting the power supply wires to the magnet in the probe. This disabled the electromagnet, eliminating any electrical currents created by water moving through the probe's magnetic field. As a result, any stray electrical currents which were present, would be detected by the probe electrodes. If significant electrical currents were indicated by movement of the meter needles, an investigation was done to determine the cause of the electrical problem.

A check for other interferences that might adversely affect the measurement of velocities was accomplished by direct comparison of electromagnetic current meter readings with a mechanical current meter. A comparison test was done by first doing a set of 5-min recordings with the electromagnetic meter at 20-sec intervals at a location selected to have minimal current variation over time. The frame was then raised and a Price Pygmy current meter was substituted for the electromagnetic probe at precisely the same location as the previous electromagnetic readings, and a set of readings was taken with the Price meter over 10-min at 60-sec intervals. After the readings with the Price meter were completed, the electromagnetic meter was resubstituted and a second 5-min set of electromagnetic readings was taken. It should be noted that the Price meter readings at 60-sec intervals are continuous measurements over each interval since the total rotation count over the interval is recorded.

Because the mechanical Price meter measures water speed but not direction and does not measure separate velocity vector components, the comparison with the electromagnetic meter results can only be done for the scaler speed portion of the vector. An immediate calculation was done in the field by averaging the velocities from the electromagnetic meter and then comparing the results to the Price current meter. Results of the velocity comparison testing were recorded on separate data sheets.

2.4 VELOCITY METERS

All velocity profile measurements reported herein were collected with a Marsh McBirney Model 511 electromagnetic water current meter. The meter used for all measurements was meter no. 80257/S-1320. Velocity readings are indicated in cm/sec on the two meter dials. The meter was calibrated prior to the survey at the Marsh McBirney factory; a certificate of calibration is contained in Appendix A.

The Price meter which was used for the direct velocity comparison testing was a Model Pygmy 232WA075, with a maximum velocity range of 90 cm/sec (3-ft/sec). The Price meter was read by counting of clicks using the standard headphone set over specific time intervals. The click counts are then converted to velocity using the conversion table for the specific meter.

2.5 DATA ANALYSIS

Field data were entered directly into a data base system designed to accept information in the same format as the field data sheets. All raw velocity data were entered into the computer as recorded in the field. The data base was then used to generate velocity averages at each of the grid points.

The velocity vectors (speed and angle) were calculated for each paired set of recorded velocity components (V_X and V_Y) using the following formulas:

$$Speed = S = \sqrt{V_X^2 + V_Y^2}$$

$$Angle = \Theta = \tan^{-1} \frac{V_Y}{V_X}$$

The angle Θ in this case is the angle of incidence, or the approach angle of the velocity to a line parallel to the screen face. A negative angle indicates a velocity vector directed away from the screen face (See Figure 2-2). The three speed and angle measurements at each grid point were averaged. After the grid point averages were computed, they were averaged over each vertical profile to generate an average velocity for each horizontal position. Finally, all grid points were averaged to produce the screen face angle. The vertically averaged vector velocities at each horizontal location were displayed graphically for the cross-sectioned area of the intake bay.

CHAPTER 3
RESULTS

Measurements were done at the Ravenswood Generating Station on March 12, 1996. Screen velocity measurements and interference checks were conducted on the same day.

3.1 INTERFERENCE CHECKS

The results of the checks for electrical interferences generally showed no electrical currents present in the water as measured by the meters, which would be judged to interfere with the velocity measurements by electromagnetic current meter. At one time, electrical interference was noted; it was determined that the cause of the electrical interference was electrical welding being performed in the area. No measurements were conducted during welding operations.

The results of the direct velocity comparisons between electromagnetic meter and mechanical Price meter are shown in Table 3-1. As indicated, the results are based on sequential measurement by electromagnetic (5-min), mechanical (10-min), and then an additional (5-min) electromagnetic meter readings. Also as described, the Price meter measures water speed regardless of direction.

The difference between the average readings of the two meters is 11% for the comparison tests done at Screen 32. Based on the lack of any measurable electrical interferences and based on the stability of the electromagnetic readings within each interval, the difference between the meters was not attributed to any interference effects.

3.2 VELOCITY PROFILE RESULTS

The results of the measurements at screen 32 are shown in Table 3-2. The table shows the average velocities (speed and angle) at each location, as well as the independent minimum and maximum values observed for the X and Y components, the vertical transect averages, and the

TABLE 3-1

CON EDISON COMPANY
RAVENSWOOD GENERATING STATION VELOCITY STUDIES

COMPARISON OF ELECTROMAGNETIC AND MECHANICAL VELOCITY MEASUREMENTS (cm/sec)

Screen No.	*Electromagnetic Measurements*			*Mechanical Meter*[b]	*% Difference*
	Rep. 1[a]	*Rep. 2*[a]	*Average*		
32	57	62	59	53	11

[a]Average of 15 readings at 20-sec intervals

[b]Average of 10 1-min intervals

TABLE 3-2
CON EDISON COMPANY
RAVENSWOOD PLANT - SCREEN No. 32 - ASCENDING FACE

SAMPLE DATE: MAR 12, 1996

START TIME: 1632
END TIME: 2044

Hoz inch	Vert ft*	Savg cm/sec	Θavg deg	Range Values X min (X_1)	X max (X_2)	Y min (Y_2)	Y max (Y_1)
13.4	14.5	60 (57.4)	105	-5	-21	-45	-65
13.4	19	23 (22.2)	15	0	28	5	-16
13.4	24.5	25 (28.6)	82	2	14	-16	-36
13.4	30	9 (13.3)	131	4	-10	1	-16
13.4	34	19	90	4	-10	-10	-26
Vertical Average		27	85				
40.2	13.5	26	99	5	-10	-15	-30
40.2	19	37	66	-2	20	-15	-42
40.2	24.5	65	90	-10	10	-50	-80
40.2	30	45	92	-10	10	-35	-55
*Vertical Average***		43	87				
67	15	59	92	2	-4	-55	-65
67	19	38	72	5	22	-25	-42
67	24.5	70	91	-8	8	-55	-80
67	30	34	70	-5	25	-15	-45
67	34	14	69	-3	18	-3	-16
Vertical Average		43	79				
93.8	15.5	34	80	-4	8	-22	-38
93.8	19	89	74	10	30	-70	-90
93.8	24.5	68	109	-10	-35	-50	-70
93.8	30	10	72	-3	10	-3	-16
93.8	34	12	74	-4	12	-2	-18
Vertical Average		43	82				
120.6	16	52	75	2	20	-45	-65
120.6	19	82	90	-10	10	-60	-95
120.6	24.5	29	128	-3	-28	-14	-42
120.6	30	58	84	0	15	-55	-70
120.6	34	12	-82	-15	15	5	20
Vertical Average		47	59				
SCREEN AVERAGE		41	78				

*Measured from the deck (elevation 16-ft 0-inches)

**Probe meter frame could not be lowered to the bottom depth total screen average. The computed average velocities (S) and the angles (Θ) relative to the screen face are also given for each of the vertical transects on the tables.

As indicated above, the horizontal locations are all given as the distance from the north side of the forebay and all vertical dimensions are given as computed from the screen house deck. The vertical dimension is the computed distance below the deck surface (elevation +16.0-ft above sea level) to each measurement location. Changes in the vertical dimensions between vertical profiles represent adjustments for changes in water depth during the measurements.

As previously described, the uppermost measurement at each vertical transect was always taken at 1-ft below the water surface. The lowermost measurement location was approximately 5.5-ft above the intake bottom (elevation -24.0-ft on sea level). The intermediate locations were distributed over the specified number of vertical intervals. Since the water surface elevation changed with the tide, the location of the upper measurements changed accordingly for each vertical transect. The distance to the water surface from the deck during each transect measurements can be obtained from the data tables by subtracting 1-ft from the uppermost vertical location indicated for each transect.

Table 3-2 also indicates the start time and end time for the measurements. As specified in the scope, all readings were taken within a time interval which excluded the periods 1-hr either side of high tide or low tide, as indicated by the tide tables. Therefore, the measurements were all conducted during the predicted period of maximum rate of tidal elevation change, centered around mean tidal level.

The distribution of velocities across the channel cross-section show significant variation between points. The only consistent trend is for lower velocities closer to the channel bottom. Also, the near bottom measurement point at the 120-inch horizontal location, flow reversal was detected.

The lower velocities at the near bottom locations of all vertical transects are attributed to the downstream blockage of flow by the bottom of the traveling screen frame and to the effects of the channel bottom. The flow reversal observed at the 120-inch transect is further evidence of reflection of the flow by a downstream blockage. While the results in Table 3-2 indicate significant variation of velocities among the grid points, there is no consistent pattern, other than the lower velocities at the near bottom grid points. The variation of velocity magnitude among grid points is high; adjacent grid points frequently have velocity magnitudes differing by a factor of 2. However, difference between the three velocities measured at any given point rarely exceeded 25% of the average at each grid point. The most likely conclusion from this result is that the flow patterns may be fluctuating over periods greater than the 1- to 2-minute measurement time at each grid point.

The average of all velocities across the measurement cross section was 1.3 fps, which is significantly higher than the predicted velocity of 0.7 to 0.8 fps based on even flow distribution across all three screen channels. This indicates that the flow through screen 32 was approximately 70% greater than the design flow, most likely due to clogging of the screens in the other two channels. The presence of significantly higher than design flow could affect the distribution and variation of velocities across the channel as compared to velocities at the lower design flow rates.

Table 3-3 summarizes the vertically averaged velocity results. Results are given as speed in cm/sec and ft/sec and the approach angle of the velocity at the screen face. Figure 3-1 illustrates the vertically averaged results as scaled velocity vectors at each horizontal measurement location.

The average velocities over each vertical transect (see Table 3-3) are very consistent between transects with the exception of the 13-inch location where the average is lower than all other transects. The consistent orientation of the velocities slightly off parallel to the channel centerline, is likely due to the upstream entry condition and the uneven distribution of flow between the three screen channels. This angular orientation could also account for the lower velocities on the north side of the channel (13-inch location). These effects are evident on Figure 3-1.

TABLE 3-3

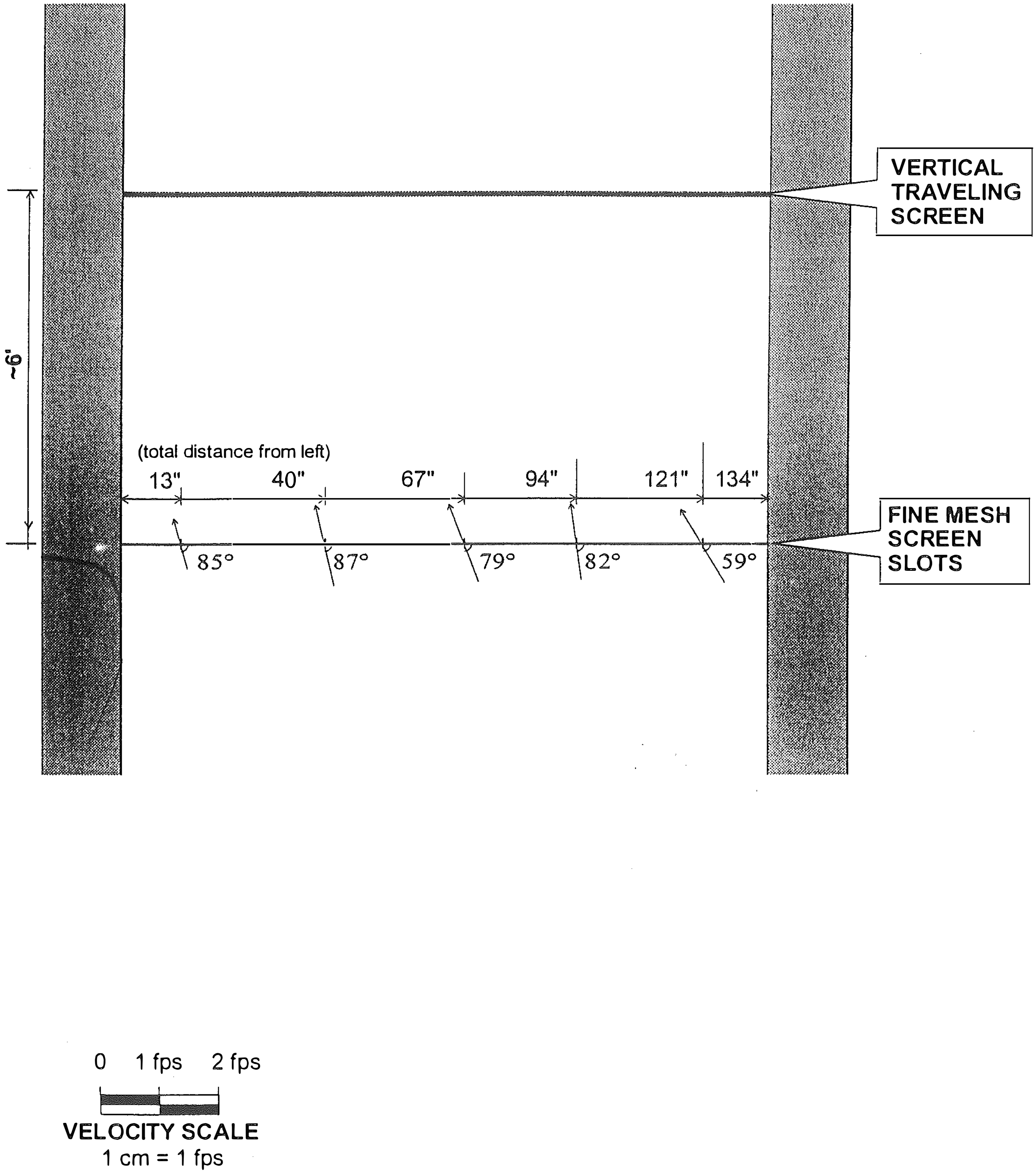
CON EDISON COMPANY
RAVENSWOOD GENERATING STATION VELOCITY STUDIES

WATER SPEED (S)[1] AND APPROACH ANGLE (θ)[2]
AVERAGES OF VERTICAL PROFILES

	HORIZONTAL LOCATION (inches)											
	13		*40*		*67*		*94*		*121*		*Average*	
Screen	*S*[1]	θ[2]	*S*[1]	θ[2]	*S*[1]	θ[2]	*S*[1]	θ[2]	*S*[1]	θ[2]	*S*[1]	θ[2]
32	27 (0.9)	85	43 (1.4)	87	43 (1.4)	79	43 (1.4)	82	47 (1.5)	59	41 (1.3)	78

[1]Speed given in cm/sec and (fps)

[2]Angle in degrees relative to screen face



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LMS Lawler, Matusky & Skelly Engineers LLP One Blue Hill Plaza • Pearl River, New York 10965 ENVIRONMENTAL SCIENCE & ENGINEERING CONSULTANTS	**Vertically Averaged Water Current Angles** CON EDISON COMPANY • RAVENSWOOD GENERATING STATION	**Figure 3-1**

Table 3-4 summarizes the averages across all transects at each depth interval. These results show the consistently lower velocities at the two lower depths. The highest average velocities are calculated for the second and third depth intervals, with the surface, or first interval slightly lower. This distribution is consistent with the expected vertical distribution for open channel flow.

Since the traveling screen face is approximately 6-ft downstream from the measurement location, the distributions of velocity (both speed and angle) may change between the two locations. However, given the limited distance and the level of velocities recorded, the measured velocities are considered representative of those at the traveling screen face.

TABLE 3-4

CON EDISON COMPANY
RAVENSWOOD GENERATING STATION VELOCITY STUDIES

SCREEN 32
AVERAGE VELOCITIES ACROSS HORIZONTAL TRANSECTS

Depth	S^1	Θ^2
14.9	46 (1.5)	90
19	54 (1.8)	63
24.5	51 (1.7)	100
30	31 (1.0)	90
34	14 (0.5)	38
Screen Average	39 (1.3)	76

[1]Speed given in cm/sec and (fps)

[2]Angle in degrees relative to screen face

APPENDIX A

CALIBRATION CERTIFICATE

CALIBRATION CERTIFICATE

Model : 511M Serial Number : 80257/S-1320

±1v = ±300 cm/sec

Type of Velocity Reading

☐ FPS ☒ CMS ☐ ____

Static Test

	Velocity: X- Axis	Velocity: Y- Axis
Standard :	Zero	Zero
Measured :	±2.5mV	±2.5mV

Dynamic Test

	Velocity: X- Axis	Velocity: Y- Axis
Standard :	192.1	192.1
Measured :	190.–	190.

Calibration Technician : [signature] Date : 10/23/95

QA Technician : [signature] Date : 10-23-95

This document certifies that the described instrument has been calibrated. Verification is indicated by the measured results shown above. Velocity calibration is traceable to the National Institute of Standards and Technology, (NIST), Gaithersburg, MD. For product information, service, or calibration, please contact the Customer Service Department.

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