Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule

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INTRODUCTION

In the Notice of Data Availability (NODA) (68 FR 13522, March 19, 2003), the Agency presented an approach for developing compliance costs that included a broad range of compliance technologies as opposed to the approach used for the proposal, which was based on a limited set of technologies. This chapter presents the technology cost modules used by the Agency to develop compliance costs at model facilities for the final rule. The Agency presents further technical information on the technology cost modules, including its analysis of the confidence of the cost estimates, in DCN 6-3584 in the record of the final rule. Chapter 2 of this document describes the Agency's methodology for assigned particular cost modules to model facilities.

1.0 SUBMERGED PASSIVE INTAKES

The modules described in this section involve submerged passive intakes, and address both adding technologies to the inlet of existing submerged intakes and converting shoreline based intakes (e.g., shoreline intakes with traveling screens) to submerged offshore intakes with added passive inlet technologies. The passive inlet technologies that are considered include passive screens and velocity caps. All intakes relocated from shore-based to submerged offshore are assumed to employ either a velocity cap or passive screens. Costs for velocity caps are presented separately in Section 3.

1.1 RELOCATED SHORE-BASED INTAKE TO SUBMERGED NEAR-SHORE AND OFFSHORE WITH FINE MESH PASSIVE SCREENS AT INLET

This section contains three sections. The first two sections respectively present documentation for passive screen technology selection and estimation parameters; and for development of capital costs for submerged passive intakes. This discussion includes: passive screen technology selection, selection of flow values, intake configurations, connecting walls, and connecting pipes. The second section discusses cost development for: screen construction materials, connecting walls, pipe manifolds, airburst systems, indirect costs, nuclear facilities, O&M costs, construction-related downtime. The third section presents a discussion of the applicability of this cost module.

1.1.1 SELECTION/DERIVATION OF COST INPUT VALUES

<u>Passive Screen Technology Selection</u>

Passive screens come in one of three general configurations: flat panel, cylindrical, and cylindrical T-type. Only passive screens constructed of welded wedgewire were considered due to the improved performance of wedgewire with respect to debris and fish protection. After discussion with vendors concerning the attributes and prevalence of the various passive screen technology configurations, EPA selected the T-screen configuration as the most versatile with respect to a variety of local intake and waterbody attributes. The most important screen attribute was the requirement for screen placement. Both cylindrical and T-screens allow for placement of the screens extending into the waterbody, which allows for debris to migrate away from the screens once dislodged. T-screens produce greater flow per screen unit and thus were chosen because they are more practical in multi-screen installations.

Due to the potential for build-up and plugging by debris, passive screens are usually installed with an airburst backwash system. This system includes a compressor, an accumulator (also known as, receiver), controls, a distributor and air piping that directs a burst of air into each screen. The air burst produces a rapid backflow through the screen; this air-induced turbulence dislodges accumulated debris, which then drifts away from the screen unit. Vendors claimed (although with minimal data) that only very stagnant water with a high debris load or very shallow water (<2 ft deep) would prevent use of this screen technology. Areas with low water velocities would simply require more frequent airburst backwashes, and few facilities are constrained by water depths as shallow as 2 feet.

While there are waterbodies with levels of debris low enough to preclude installation of an airburst system, EPA has chosen to include an airburst backwash system with each T-screen installation as a prudent precaution. The capital cost of the airburst backwash system is a substantial component, particularly in offshore applications, because of the need to install a separate air supply pipe from the shoreline air supply to each screen or group of smaller screens. Thus, the assumption that airburst backwash systems are needed in all applications is considered as part of an overall cost approach that increases projected capital costs to the industry to develop a high-side cost estimate.

T-screens ranging in diameter from 2 feet (T24) to 8 feet (T96), in one-foot intervals, are used in the analysis. Costs provided are for two types of screens one with a slot size of approximately 1.75 mm referred to as "fine mesh" and one with a slot size of 0.76 mm referred to as "very fine mesh." The design flow values used for each size screen correspond to wedgewire T-screens with a through screen velocity of 0.5 fps. Tables 1-1 and 1-2 presents design specifications for the fine mesh and very fine mesh wedgewire T-screens costed.

TABLE 1-1

Fine Mesh Passive T-Screen Design Specifications

Screen Size	Capacity	Slot Size	Screen Length	Airburst Pipie Diameter	Screen Outlet Diameter	Screen Weight
	gpm	mm	Ft	Inches	Inches	Lbs
T24	2,500	1.75	6.3	2	18	375
T36	5,700	1.75	9.3	3	30	1,050
T48	10,000	1.75	13.3	4	36	1,600
T60	15,800	1.75	16.6	6	42	2,500
T72	22,700	1.75	19.8	8	48	4,300
T84	31,000	1.75	22.9	10	60	6,000
T96	40,750	1.75	26.4	12	72	NA

*Source: Johnson Screen - Brochure 2002 - High Capacity Screen at 50% Open Area

TABLE 1-2

Very Fine Mesh Passive T-Screen Design Specifications

Screen Size	Capacity	Slot Size	Screen Length	Airburst Pipie Diameter	Screen Outlet Diameter	Screen Weight
	gpm	mm	Ft	Inches	Inches	Lbs
T24	1,680	0.76	6.3	2	18	375
T36	3,850	0.76	9.3	3	30	1,050
T48	6,750	0.76	13.3	4	36	1,600
T60	10,700	0.76	16.6	6	42	2,500
T72	15,300	0.76	19.8	8	48	4,300
T84	20,900	0.76	22.9	10	60	6,000
T96	27,500	0.76	26.4	12	72	NA

*Source: Johnson Screen - Brochure 2002 - High Capacity Screen at 33% Open Are

Selection of Flow Values

The flow values used in the development of cost equations range from a design flow of 2,500 gpm (which is the design flow for the smallest screen (T24) for which costs were obtained) to a flow of 163,000 gpm (which is equivalent to the design flow of four T96 screens) for fine mesh screens and 1,680 gpm to 165,000 (which is equivalent to the design flow of six T96 screens) for very fine mesh screens. The higher flow values were chosen because they were nearly equal to the flow in a 10-foot diameter pipe at a pipe velocity of just 4.6 fps. A 10-foot diameter pipe was chosen as the largest size for individual pipes because this size was within the range of sizes that are capable of being installed using the technology assumed in the cost model. Additionally, the need to spread out the multiple screens across the bottom is facilitated by multiple pipes. One result of this decision is that for facilities with design flows significantly greater than 165,000 gpm, the total costs are based on dividing the intake into multiple units and summing the costs of each.

Intake Configuration

The scenarios evaluated in this analysis are based on retrofit construction in which the new passive screens are connected to the existing intake by newly installed pipes, while the existing intake pumps and pump wells remain intact and functional. The cost scenario also retains the existing screen wells and bays, since in most cases they are connected directly to the pump wells. Facilities may retain the existing traveling screens as a backup, but the retention of functioning traveling screens is not necessary. No operating costs are considered for the existing screens since they are not needed. Even if they are retained, there should be almost no debris to collect on their surfaces. Thus, they would only need to be operated on an infrequent basis to ensure they remain functional.

The new passive screens are placed along the bottom of the waterway in front of the existing intake and connected to the existing intake with pipes that are laid either directly on or buried below the stream bed. The key components of the retrofit are: the transition connection to the existing intake, the connecting pipe or pipes (a.k.a. manifold or header), the passive screens or velocity cap located at the pipe inlet, and if passive screens are used, the backwash system.

At most of the T-screen retrofit installations, particularly those requiring more than one screen, the installation of passive T-screens will likely require relocating the intake to a near-shore location or to a submerged location farther offshore, depending on the screen spacing, water depth, and other requirements. An exception would be smaller flow intakes where the screen could be connected directly to the front of the intake with a minimal pipe length (e.g., half screen diameter). Other considerations that may make locating farther offshore necessary or desirable include: the availability of cooler water, lower levels of debris, and fewer aquatic organisms for placements outside the littoral zone. As such, costs have been developed for a series of distances from the shoreline.

In retrofits where flow requirements do not increase, EPA has found existing pumps and pump wells can be, and have been, retained as part of the new system. The cost scenarios assume flow volumes do not increase. Thus, using existing pumps and pump wells is both feasible and economically prudent. There are, however, two concerns regarding the use of existing pumps and pump wells. One is the degree of additional head loss associated with the new pipes and screens. The second is the intake downtime needed to complete the installation and connection of the new passive screen system or velocity cap. The downtime considerations are discussed later in a separate section.

The additional head losses associated with the passive screen retrofit scenario described here include the frictional losses in the connecting pipes and the losses through the screen surface. If the new connecting pipe velocities are kept low (e.g., 5 fps is used in this analysis), then the head loss in the extension pipe should remain low enough to allow the existing pumps to function properly in most instances. For example, a 48-inch diameter pipe at a flow of 28,000 gpm (average velocity of 4.96 fps) will have a head loss of 2.31 feet of water per 1,000-foot pipe length (Shaw and Loomis 1970). The new passive screens will contribute an additional 0.5 to 0.75 feet of water to this head loss, which will further increase when the screen is clogged by debris (Screen Services 2002). In fact, the rate at which this screen head loss increases due to debris build-up will dictate the frequency of use of the air backwash. Pump wells are generally equipped with alarms that warn of low water levels due to increased head loss through the intake. If the screen becomes plugged to the point where backwash fails to maintain the necessary water level in the pump well, the pump flow rate must be reduced. This reduction may result in a derating or shut down of the associated generating unit. Lower than normal surface water levels may exacerbate this problem.

In terms of required dimensions for installation, Tables 1-1 and 1-2 show screen length is just over three times the diameter and each screen requires a minimum clearance of one-half diameter on all sides except the ends. Thus, an 8-foot diameter screen will require a minimum water depth of 16 feet at the screen location (four feet above, four feet below, and eight feet for the screen itself). It is recommended that T-screens be oriented such that the long axis is parallel to the waterbody flow direction. T-screens can be arranged in an end-to-end configuration if necessary. However, using a greater separation above the minimum will facilitate dispersion of the released accumulated debris during screen backwashes.

In the retrofit scenario described here, screen size and number are based on using a single screen with the screen size increasing with increasing design flows. When flow exceeds the capacity of a single T96 screen, multiple T96 screens are used. This retrofit scenario also assumes the selected screen location has a minimum water depth equal to or greater than the values shown in Table 1-3.

TABLE 1-3
Minimum Depth at Screen Location
For Single Screen Scenario

Fine Mesh Flow	Very Fine Mesh Flow	Screen Size	Minimum Depth
2,500 gpm	1,680 gpm	T24	4 ft
5,700 gpm	3,850 gpm	T36	6 ft
10,000 gpm	6,750 gpm	T48	8 ft
15,800 gpm	10,700 gpm	T60	10 ft
22,700 gpm	15,300 gpm	T72	12 ft
31,000 gpm	20,900 gpm	T84	14 ft
40,750 gpm	27,500 gpm	T96	16 ft
>40,750 gpm	>27,500 gpm	Multiple T96	16 ft

In certain instances water depth or other considerations will require using a greater number of smaller diameter screens. For these cases the same size header pipe can be used, but the intake will require either more branched piping or multiple connections along the header pipe.

Connecting Wall

The retrofit of passive T-screen technology where the existing pump well and pumps are retained will require a means of connecting the new screen pipes to the pump well. Pump wells that are an integral part of shoreline intakes (often the case) will require installing a wall in front of the existing intake pump well or screen bays. This wall serves to block the existing intake opening and to connect the T-screen pipe(s) to the existing intake pump wells. In the proposed cost scenario, the T-screen pipe(s) can be attached directly to holes passing through the wall at the bottom.

Two different types of construction have been used in past retrofits or have been proposed in feasibility studies. In one, a wall constructed of steel plates is attached to and covers the front of each intake bay or pump well, such that one or more connecting pipes feed water into each screen bay or pump well individually. In this scenario, a single steel plate or several interlocking plates are affixed to the front of the screen bays by divers, and the T-screen pipe manifolds are then attached to flanged fittings welded at the bottom of the plate(s). For smaller flow intakes that require a single screen, this may be the best configuration since the screen can be attached directly to the front of the intake minimizing the intrusion of the retrofit operation into the waterway.

In the second scenario, an interlocking sheet pile wall is installed in the waterbody directly in front of, and running the length of, the existing intake. Individual screen manifold pipe(s) are attached to holes cut in the bottom along the length of the sheet pile wall. In this case, a common plenum between the sheet pile wall and the existing intake runs the length of the intake. This configuration provides the best performance from an operational standpoint because it allows for flow balancing between the screen/pump bays and the individual manifold pipes. If there are no concerns with obstructing the waterway, the sheet pile wall can be placed far enough out so that the portion of the wall parallel to the intake can be installed first along with the pipes and screens that extend further offshore. In this case, the plenum ends are left open so that the intake can remain functional until the offshore construction is completed. At that point, the intake must shut down to install the final end portions of the wall, the air piping connection to the air supply, and make final connections of the manifold pipes. EPA is not aware of any existing retrofits where this construction technique has been used. However, it has been proposed in a feasibility study where a new, larger intake was to be constructed offshore (see discussion in Construction Downtime Section).

Costs were developed for this module based on the second scenario described above. These costs are assumed equal or greater than costs for steel plate(s) affixed to the existing intake opening, and therefore inclusive of either approach. This assumption is based on the use of a greater amount of steel material for sheet piles (which is offset somewhat by the fabrication cost for the steel plates), the use of similarly-sized heavy equipment (pile driver versus crane), and similar diver costs for constructing pipe connections and reinforcements in the sheet pile wall versus installing plates. Costs were developed for both freshwater environments and, with the inclusion a cost factor for coating the steel with a corrosion-resistant material, for saltwater environments.

Connecting Pipes

The design (length and configuration) of the connecting pipes (also referred to as pipe manifold or header) is partly dictated by intake flow and water depth. A review of the pipe diameter and design flow data submitted to EPA by facilities with submerged offshore intakes indicates intake pipe velocities at design flow were typically around 5 fps. Note that a minimum of 2.5 to 3 fps is recommended to prevent deposition of sediment and sand in the pipe (Metcalf & Eddy 1972). Also, calculations based on vendor data concerning screen attachment flange size and design flow data resulted in pipe velocities ranging from 3.2 to 4.5 fps for the nominal size pipe connection. EPA has elected to size the connecting pipes based on a typical design pipe velocity of 5 fps.

Even at 5 fps, the piping requirements are substantial. For example, if the existing intake has traveling screens with a high velocity (e.g., 2.5 fps through-screen velocity), then the cross-sectional area of the intake pipe needed to provide the same flow would be approximately one-third of the existing screen area (assuming existing screen open area is 68%). Given the above assumptions, an existing intake with a 10-foot wide traveling screen and a 20-foot water depth would require a 9.4-foot diameter pipe and be connected to at least four 8-foot diameter fine mesh T-screens (T96). The flow rate for this hypothetical intake screen would be 155,000 gpm.

For small volume flows (40,750 gpm or less for fine mesh–see Table 1-3), T-screens (particularly those with a single screen unit) can be installed very close to the existing intake structure, as the upstream or downstream extensions of the screen should not be an issue. In the 10-foot wide by 20-foot deep traveling screen example above, each of the T96 screens required is 26 feet long. For this example, it is possible to place the four T96 screens directly in front of the existing intake connected to a single manifold extending 56 feet (2*8+2*8+2*8+8) to the centerline of the last T-screen. This is based on a configuration where the manifold has multiple ports (four in this case) spaced along the top. However, this configuration will experience some flow imbalance between the screens. A better configuration would be a single pipe branching twice in a double "H" arrangement. In this case, the total pipe length would be 62 feet (20+26+2*8). Therefore, a minimum pipe length of 66 feet (20 meters) was selected to cover the pipe installation costs for screens installed close to the intake.

Based on the above discussion, facilities with design flow values requiring multiple manifold pipes (i.e., >163,000 gpm) will require the screens to extend even further out. In these cases, costs for a longer pipe size are appropriate. Using a longer pipe allows for individual screens to be spread out laterally and/or longitudinally. Longer pipes would also tend to provide access to deeper water where larger screens can be used. While using smaller screens allows for operations in shallower water, many more screens would be needed. This configuration covers a greater bottom area and requires more branching and longer, but smaller, pipes. Therefore, with the exception of the lower intake flow facilities, a length of connecting pipe longer than66 feet (20 meters) is assumed to be required.

The next assumed pipe length is 410 feet (125 meters), based on the Phase I proposed rule cost estimates. A length of 125 meters was selected in Phase I costing as a reasonable estimate for extending intakes beyond the littoral zone. Additional lengths of 820 feet (250 meters) and 1640 feet (500 meters) were selected to cover the possible range of intake distances. The longest distance (1640 feet) is similar in magnitude to the intake distances reported for many of the Phase II facilities with offshore intakes located on large bodies of water, such as oceans and Great Lakes.

As described in the document Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A, submerged intake pipes can be constructed in two ways. One construction uses steel that is concrete-lined and coated on the outside with epoxy and a concrete overcoat. The second construction uses prestressed concrete cylinder pipe (PCCP). Steel is generally used for lake applications; both steel and PCCP are used for riverine applications; PCCP is typically used in ocean applications. A review of the submerged pipe laying costs developed for the Phase I proposed rule showed that the costs of installing steel and PCCP pipe using the conventional method were similar, with steel being somewhat higher in cost. EPA has thus elected to use the Phase I cost methodology for conventional steel pipe as representative of the cost for both steel and concrete pipes installed in all waterbodies. The conventional pipe laying method was selected because it could be performed in front of an existing intake and was least affected by the limitations associated with local topography.

While other methods such as the bottom-pull or micro-tunneling methods could potentially be used, the bottom-pull method requires sufficient space for laying pipe onshore while the micro-tunneling method requires that a shaft be drilled near the shoreline, which may be difficult to perform in conjunction with an existing intake. The conventional steel pipe laying cost methodology and assumptions are described in detail in the document Economic and Engineering Analyses of the Proposed Section 316(b) New

Facility Rule, Appendix A.

1.1.2 CAPITAL COST DEVELOPMENT

Screen Material Construction and Costs

Costs were obtained for T-screens constructed of three different types of materials: 304 stainless steel, 316 stainless steel, and copper-nickel (CuNi) alloy. In general, screens installed in freshwater are constructed of 304 stainless steel. However, where Zebra Mussels are a problem, CuNi alloys are often used because the leached copper tends to discourage screen biofouling with Zebra mussels. In corrosive environments such as brackish and saltwater, 316 stainless steel is often used. If the corrosive environment is harsh, particularly where oxygen levels are low, CuNi alloys are recommended. Since the T-screens are to be placed extending out into the waterway, such low oxygen environments are not expected to be encountered.

Based on this information, EPA has chosen to base the cost estimates on utilizing screens made of 304 stainless steel for freshwater environments without Zebra Mussels, CuNi alloy for freshwater environments with the potential for Zebra Mussels and 316 stainless steel for brackish and saltwater environments. Table 1-4 provides a list of states that contain or are adjacent to waterbodies where Zebra Mussels are currently found. The cost for CuNi screens are applied to all freshwater environments located within these states. EPA notes that the screens comprise only a small portion of the total costs, particularly where the design of other components are the same, such as the proposed design scenarios for freshwater environments with Zebra Mussels versus those without.

TABLE 1-4

List of States with Freshwater Zebra Mussels as of 2001	
State Name	**Abbreviation**
Alabama	AL
Connecticut	CT
Illinois	IL
Indiana	IN
Iowa	IA
Kentucky	KY
Louisiana	LA
Michigan	MI
Minnesota	MN
Mississippi	MS
Missouri	MO
New York	NY
Ohio	OH
Oklahoma	OK
Pennsylvania	PA
Tennessee	TN
Vermont	VT
West Virginia	WV
Wisconsin	WI

Table 1-5 presents the component and total installed costs for the three types of screens. A vendor indicated that the per screen costs will not change significantly between those with fine mesh and very fine mesh so the same screen costs are used for each. Installation and mobilization costs are based on vendor-provided cost estimates for velocity caps, which are comparable to those for T-screens. The individual installation cost per screen of $35,000 was reduced by 30% for multiple screen installations. Costs for steel fittings are also included. These costs are based on steel fitting costs developed for the new facility Phase I effort and are adjusted for a pipe velocity of 5 fps and converted to 2002 dollars. An additional 5% was added to the total installed screen costs to account for installation of intake protection and warning devices such as pilings, dolphins, buoys, and warning signs.

TABLE 1-5

T-Screen Equipment and Installation Costs

Size	Number of Screens	Capacity	Total Screen Cost by Material			Air Burst Equipment	Screen Installation	Mobilization	Steel Fitting
		gpm	304SS	316SS	CuNi				
T24	1	2,500	$5,800	$6,100	$8,000	$10,450	$25,000	$15,000	$2,624
T36	1	5,700	$10,000	$11,200	$18,000	$15,050	$25,000	$15,000	$3,666
T48	1	10,000	$17,000	$18,800	$31,700	$22,362	$30,000	$15,000	$5,067
T60	1	15,800	$23,000	$26,200	$44,500	$28,112	$35,000	$15,000	$6,964
T72	1	22,700	$34,000	$39,500	$69,700	$35,708	$35,000	$20,000	$9,227
T84	1	31,000	$45,000	$51,900	$93,400	$43,588	$35,000	$20,000	$11,961
T96	1	40,750	$61,000	$70,200	$124,000	$49,338	$35,000	$25,000	$15,189
T96	2	81,500	$122,000	$140,400	$248,000	$49,338	$49,000	$25,000	$28,865
T96	3	122,250	$183,000	$210,600	$372,000	$49,338	$73,500	$30,000	$42,840
T96	4	163,000	$244,000	$280,800	$496,000	$49,338	$98,000	$30,000	$57,113

The same costs are used for both fine mesh and very fine mesh with major difference being the design flow for each screen size.

Connecting Wall Cost Development

The cost for the connecting wall that blocks off the existing intake and provides the connection to the screen pipes is based on the cost of an interlocking sheet pile wall constructed directly in front of the existing intake. In general, the costs are mostly a function of the total area of the wall and will vary with depth. Cost estimates were developed for a range of wall dimensions. The first step was to estimate the nominal length of the existing intake for each of the design flow values shown in Tables 1-1 and 1-2. The nominal length was estimated using an assumed water depth and intake velocity. The use of actual depths and intake velocities imparted too many variables for the selected costing methodology. A depth of 20 feet was selected because it was close to both the mean and median intake water depth values reported by Phase II facilities in their Detailed Technical Questionnaires.
The length of the wall was also based on an assumed existing intake, through-screen velocity of 1 fps and an existing screen open area of 50%. Most existing coarse screens have an open area of 68%. However, a 50% area was chosen to produce a larger (i.e., more costly) wall size. Selecting a screen velocity of 1 fps also will overestimate wall length (and therefore, costs) for existing screen velocities greater than 1 fps. This is the case for most of the facilities (just under 70% of the Phase II Facilities reported screen velocities of 1 fps or greater). An additional length of 30 to 60 feet (scaled between 30 feet for 2,500 to 60 feet for 163,000 gpm with a minimum of 30 ft for lower flows) was added to cover the end portions of the wall and to cover fixed costs for smaller intakes. The costs are based on the following:

- Sheet pile unit cost of $24.50/sq ft RS Means 2001)
- An additional 50% of sheet pile cost to cover costs not included in sheet pile unit cost[1]
- Total pile length of 45 feet for 20-foot depth including 15-foot penetration and 10-foot extension above water level
- Mobilization of $18,300 for 20-foot depth RS Means 2001), added twice (assuming sheet pile would be installed in two stages to minimize generating unit downtime (see Downtime discussion). The same mobilization costs are used for both saltwater and freshwater environments.
- An additional cost of 33% for corrosion-resistant coating for saltwater environments.

[1]Note that this 50% value was derived by comparing the estimated costs of a sheet pile wall presented in a feasibility study for the Salem Nuclear Plant to the cost estimated for a similarly sized sheet pile wall using the EPA method described here. This factor was intended to cover the cost of items such as walers, bracing and installation costs not included in the R S Means unit cost. The Salem facility costs included bypass gates, which are assumed to be similar in cost to the pipe connections.

Tables 1-6 and 1-7 present the estimated wall lengths, mobilization costs, and total costs for 20-foot depth for both freshwater and saltwater environments for fine mesh and very fine mesh screens, respectively.

TABLE 1-6

Sheet Pile Wall Capital Costs for Fine Mesh Screens

Design Flow	Total Estimated Wall Length	Mobilization	Sheet Pile Wall Total Costs 20 Ft Water Depth*	
gpm	Ft		Freshwater	Saltwater
2,500	31	$36,600	$87,157	$103,840
5,700	32	$36,600	$89,351	$106,758
10,000	34	$36,600	$92,359	$110,759
15,800	36	$36,600	$96,416	$116,155
22,700	39	$36,600	$101,243	$122,575
31,000	43	$36,600	$107,049	$130,297
40,750	47	$36,600	$113,870	$139,369
81,500	64	$36,600	$142,376	$177,283
122,250	81	$36,600	$170,883	$215,196
163,000	96	$36,600	$195,960	$248,549

* Total costs include mobilization

TABLE 1-7

Sheet Pile Wall Capital Costs for Very Fine Mesh Screens

Design Flow	Total Estimated Wall Length	Mobilization	Sheet Pile Wall Costs 20 Ft Water Depth*	
gpm	Ft		Freshwater	Saltwater
1,680	30	$36,600	$86,854	$103,438
3,850	31	$36,600	$88,056	$105,037
6,750	32	$36,600	$90,085	$107,735
10,700	34	$36,600	$92,848	$111,410
15,300	36	$36,600	$96,066	$115,690
20,900	38	$36,600	$99,984	$120,900
27,500	41	$36,600	$104,601	$127,041
55,000	53	$36,600	$123,838	$152,627
82,500	64	$36,600	$143,076	$178,213
110,000	76	$36,600	$162,314	$203,799
165,000	99	$36,600	$200,789	$254,971

* Total costs include mobilization

Pipe Manifold Cost Development

For facilities with design intake flows that are 10% or more greater than the 163,000 gpm to 165,000 gpm maximum costed (i.e., above 180,000 gpm), multiple intakes are costed and the costs are summed. This approach leads to probable costing over-estimates for both the added length of end sections wall costs.

Pipe costs are developed using the same general methodology as described in Economic and Engineering Analyses of the Proposed Section 316(b) New Facility Rule, Appendix A, but modified based on a design pipe velocity of 5 fps. The pipe laying cost methodology was revised to include: costs for several different pipe lengths were developed. These pipe lengths include: 66 feet (20 meters), 410 feet (125 meters), 820 feet (250 meters), and 1640 feet (500 meters). The cost for pipe installation includes an equipment rental component for the pipe laying vessel, support barge, crew, and pipe laying equipment. The Phase I proposed rule Economic and Engineering Analyses document estimates that 500 feet of pipe can be laid in a day under favorable conditions. Equipment rental costs for the longer piping distances were adjusted upward, in single-day increments, to limit daily production rates not to exceed 550 feet/day. For the shorter distance of 66 feet (20 meters), the single-day pipe laying vessel/equipment costs were reduced by a factor of 40%. This reduction is based on the assumption that, in most cases, a pipe laying vessel is not needed because installation can be performed via crane located on the shoreline.

Figure 1-1 presents the capital cost curves for the pipe portion only for each of the offshore distance scenarios. The pipe cost development methodology adopted from the Phase I effort used a different set of flow values than are shown in Table 1-1. Therefore, second-order, best-fit equations were derived from pipe cost data. These equations were applied to the flow values in Table 1-1 to obtain the relevant installed pipe cost component.

An additional equipment component representing the cost of pipe fittings such as tees or elbows are included in the screen equipment costs. The costs are based on the cost estimates developed for the Phase I proposed rule, adjusted to a pipe velocity of 5 fps and 2002 dollars.

Airburst System Costs

Capital costs for airburst equipment sized to backwash each of the T-screens were obtained from vendor estimates. These costs included air supply equipment (compressor, accumulator, distributor) minus the piping to the screens, air supply housing, and utility connections and wiring. Capital costs of the airburst air supply system are shown in Table 1-8. Costs for a housing structure, electrical, and controls were added based on the following:

- electrical costs = 10% of air supply equipment (BPJ)
- Controls = 5% of air supply equipment (BPJ)
- Housing = $142/sq ft for area shown in Table 1-8. This cost was based on the $130/sq ft cost used in the Phase I cost for pump housing, adjusted to 2002 dollars.

TABLE 1-8
Capital Costs of Airburst Air Supply Equipment

Screen Size	Vendor Supplied Equipment Costs	Estimated Housing Area	Housing Area	Housing Costs	Electrical	Controls	Total Airburst Minus Air Piping to Screens
			sq ft		10%	5%	
T24	$6,000	5x5	25	$3,550	$600	$300	$10,450
T36	$10,000	5x5	25	$3,550	$1,000	$500	$15,050
T48	$15,000	6x6	36	$5,112	$1,500	$750	$22,362
T60	$20,000	6x6	36	$5,112	$2,000	$1,000	$28,112
T72	$25,000	7x7	49	$6,958	$2,500	$1,250	$35,708
T84	$30,000	8x8	64	$9,088	$3,000	$1,500	$43,588
T96	$35,000	8x8	64	$9,088	$3,500	$1,750	$49,338

The costs of the air supply pipes, or "blow pipes," are calculated for each installation depending on the length of the intake pipe, plus an assumed average distance of 70 feet from the airburst system housing to the intake pipe at the front of the sheet pile wall. Pipe costs are based on this total distance multiplied by a derived unit cost of installed pipe Vendors indicated that the pipes are typically made of schedule 10 stainless steel or high density polyethylene and that material costs are only a portion of the total installed costs. Consistent with the selection of screen materials, EPA chose to assume that the blow pipes are constructed of 304 stainless steel for freshwater and 316 stainless steel for saltwater applications.

The unit costs for the installed blow pipes are based on the installed cost of similar pipe in a structure on land multiplied by an underwater installation factor. This underwater installation factor was derived by reviewing the materials-versus-total costs for underwater steel pipe installation, which ranged from about 3.2 to 4.5 with values decreasing with increasing pipe size. A review of the materials-versus-installed-on-land costs for the smaller diameter stainless steel pipe ® S Means 2001) found that if the installed-on-land unit costs are multiplied by 2.0, the resulting materials-to-total- estimated (underwater)-installed-cost ratios fell within a similar range. These costs are considered as over-estimating costs somewhat because they include 304 and 316 stainless steel where less costly materials may be used. Also, they do not consider potential savings associated with concurrent installation alongside the much larger water intake pipe.

Blow pipe sizes were provided by vendors for T60 and smaller screens. For larger screens, the blow pipe diameter was derived by calculating pipe diameters (and rounding up to even pipe sizes) using the same ratio of screen area to blow pipe area calculated for T60 screens. This is based on the assumption that blow pipe air velocities are proportional to the needed air/water backwash velocities at the screen surface. A separate blow pipe was included for each T-screen where multiple screens are included, but only one set of the air supply equipment (compressor, accumulator, distributor, controls etc.) is included in each installation. The calculated costs for the air supply pipes are shown in Table 1-9.

TABLE 1-9
Capital Costs of Installed Air Supply Pipes for Fine Mesh Screens

Design Flow Fine Mesh	Design Flow Very Fine Mesh	Air Pipe Unit Cost - Schedule 10 304 SS	Air Pipe Unit Cost - Schedule 10 316 SS	Freshwater Airburst Distribution Installed Pipe Costs				Saltwater Airburst Distribution Installed Pipe Costs			
gpm	gpm	$/Ft	$/Ft	20 Meters	125 Meters	250 Meters	500 Meters	20 Meters	125 Meters	250 Meters	500 Meters
2,500	1,680	$57.3	$119.5	$7,764	$27,485	$50,961	$97,915	$16,210	$57,379	$106,391	$204,413
5,700	3,850	$85.4	$102.0	$11,575	$40,973	$75,970	$145,966	$13,834	$48,970	$90,798	$174,454
10,000	6,750	$102.0	$118.7	$13,834	$48,970	$90,798	$174,454	$16,093	$56,966	$105,625	$202,943
15,800	10,700	$160.3	$188.4	$21,739	$76,954	$142,685	$274,147	$25,550	$90,442	$167,694	$322,198
22,700	15,300	$222.8	$279.0	$30,209	$106,934	$198,274	$380,954	$37,830	$133,910	$248,292	$477,056
31,000	20,900	$304.0	$368.5	$41,220	$145,910	$270,542	$519,806	$49,971	$176,890	$327,983	$630,169
40,750	27,500	$376.8	$456.0	$51,100	$180,883	$335,388	$644,396	$61,828	$218,861	$405,804	$779,692
81,500	55,000	$376.8	$456.0	$102,199	$361,766	$670,775	$1,288,793	$123,656	$437,722	$811,609	$1,559,383
122,250	82,500	$376.8	$456.0	$153,299	$542,650	$1,006,163	$1,933,189	$185,485	$656,582	$1,217,413	$2,339,075
163,000	110,000	$376.8	$456.0	$204,398	$723,533	$1,341,550	$2,577,586	$247,313	$875,443	$1,623,218	$3,118,766
-	165,000	$376.8	$456.0	$306,597	$1,085,299	$2,012,326	$3,866,378	$370,969	$1,313,165	$2,434,826	$4,678,150

<u>Indirect Costs</u>

The total calculated capital costs were adjusted to include the following added costs:

- Engineering at 10% of direct capital costs
- Contractor overhead and profit at 15% of direct capital costs (based on O&P component of installing lift station in RS Means 2001); some direct cost components, e.g., the intake pipe cost and blow pipe cost, already include costs for contractor overhead and profit
- Contingency at 10% of direct capital costs
- Sitework at 10% of direct capital costs; based on sitework component of Fairfax Water Intake costs data, including costs for erosion & sediment control, trash removal, security, dust control, access road improvements, and

restoration (trees, shrubs, seeding & sodding).

Total Capital Costs

Fine Mesh

Table 1-10 presents the total capital costs of the complete system for fine mesh screens including indirect costs. Figures 1-2, 1-3, and 1- 4 present the plotted capital costs in Table 1-10 for freshwater, saltwater, and freshwater with Zebra mussels, respectively. Figures 1-2, 1-3, and 1-4 also present the best-fit, second order equations used in estimating compliance costs.

Very Fine Mesh

Table 1-11 presents the total capital costs of the complete system for very fine mesh screens including indirect costs. Figures 1-5, 1-6, and 1-7 present the plotted capital costs in Table 1-11 for freshwater, saltwater, and freshwater with Zebra mussels, respectively.

TABLE 1-10
Total Capital Costs of Installed Fine Mesh T-screen System at Existing Shoreline Based Intakes

Design Flow gpm	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
2,500	$330,608	$356,632	$333,958	$458,425	$487,945	$461,775	$694,677	$728,359	$698,027	$1,007,472	$1,049,477	$1,010,822
5,700	$359,106	$389,320	$371,286	$524,990	$563,194	$537,170	$807,170	$854,887	$819,350	$1,210,950	$1,277,690	$1,223,130
10,000	$405,008	$437,575	$427,389	$612,009	$652,566	$634,390	$944,036	$994,105	$966,417	$1,446,429	$1,515,522	$1,468,810
15,800	$460,179	$498,982	$492,913	$739,998	$792,284	$772,732	$1,160,061	$1,228,398	$1,192,795	$1,837,241	$1,937,682	$1,869,975
22,700	$530,563	$580,486	$584,916	$893,959	$970,848	$948,312	$1,415,327	$1,524,319	$1,469,680	$2,293,842	$2,467,040	$2,348,195
31,000	$602,745	$659,150	$676,434	$1,069,950	$1,157,317	$1,143,639	$1,717,372	$1,841,598	$1,791,061	$2,846,829	$3,044,774	$2,920,518
40,750	$691,543	$757,467	$787,461	$1,270,404	$1,374,281	$1,366,322	$2,054,067	$2,203,125	$2,149,984	$3,455,143	$3,694,566	$3,551,061
81,500	$1,034,259	$1,142,774	$1,226,094	$2,120,425	$2,304,845	$2,312,260	$3,526,716	$3,801,500	$3,718,551	$6,175,421	$6,630,933	$6,367,256
122,250	$1,420,292	$1,571,396	$1,708,044	$3,023,393	$3,288,357	$3,311,146	$5,071,576	$5,472,086	$5,359,329	$9,016,065	$9,687,666	$9,303,817
163,000	$1,813,456	$2,005,510	$2,197,126	$3,943,125	$4,286,990	$4,326,795	$6,652,462	$7,177,056	$7,036,132	$11,940,891	$12,826,940	$12,324,561

TABLE 1-11
Total Capital Costs of Installed Very Fine Mesh T-screen System at Existing Shoreline Based Intakes

Design Flow gpm	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
1,680	$329,296	$355,254	$332,813	$451,952	$481,545	$455,469	$681,911	$715,832	$685,428	$982,352	$1,024,929	$985,869
3,850	$354,622	$384,438	$367,411	$507,964	$546,100	$520,753	$774,855	$822,895	$787,644	$1,148,553	$1,216,401	$1,161,342
6,750	$396,579	$428,325	$420,079	$580,540	$620,605	$604,039	$884,451	$934,421	$907,951	$1,331,420	$1,401,198	$1,354,919
10,700	$446,379	$483,934	$480,749	$689,904	$741,492	$724,274	$1,065,566	$1,133,860	$1,099,937	$1,655,065	$1,756,769	$1,689,435
15,300	$510,005	$558,302	$567,076	$820,297	$896,659	$877,368	$1,276,515	$1,386,288	$1,333,586	$2,026,108	$2,202,703	$2,083,179
20,900	$573,744	$627,794	$651,118	$968,061	$1,054,341	$1,045,435	$1,525,747	$1,650,395	$1,603,120	$2,477,203	$2,678,590	$2,554,577
27,500	$652,189	$714,992	$752,903	$1,134,364	$1,236,677	$1,235,077	$1,798,524	$1,947,874	$1,899,238	$2,961,902	$3,205,326	$3,062,615
55,000	$944,813	$1,047,085	$1,146,240	$1,832,361	$2,013,654	$2,033,788	$2,989,159	$3,264,526	$3,190,586	$5,136,240	$5,599,755	$5,337,667
82,500	$1,270,016	$1,411,756	$1,572,156	$2,567,323	$2,827,597	$2,869,463	$4,225,531	$4,626,915	$4,527,671	$7,378,247	$8,061,852	$7,680,387
110,000	$1,596,585	$1,777,795	$1,999,439	$3,308,039	$3,647,292	$3,710,892	$5,476,429	$6,003,830	$5,879,283	$9,656,711	$10,560,407	$10,059,565
165,000	$2,276,664	$2,536,812	$2,880,944	$4,829,568	$5,326,782	$5,433,848	$8,044,641	$8,824,075	$8,648,921	$14,345,849	$15,689,726	$14,950,129

Nuclear Facilities

Construction and material costs tend to be substantially greater for nuclear facilities due to burden of increased security and to the requirements for more robust system design. Rather than performing a detailed evaluation of the differences in capital costs for nuclear facilities, EPA has chosen to apply a simple cost factor based on total costs.

In the Phase I costing effort, EPA used data from an Argonne National Lab study on retrofitting costs of fossil fuel power plants and nuclear power plants. This study reported average, comparative costs of $171 for nuclear facilities and $108 for fossil fuel facilities, resulting in a 1.58 costing factor. In comparison, recent consultation with a traveling screen vendor, the vendor indicated costing factors in the range of 1.5-2.0 were reasonable for estimating the increase in costs associated with nuclear power plants based on their experience. Because today there are likely to be additional security burdens above that experienced when the Argonne Report was generated, EPA has selected 1.8 as a capital costing factor for nuclear facilities. Capital costs for nuclear facilities are not presented here but can be estimated by multiplying the applicable non-nuclear facility costs by the 1.8 costing factor.

O&M Costs

O&M cost are based on the sum of costs for annual inspection and cleaning of the intake screens by a dive team and for estimated operating costs for the airburst air supply system. Dive team costs were estimated for a total job duration of one to four days, and are shown in Table 1-12. Dive team cleaning and inspections were estimated at once per year for low debris locations and twice per year for high debris locations. The O&M costs for the airburst system are based on power requirements of the air compressor and labor requirements for routine O&M. Vendors cited a backwash frequency per screen from as low as once per week to as high as once per hour for fine mesh screens. The time needed to recharge the accumulator is about 0.5 hours, but can be as high as 1 hour for those with smaller compressors or accumulators that backwash more than one screen simultaneously.

The Hp rating of the typical size airburst compressor for each screen size was obtained from a vendor and is presented in the table in Attachment A. A vendor stated that several hours per week would be more than enough labor for routine maintenance, so labor is assumed to be two to four hours per week based on roughly half-hour daily inspection of the airburst system. However, during seasonal periods of high debris such as leaves in the fall, it may be necessary for someone to man the backwash system 24 hours/day for several weeks (Frey 2002). Thus, an additional one to 4.5 weeks of 24-hour labor are included for these periods (one week low debris fine mesh; 1.5 weeks low debris very fine mesh; three weeks high debris fine mesh; and 4.5 weeks high debris very fine mesh). Since very fine mesh screens will tend to collect debris at a more rapid rate, backwash frequencies and labor requirements were increased by 50% for very fine mesh screens.

The O&M cost of the airburst system are based on the following:

- Average backwash frequency in low debris areas is 2 times per day (3 times per day for very fine mesh)
- Average backwash frequency in high debris areas is 12 times per day (18 times per day for very fine mesh)
- Time to recharge accumulator is 0.5 hours
- Compressor motor efficiency is 90%
- Cost of electric power consumed is $0.04/Kwh
- Routine inspection and maintenance labor is 3 hours per week (4.5 hours per week for very fine mesh) for systems up to 182,400 gpm
- O&M labor rate per hour is $41.10/hr. The rate is based on Bureau of Labor Statistics Data using the median labor rates for electrical equipment maintenance technical labor (SOC 49-2095) and managerial labor (SOC 11-1021); benefits and other compensation are added using factors based on SIC 29 data for blue collar and white collar labor. The two values were combined into a single rate assuming 90% technical labor and 10% managerial. See Doley 2002 for details.

Table 1-13 presents the total O&M cost for relocating intakes offshore with fine mesh and very fine mesh passive screens. These data are plotted in Figures 1-8 and 1-9 which also shows the second-order equations that were fitted to these data and used to estimate the O&M costs for individual Phase II facilities. Attachment A presents the worksheet data used to develop the annual O&M costs. As with the capital costs, at facilities where the design flow exceeds the maximum cost model design flow of 165,000 gpm plus 10% (180,000 gpm), the design flow are divided and the corresponding costs are summed.

TABLE 1-12
ESTIMATED COSTS FOR DIVE TEAM TO INSPECT AND CLEAN T-SCREENS

Installation and Maintenance Diver Team Costs

Item	Daily Cost*	One Time Cost*	Total	Adjusted Total			
Duration			One Day	One Day	Two Day	Three Day	Four Day
Cost Year			1999	2002	2002	2002	2002
Supervisor	$575		$575	$627	$1,254	$1,880	$2,507
Tender	$200		$200	$218	$436	$654	$872
Diver	$375		$750	$818	$1,635	$2,453	$3,270
Air Packs	$100		$100	$109	$218	$327	$436
Boat	$200		$200	$218	$436	$654	$872
Mob/Demob		$3,000	$3,000	$3,270	$3,270	$3,270	$3,270
Total			$4,825	$5,260	$7,250	$9,240	$11,230

***Source: Paroby 1999 (cost adjusted to 2002 dollars).**

Table 1-13
Total O&M Costs for Passive Screens Relocated Offshore

Relocate Ofshore With New Fine Mesh Screens			Relocate Ofshore With New Very Fine Mesh Screens		
Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris	Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris
gpm			gpm		
2,500	$16,463	$35,654	1,680	$22,065	$48,221
5,700	$16,500	$35,872	3,850	$22,120	$48,548
10,000	$16,560	$36,235	6,750	$22,210	$49,092
15,800	$20,712	$42,497	10,700	$27,442	$56,496
22,700	$20,748	$42,715	15,300	$27,497	$56,823
31,000	$20,808	$43,078	20,900	$27,588	$57,367
40,750	$20,869	$43,441	27,500	$27,678	$57,912
81,500	$25,299	$51,374	55,000	$33,328	$67,821
122,250	$25,601	$53,189	82,500	$33,782	$70,544
163,000	$27,894	$58,984	110,000	$36,226	$77,246
-	-	-	165000	$37,133	$82,692

Construction Related Downtime

Downtime may be a substantial cost item for retrofits using the existing pump wells and pumps. The EPA retrofit scenario includes a sheet pile wall in front of the existing intake. This scenario is modeled after a proposed scenario presented in a feasibility study for the Salem Nuclear Plant. In this scenario, a sheet pile plenum with bypass gates is constructed 40 feet in front of the existing intake with about twelve 10-foot diameter header pipes connecting the plenum to about 240 T-screens. Construction is estimated to take two years, with installation of the sheet pile plenum in the first year. The facility projects the installation of 10-foot header pipes and screens to take nine months and the air backwash piping to take two months. The feasibility study states that Units 1 & 2 would each have to be shutdown for about six months, to install the plenum, and for an additional two months to install the 10-foot header pipe connection to the plenum and to install the air piping. Thus, an estimated total of eight months downtime is estimated for this very large (near worst case) intake scenario. This scenario was discarded by the facility due to uncertainty about biofouling and debris removal at slack tides. No cost estimates were developed and, therefore no incentive to focus on a system design and a construction sequence that would minimize downtime existed.

In the same feasibility study, a scenario is proposed where a new intake with dual flow traveling screens is installed at a distance of 65 feet offshore inside a cofferdam. In this scenario, a sheet pile plenum wall connects the new intake to the existing shore intake. In this scenario the intake is constructed first; Units 1 & 2 are estimated to be shut down for about one month each to construct and connect the plenum walls to the existing intake.

It would seem that the T-screen plenum construction scenario could follow the same approach, i.e., performed while the units are operating. This approach would result in a much lower downtime, similar to that for the offshore intake, but including consideration for added time for near-shore air pipe installation. There are two relevant differences between these scenarios. One is the distance offshore to the T-screen piping connection versus the new intake structure (40 feet versus 65 feet). The second is that T-screens, pipes, and plenum would be installed underwater while the new intake would be constructed behind a coffer dam. Conceivably the offshore portion of the T-screen plenum (excluding the ends) and all pipe and screen installation on the offshore side could be performed without shutting down the intake.

The WH Zimmer plant is a facility that EPA has identified as actually having converted an existing shoreline intake with traveling screens to submerged offshore T-screens. This facility was originally constructed as a nuclear facility but was never completed. In the late 80's it was converted to a coal fired plant. The original intake was to supply service water and make-up water for recirculating wet towers, and had been completed. However, the area in front of the intake was plagued with sediment deposition. A decision was made to abandon the traveling screens and install T-screens approximately 50 feet offshore. However, because the facility was not operating at the time of this conversion, there was no monetary incentive to minimize construction time. Actual construction took six to eight months for this intake, with a design flow of about 61,000 gpm (Frey 2002). The construction method in this case used a steel wall installed in front of the existing intake pump wells.

The Agency consulted the WH Zimmer plant engineer and asked him to estimate how long it would take to perform this retrofit particularly with a goal of minimizing generating unit downtime. The estimated downtime was a minimum of seven to nine weeks, assuming mobilization goes smoothly and a tight construction schedule is maintained. A more generous estimate of a total of 12 to 15 weeks was estimated for their facility assuming some predictable disruption to construction schedules. This estimate includes five to six weeks for installing piping (some support pilings can be laid ahead of time), an additional five to six weeks to tie in piping and install the wall, and an additional two to three weeks to clean and dredge the intake area. This last two- to three-week period was a construction step somewhat unique to the Zimmer plant, especially because the presence of sediment was the driving factor in the decision to convert the system.

Based on the above information, EPA has concluded that a reasonable unit downtime should be in the range of 13 to 15 weeks for total downtime. It is reasonable to assume that this downtime can be scheduled to coincide with routine generating unit downtime of approximately four weeks, resulting in a total potential lost generation period of nine to 11 weeks. Rather than select a single downtime for all facilities installing passive screens, EPA chose to apply a 13 to 15 week total downtime duration based on variations in project size using design flow as a measure of size. As such, EPA assumed a downtime of 13 weeks for facilities with intake flow volumes of less than 400,000 gpm, 14 weeks for facilities with intake flow volumes greater than 400,000 gpm but less than 800,000 gpm, and 15 weeks for facilities with intake flow volumes greater than 800,000 gpm.

<u>Application</u>

General Applicability

The following site-related conditions may preclude the use of passive T-screens or create operational problems:

- Water depths of <2 feet at screen location; for existing facilities this should not be an issue
- Stagnant waterbodies with high debris load

- Waterbodies with frazil ice in winter.

Frazil ice consists of fine, small, needle-like structures or thin, flat, circular plates of ice suspended in water. In rivers and lakes it is formed in supercooled, turbulent water. Remedies for this problem include finding another location such as deeper water that is outside of the turbulent water or creating a provision for periodically applying heated water to the screens. The application of heated water may not be feasible or economically justifiable in many instances.

Some facilities have reported limited success in alleviating frazil ice problems by blowing a small constant stream of air through the screen backwash system (Whitaker 2002b).

Application of Different Pipe Lengths

As noted previously, the shortest pipe length cost scenario (20 meters) are assumed to be applicable only to facilities with flows less than 163,000 gpm. Conversely, facilities located on large waterbodies that are subject to wave action and shifting sediment are assumed to install the longest pipe length scenario of 500 meters. Large waterbodies in this instance will include Great Lakes, oceans, and some estuarine/tidal rivers. The matrix in Table 1-14 will provide some initial guidance. Generally, if the waterbody width is known, the pipe length should not exceed half the width.

TABLE 1-14
SELECTION OF APPLICABLE RELOCATION OFFSHORE PIPE LENGTHS BY WATERBODY

	Freshwater Rivers/Streams	Lakes/Reservoirs	Estuaries/Tidal Rivers	Great Lakes	Oceans
20 Meters	Flow <163,000	Flow <163,000	NA	NA	NA
125 Meters	TBD	TBD	TBD	NA	NA
250 Meters	TBD	TBD	TBD	TBD	NA
500 Meters	NA	NA	TBD	TBD	ALL

TBD: Criteria or selection to be determined; criteria may include design flow, waterbody size (if readily available).

1.2 ADD SUBMERGED FINE MESH PASSIVE SCREENS TO EXISTING OFFSHORE INTAKES

Please note that much of the supporting documentation has been previously described in Section 1.1.

Capital Costs

Adding passive screens to an existing submerged offshore intake requires many of the same construction steps and components described in section 1.1 above, excluding those related to the main trunk of the manifold pipe and connecting wall. Similar construction components include: modifying the submerged inlet to connect the new screens, installing T-screens, and installing the airburst backwash air supply equipment and the blowpipes. Nearly all of these components will require similar equipment, construction steps and costs as described in Section 1.1 for the specific components. One possible difference is that the existing submerged piping distance may not match one of the four lengths for which costs were estimated. This difference only affects this component of cost. The cost scenario distance chosen is the one that closely matches or exceeds the existing offshore distance. Tables 1-15 and 1-16 present the combined costs of the installed T-screens, airburst air supply system, and air supply pipes for fine mesh and very fine mesh screens, respectively. The costs in Tables 1-15 and 1-16 include direct and indirect costs, as described in Section 1.1. Figures 1-10, 1- 11, 1-12, 1-13, 1-14, and 1-15 present plots of the data in Tables 1-15 and 1-16. The figures include the second-order, best-fit equations are used to estimate technology costs for specific facilities.

TABLE 1-15
Capital Cost of Installing Fine Mesh Passive T-screens at an Existing Submerged Offshore Intake

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
2,500	$100,137	$112,839	$103,487	$128,732	$172,535	$132,081	$162,773	$243,602	$166,122	$230,855	$385,735	$234,204
5,700	$120,312	$125,414	$132,492	$162,939	$176,361	$175,119	$213,685	$237,012	$225,865	$315,178	$358,314	$327,358
10,000	$154,594	$160,610	$176,975	$205,541	$219,877	$227,922	$266,192	$290,432	$288,573	$387,494	$431,543	$409,874
15,800	$194,029	$204,426	$226,763	$274,090	$298,519	$306,823	$369,400	$410,535	$402,134	$560,020	$634,566	$592,754
22,700	$245,131	$264,554	$299,484	$356,382	$403,871	$410,736	$488,825	$569,725	$543,178	$753,711	$901,432	$808,064
31,000	$293,433	$316,628	$367,122	$445,234	$500,659	$518,923	$625,950	$719,744	$699,639	$987,382	$1,157,915	$1,061,071
40,750	$352,983	$382,546	$448,900	$541,169	$610,243	$637,086	$765,200	$881,312	$861,118	$1,213,263	$1,423,448	$1,309,181
81,500	$562,086	$621,213	$753,921	$938,458	$1,076,608	$1,130,293	$1,386,521	$1,618,744	$1,578,356	$2,282,647	$2,703,017	$2,474,482
122,250	$795,243	$883,934	$1,082,995	$1,359,802	$1,567,025	$1,647,554	$2,031,896	$2,380,230	$2,319,649	$3,376,084	$4,006,639	$3,663,837
163,000	$1,021,242	$1,139,497	$1,404,912	$1,773,988	$2,050,286	$2,157,658	$2,670,113	$3,134,559	$3,053,783	$4,462,364	$5,303,105	$4,846,034

TABLE 1-16
Capital Cost of Installing Very Fine Mesh Passive T-screens at an Existing Submerged Offshore Intake

O&M Costs

Design Flow	Total Costs 20 Meters Offshore			Total Costs 125 Meters Offshore			Total Costs 250 Meters Offshore			Total Costs 500 Meters Offshore		
gpm	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi	304 SS	316 SS	CuNi
	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels	Freshwater	Saltwater	Zebra Mussels
1,680	$100,173	$102,084	$103,690	$128,768	$134,314	$132,284	$162,809	$172,683	$166,326	$230,891	$249,421	$234,408
3,850	$120,156	$125,350	$132,945	$162,783	$176,297	$175,572	$213,530	$236,948	$226,319	$315,023	$358,250	$327,812
6,750	$154,275	$160,428	$177,774	$205,221	$219,694	$228,721	$265,872	$290,250	$289,372	$387,174	$431,360	$410,674
10,700	$193,241	$203,882	$227,611	$273,302	$297,975	$307,672	$368,612	$409,990	$402,982	$559,232	$634,022	$593,603
15,300	$244,023	$263,866	$301,094	$355,275	$403,183	$412,346	$487,718	$569,036	$544,789	$752,603	$900,743	$809,674
20,900	$291,795	$315,515	$369,168	$443,596	$499,547	$520,970	$624,313	$718,632	$701,686	$985,745	$1,156,802	$1,063,118
27,500	$350,954	$381,218	$451,667	$539,140	$608,915	$639,854	$763,172	$879,984	$863,885	$1,211,235	$1,422,120	$1,311,948
55,000	$557,781	$618,309	$759,208	$934,154	$1,073,703	$1,135,580	$1,382,216	$1,615,840	$1,583,643	$2,278,342	$2,700,113	$2,479,769
82,500	$788,414	$879,206	$1,090,554	$1,352,973	$1,562,298	$1,655,113	$2,025,067	$2,375,502	$2,327,207	$3,369,255	$4,001,912	$3,671,395
110,000	$1,011,641	$1,132,697	$1,414,495	$1,764,387	$2,043,486	$2,167,240	$2,660,512	$3,127,759	$3,063,366	$4,452,763	$5,296,305	$4,855,617
165,000	$1,458,718	$1,640,302	$2,062,999	$2,587,837	$3,006,486	$3,192,117	$3,932,025	$4,632,895	$4,536,305	$6,620,401	$7,885,714	$7,224,682

O&M costs are assumed to be nearly the same as for relocating the intake offshore with passive screens. EPA assumes there are some offsetting costs associated with the fact that the existing intake should already have periodic inspection/cleaning by divers. The portion of the costs representing a single annual inspection has therefore been deducted. Tables 1-17 and 1-18 presents the annual O&M costs for fine mesh and very fine mesh screens, respectively. Separate costs are provided for low debris and high debris locations. Figure 1-16 and 1-17 present the plotted O&M data along with the second-order, best fit equations.

TABLE 1-17
Net Intake O&M Costs for Fine Mesh Passive T-screens Installed at Existing Submerged Offshore Intakes

Existing Offshore With New Fine Mesh Screens			Existing Offshore With New Very Fine Mesh Screens		
Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris	Design Flow	Total O&M Costs - Low Debris	Total O&M Costs - High Debris
gpm			gpm		
2,500	$11,203	$30,394	1,680	$16,805	$42,961
5,700	$11,240	$30,612	3,850	$16,860	$43,288
10,000	$11,300	$30,975	6,750	$16,950	$43,832
15,800	$13,462	$35,247	10,700	$20,192	$49,246
22,700	$13,498	$35,465	15,300	$20,247	$49,573
31,000	$13,558	$35,828	20,900	$20,338	$50,117
40,750	$13,619	$36,191	27,500	$20,428	$50,662
81,500	$16,059	$42,134	55,000	$24,088	$58,581
122,250	$16,361	$43,949	82,500	$24,542	$61,304
163,000	$16,664	$47,754	110,000	$24,996	$66,016
-	-	-	165000	$25,903	$71,462

<u>Construction Downtime</u>

Unlike the cost for relocating the intake from shore-based to submerged offshore, the only construction activities that would require shutting down the intake is to modify the inlet and install the T-screens. Installing the air supply system and the major portion of the air blowpipes can be performed while the intake is operating. Downtimes are assumed to be similar to those for adding velocity caps, which were reported to range from two to seven days. An additional one to two days may be needed to connect the blowpipes to the T-screens. The total estimated intake downtime of three to nine days can easily be scheduled to coincide with the routine maintenance period for power plants (which the Agency assumed to be four weeks for typical plants).

<u>Application</u>

Separate capital costs have been developed for freshwater, freshwater with Zebra mussels, and saltwater environments. In selecting the materials of construction, the same methodology described in Section 1.1 is used. Because the retrofit is an addition to an existing intake, selecting the distance offshore involves matching the existing distance to the nearest or next highest distance costed.

Similarly, the O&M costs are applied using the same method as described in Section 1.1.

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ATTACHMENT A
O&M DEVELOPMENT DATA

Table A-1
O&M Development Data - Relocate Offshore with Fine Mesh Screens

Design Flow	Compressor Power	Low Debris Backwash Frequency	High Debris Backwash Frequency	Annual Power Required - Low Debris	Annual Power Required - High Debris	Annual Power Costs - Low Debris*	Annual Power Costs - High Debris*	Annual Labor Required - Low Debris	Annual Labor Cost - Low Debris	Annual Labor Required - High Debris	Annual Labor Cost - High Debris	Dive Team Days Low Debris	Dive Team Costs Low Debris	Dive Team Costs High Debris
		Events/day	Events/day	Kwh	Kwh	$0.04	$0.04	Hours		Hours				
2,500	2	2	12	605	3,631	$24	$145	272	$11,179	608	$24,989	1	$5,260	$10,520
5,700	5	2	12	1,513	9,076	$61	$363	272	$11,179	608	$24,989	1	$5,260	$10,520
10,000	10	2	12	3,025	18,153	$121	$726	272	$11,179	608	$24,989	1	$5,260	$10,520
15,800	12	2	12	3,631	21,783	$145	$871	324	$13,316	660	$27,126	2	$7,250	$14,500
22,700	15	2	12	4,538	27,229	$182	$1,089	324	$13,316	660	$27,126	2	$7,250	$14,500
31,000	20	2	12	6,051	36,305	$242	$1,452	324	$13,316	660	$27,126	2	$7,250	$14,500
40,750	25	2	12	7,564	45,382	$303	$1,815	324	$13,316	660	$27,126	2	$7,250	$14,500
81,500	25	4	24	15,127	90,763	$605	$3,631	376	$15,454	712	$29,263	3	$9,240	$18,480
122,250	25	6	36	22,691	136,145	$908	$5,446	376	$15,454	712	$29,263	3	$9,240	$18,480
163,000	25	8	48	30,254	181,527	$1,210	$7,261	376	$15,454	712	$29,263	4	$11,230	$22,460

Table A-2
O&M Development Data - Relocate Offshore with Very Fine Mesh Screens

Design Flow	Compressor Power	Low Debris Backwash Frequency	High Debris Backwash Frequency	Annual Power Required - Low Debris	Annual Power Required - High Debris	Annual Power Costs - Low Debris*	Annual Power Costs - High Debris*	Annual Labor Required - Low Debris	Annual Labor Cost - Low Debris	Annual Labor Required - High Debris	Annual Labor Cost - High Debris	Dive Team Days Low Debris	Dive Team Costs Low Debris	Dive Team Costs High Debris
gpm	Hp					at $/kw =	at $/kw =							
		Events/day	Events/day	Kwh	Kwh	$0.04	$0.04	Hours		Hours				
1,680	2	3	18	908	5,446	$36	$218	408	$16,769	912	$37,483	1	$5,260	$10,520
3,850	5	3	18	2,269	13,615	$91	$545	408	$16,769	912	$37,483	1	$5,260	$10,520
6,750	10	3	18	4,538	27,229	$182	$1,089	408	$16,769	912	$37,483	1	$5,260	$10,520
10,700	12	3	18	5,446	32,675	$218	$1,307	486	$19,975	990	$40,689	2	$7,250	$14,500
15,300	15	3	18	6,807	40,844	$272	$1,634	486	$19,975	990	$40,689	2	$7,250	$14,500
20,900	20	3	18	9,076	54,458	$363	$2,178	486	$19,975	990	$40,689	2	$7,250	$14,500
27,500	25	3	18	11,345	68,073	$454	$2,723	486	$19,975	990	$40,689	2	$7,250	$14,500
55,000	25	6	36	22,691	136,145	$908	$5,446	564	$23,180	1068	$43,895	3	$9,240	$18,480
82,500	25	9	54	34,036	204,218	$1,361	$8,169	564	$23,180	1068	$43,895	3	$9,240	$18,480
110,000	25	12	72	45,382	272,290	$1,815	$10,892	564	$23,180	1068	$43,895	4	$11,230	$22,460
165000	25	18	108	68,073	408,435	$2,723	$16,337	564	$23,180	1068	$43,895	4	$11,230	$22,460

Figure 1-1
Capital Costs Conventional Steel Pipe Laying Method At Various Offshore Distances

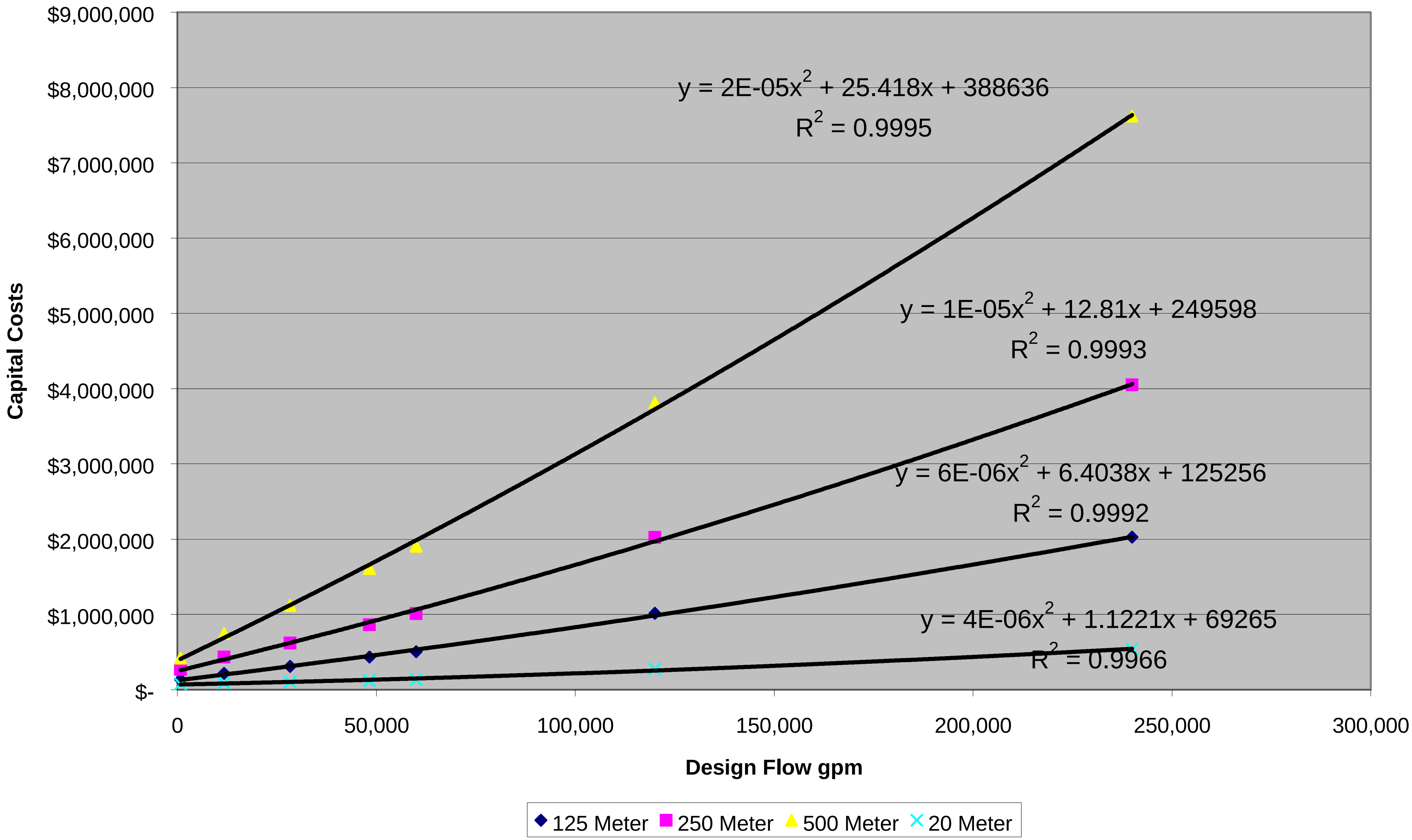


Figure 1-2
Capital Costs forFine Mesh Passive Screen Relocation Offshore in Freshwater at Selected Offshore Distances

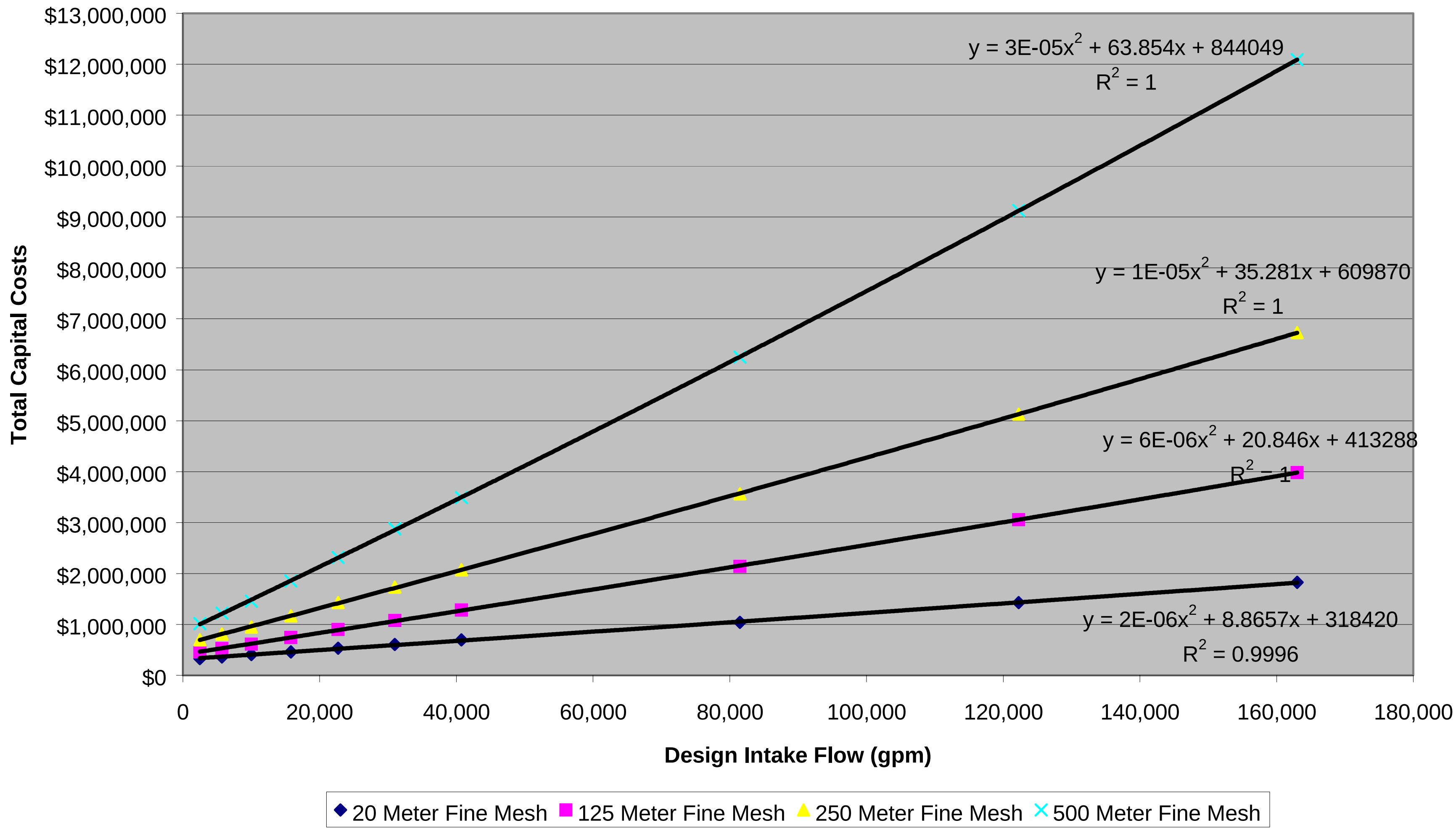


Figure 1-3
Capital Costs for Fine Mesh Passive Screen Relocation Offshore in Saltwater at Selected Offshore Distances

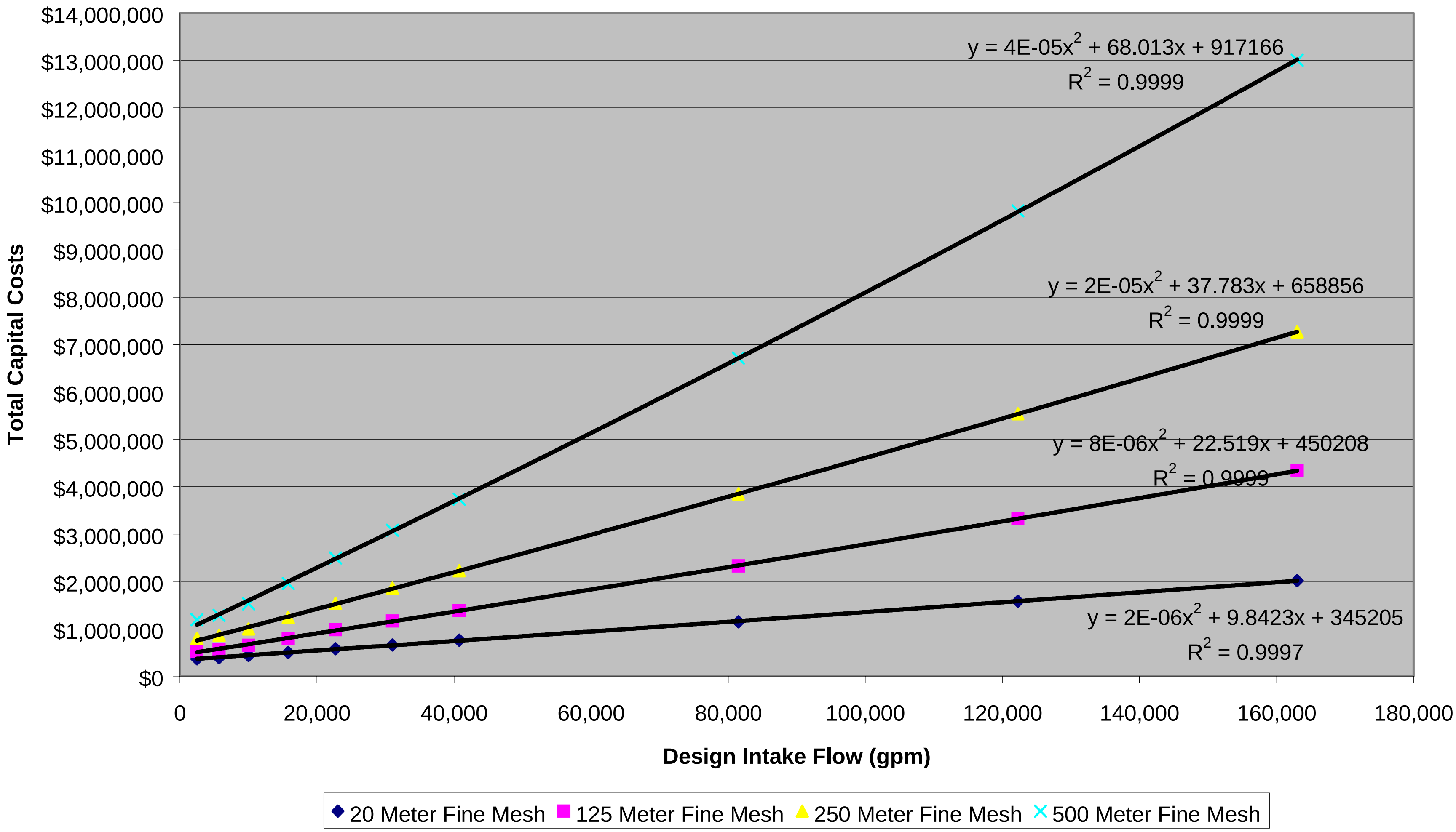


Figure 1-4
Capital Costs for Fine Mesh Passive Screen Relocation Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

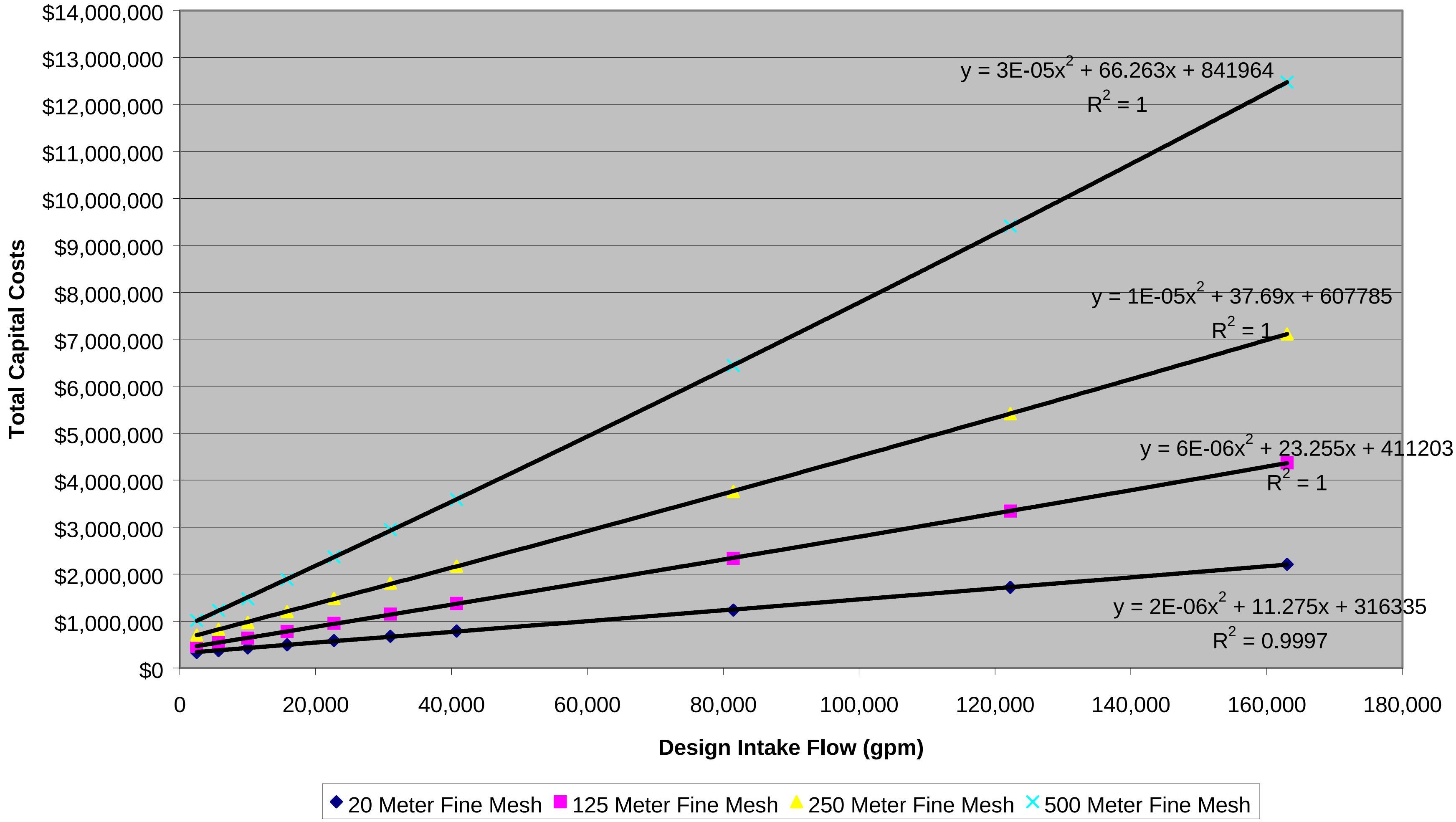


Figure 1-5
Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Freshwater at Selected Offshore Distances

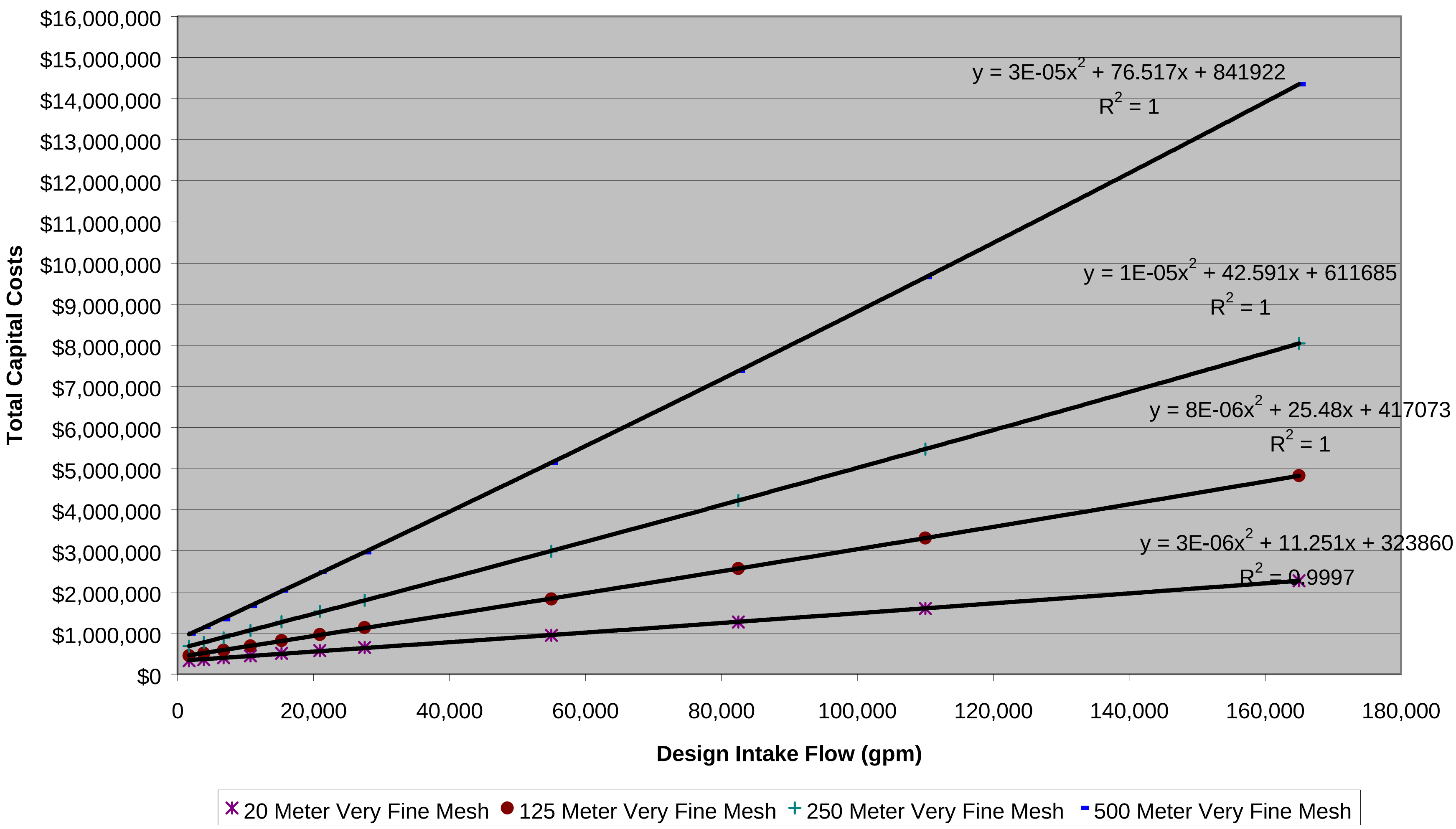


Figure 1-6
Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Saltwater at Selected Offshore Distances

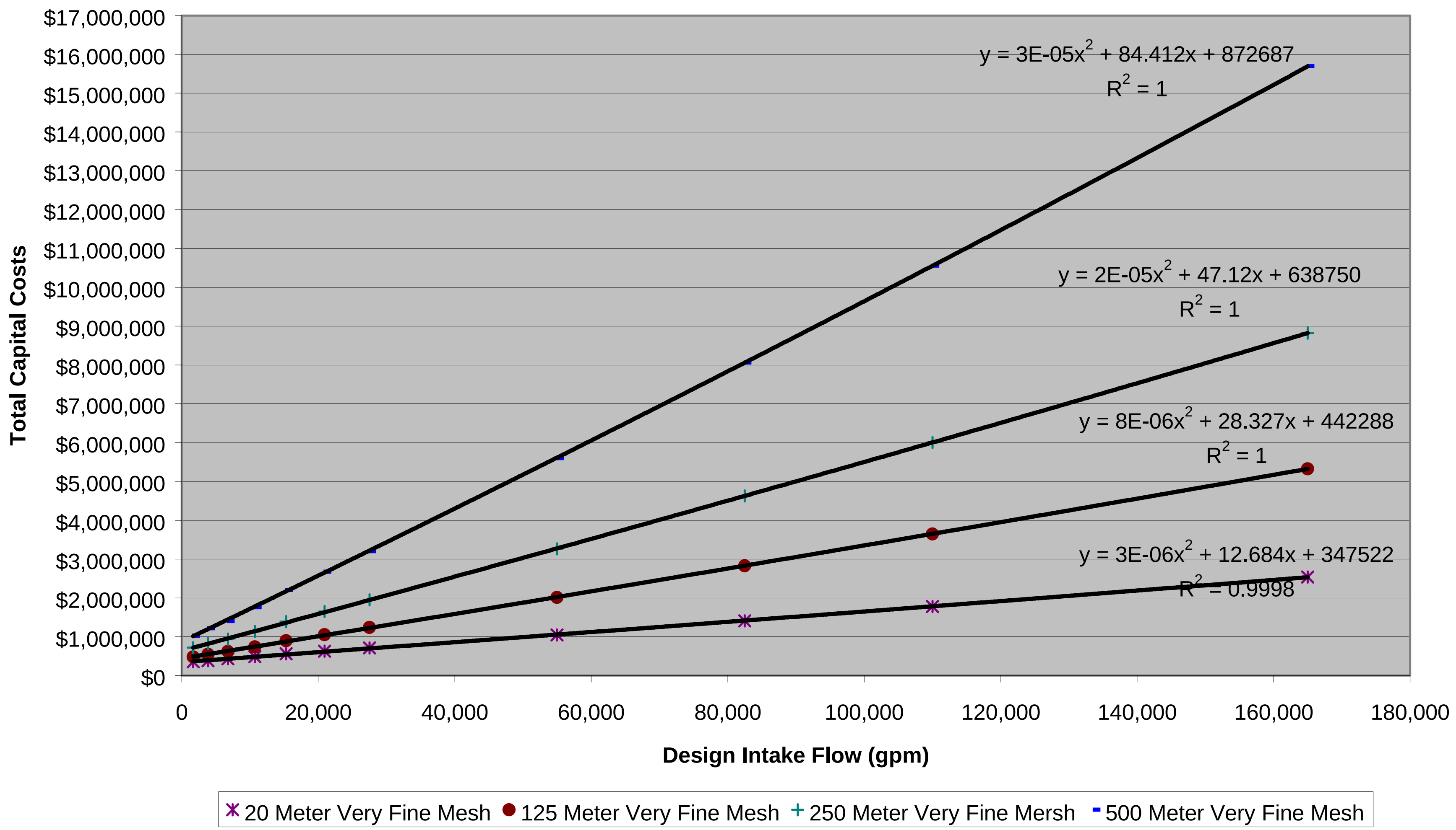


Figure 1-7
Capital Costs for Very Fine Mesh Passive Screen Relocation Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

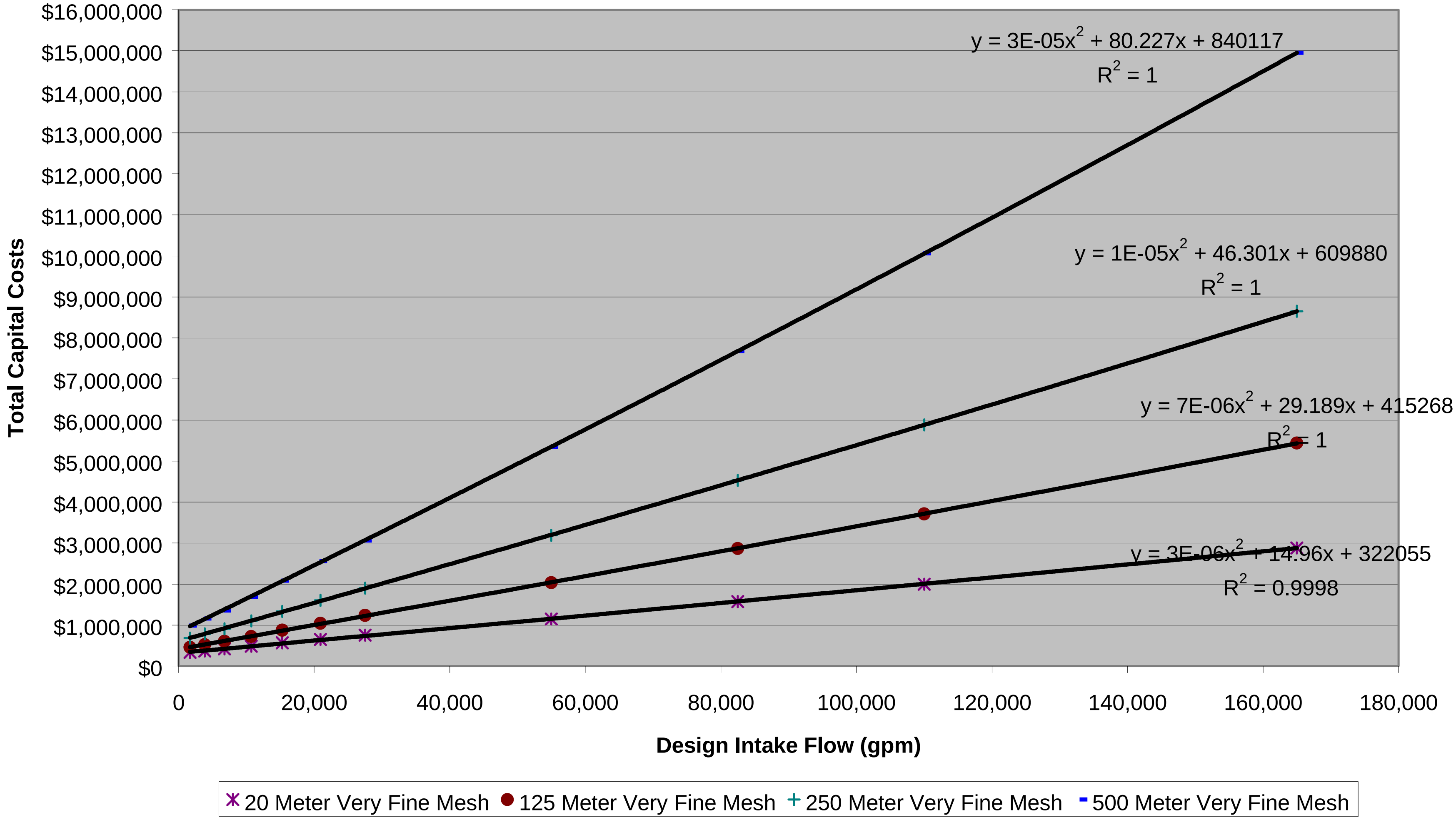


Figure 1-8
Total O&M Cost for Fine Mesh Passive Screen Relocated Offshore with Airburst Backwash

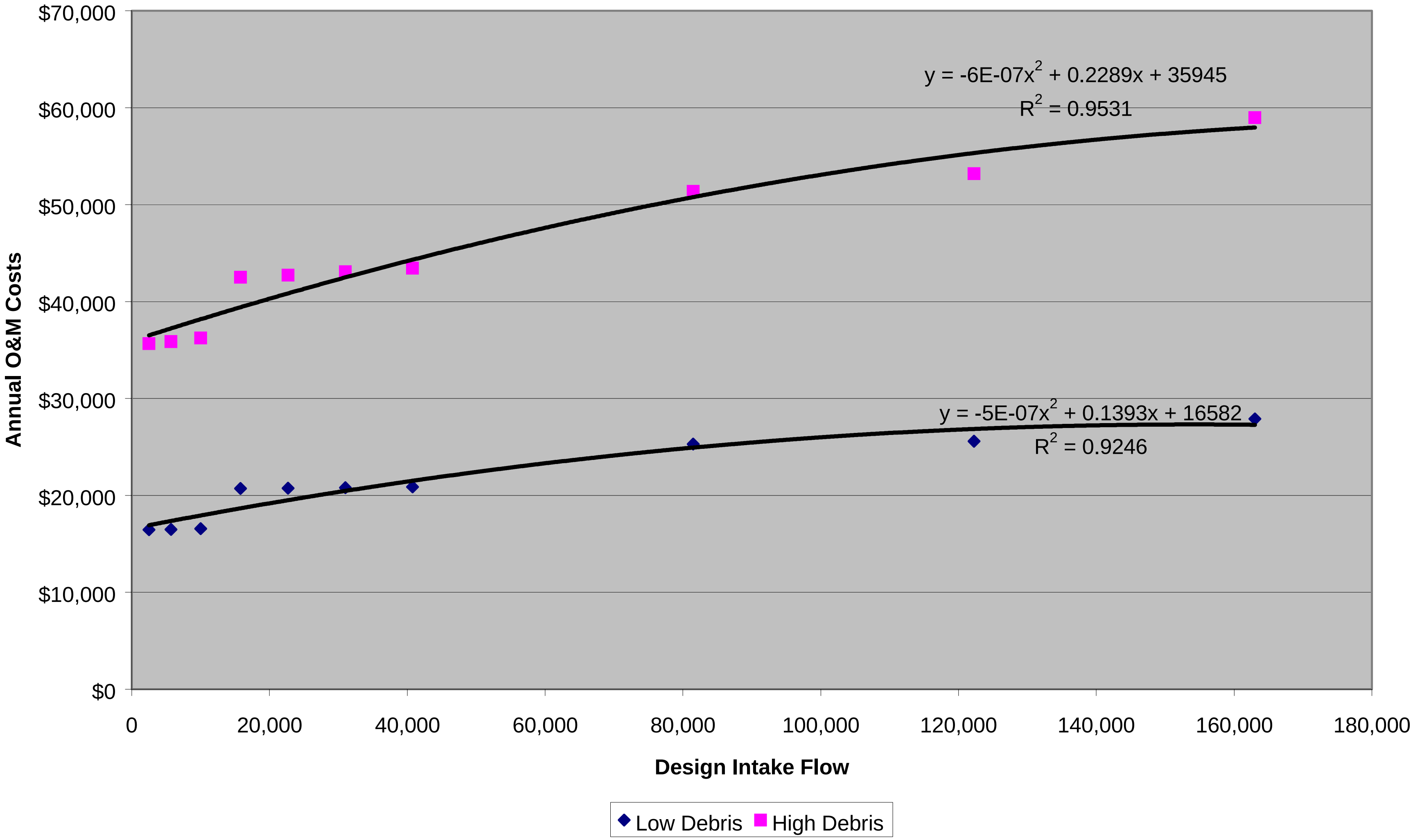


Figure 1-9
Total O&M Cost for Very Fine Mesh
Passive Screen Relocated Offshore with Airburst Backwash

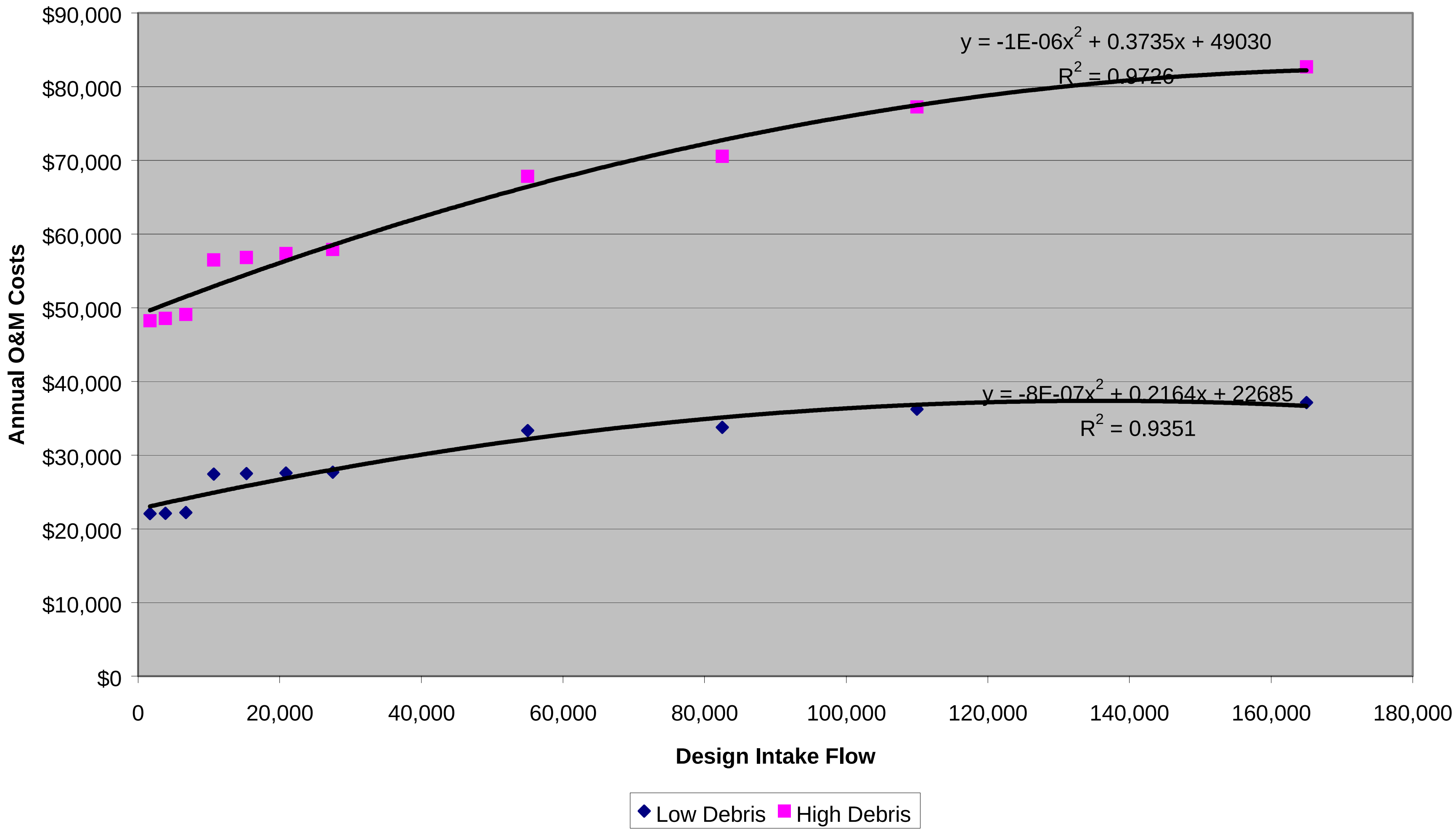


Figure 1-10
Capital Costs for Fine Mesh Passive Screen Existing Offshore in Freshwater at Selected Offshore Distances

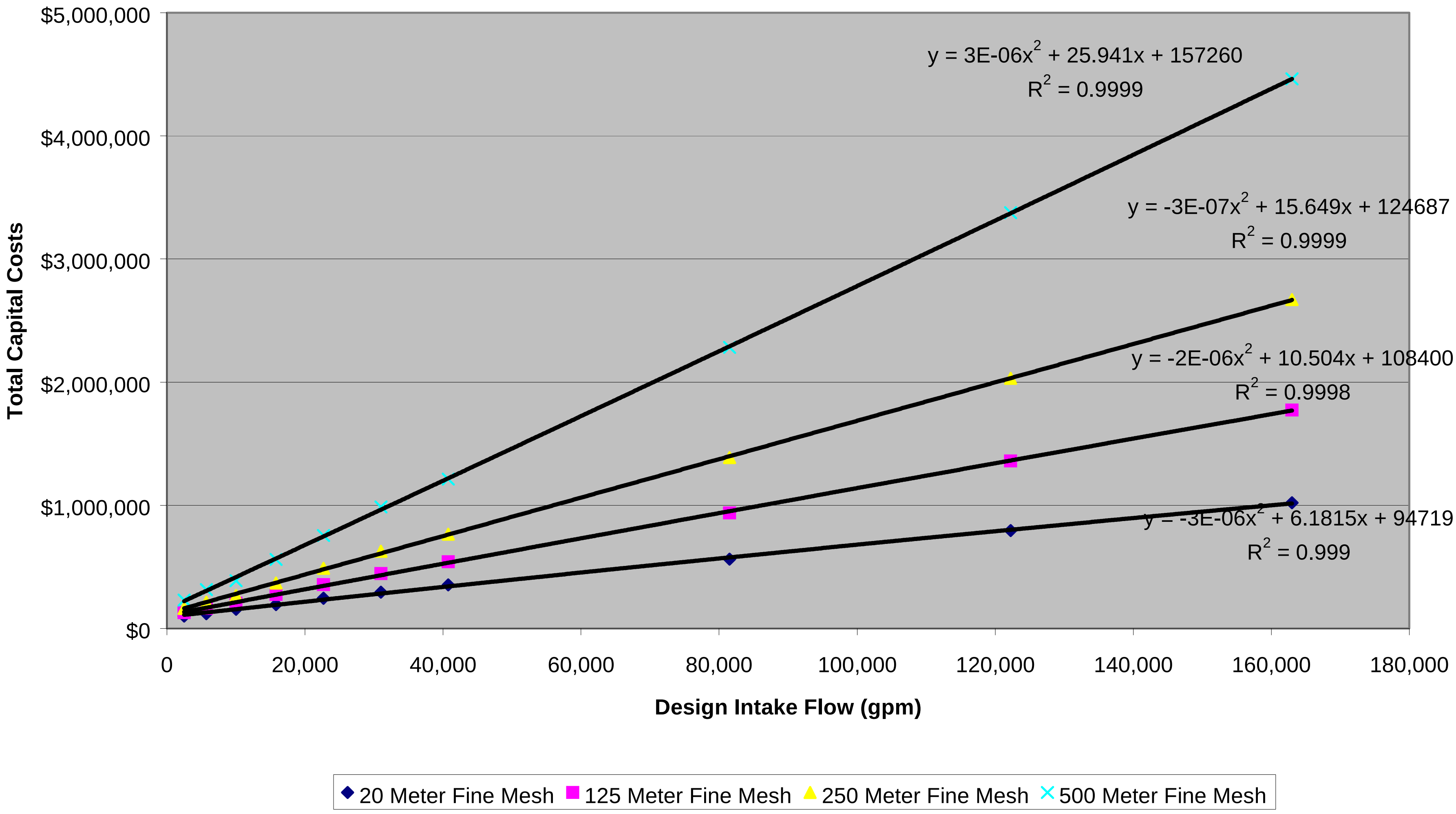


Figure 1-11
Capital Costs for Fine Mesh Passive Screen at Existing Offshore in Saltwater at Selected Offshore Distances

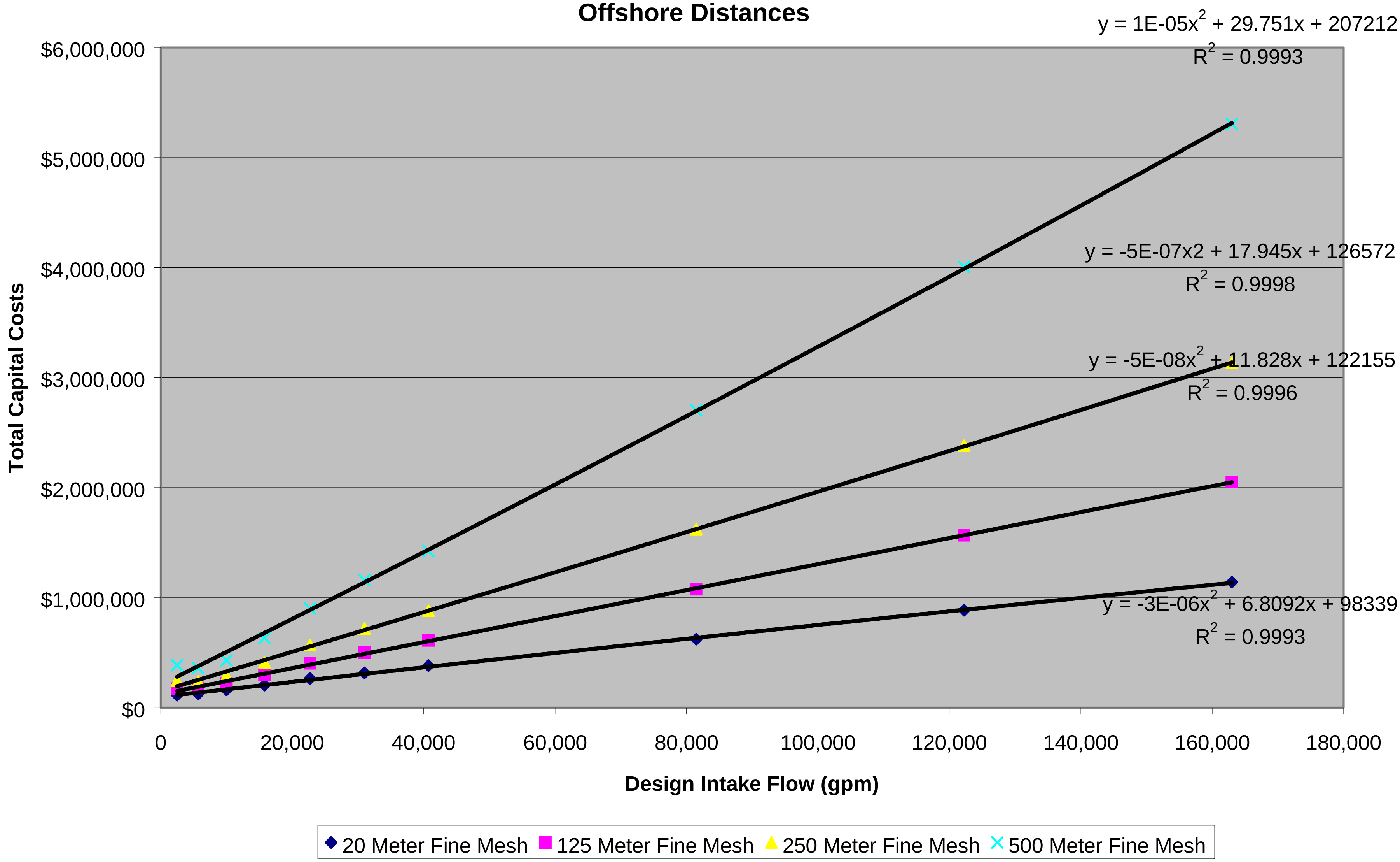


Figure 1-12
Capital Costs for Fine Mesh Passive Screen Existing Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

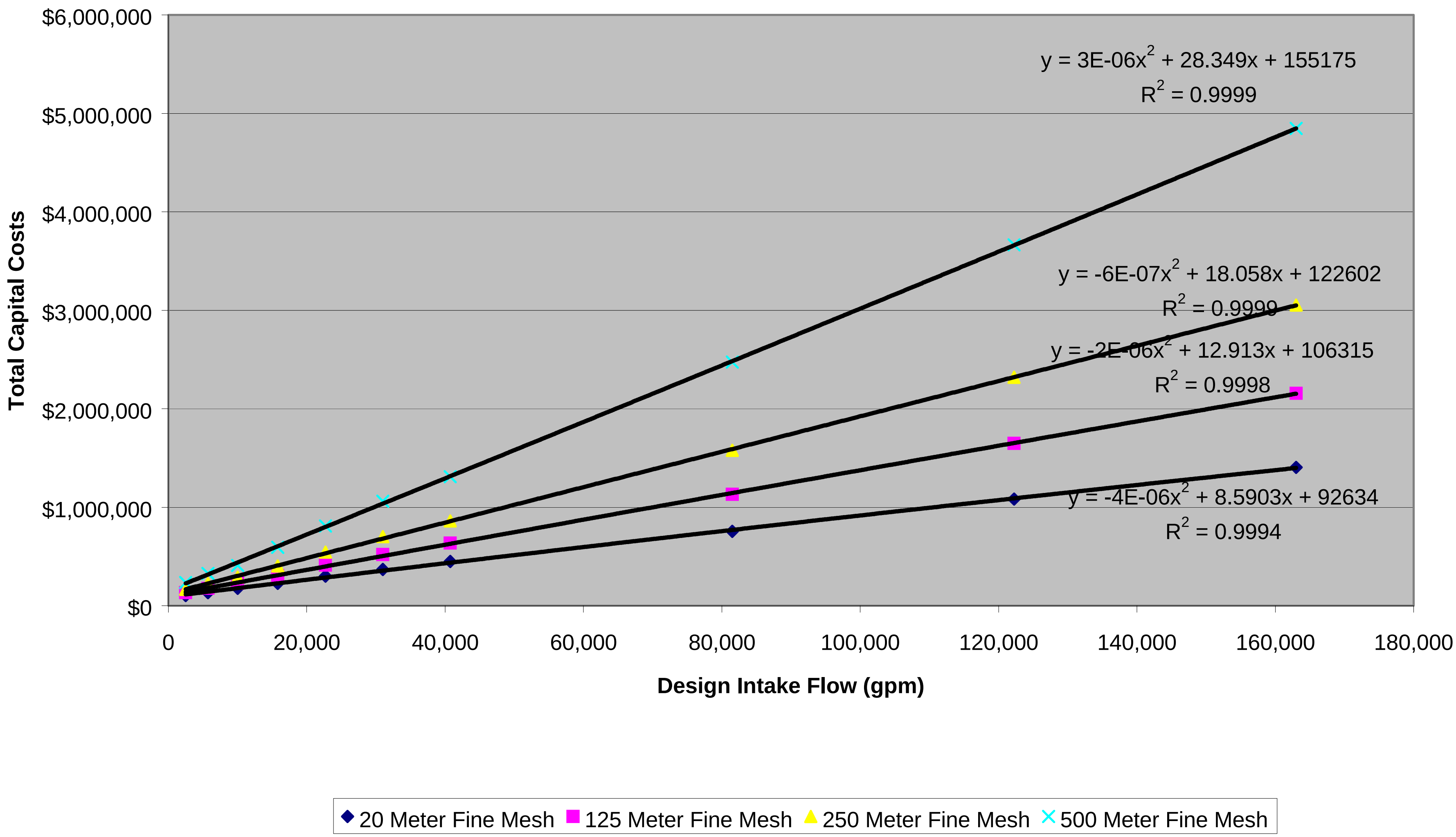


Figure 1-13
Capital Costs for Very Fine Mesh Passive Screen Existing Offshore in Freshwater at Selected Offshore Distances

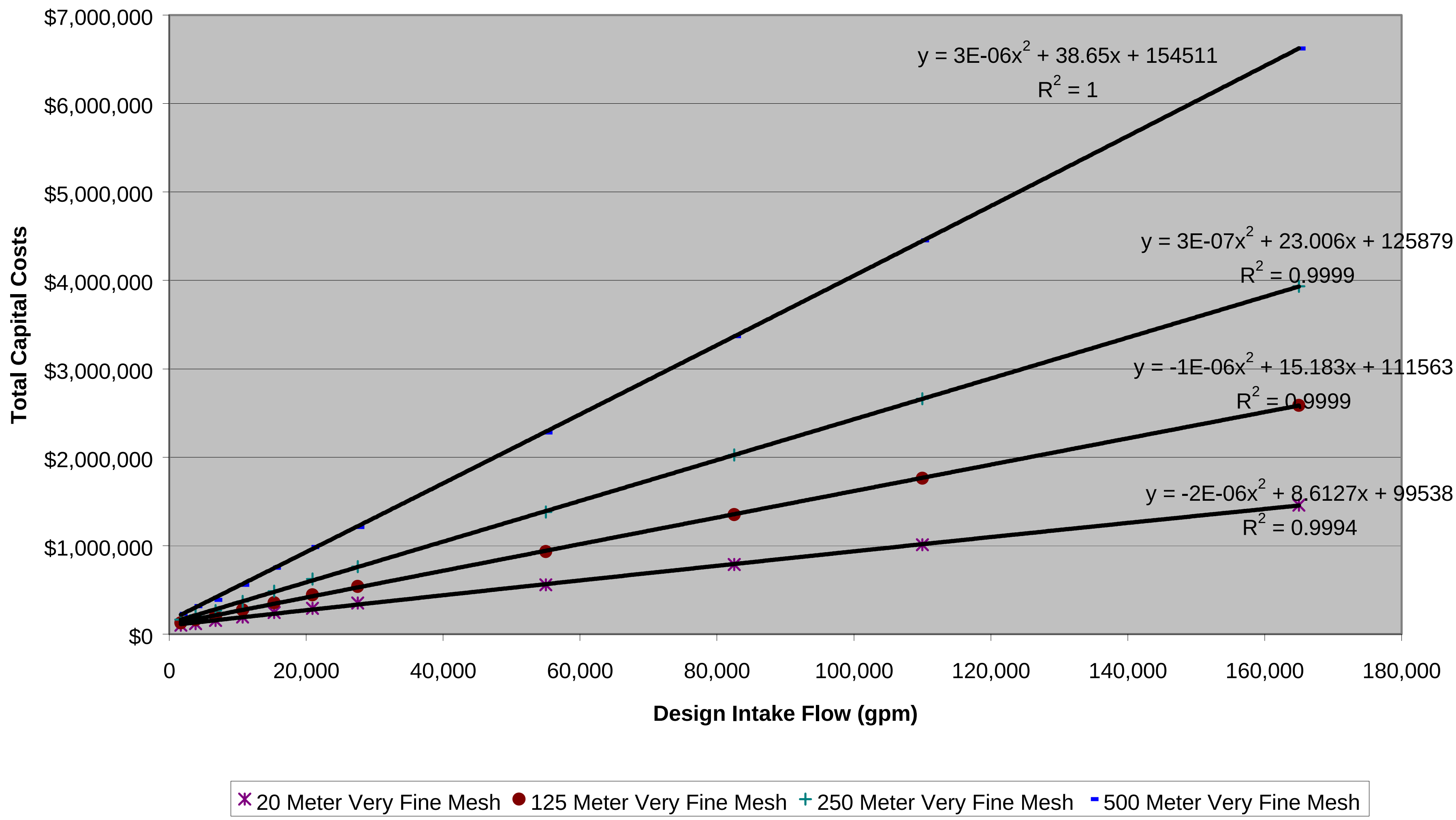


Figure 1-14
Capital Costs for Very Fine Mesh Passive Screen at Existing Offshore in Saltwater at Selected Offshore Distances

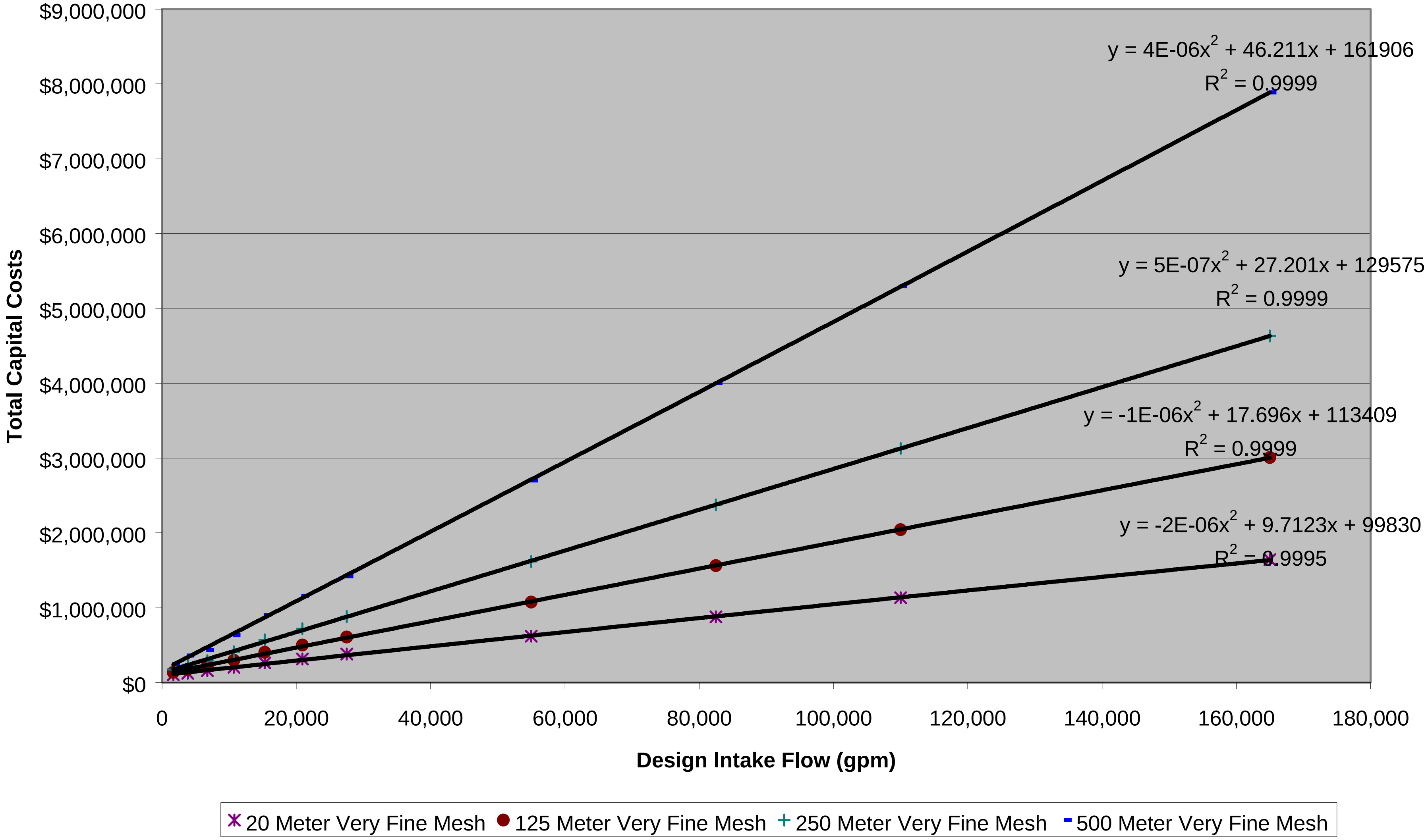


Figure 1-15
Capital Costs for Very Fine Mesh Passive Screen Existing Offshore in Freshwater with Zebra Mussels at Selected Offshore Distances

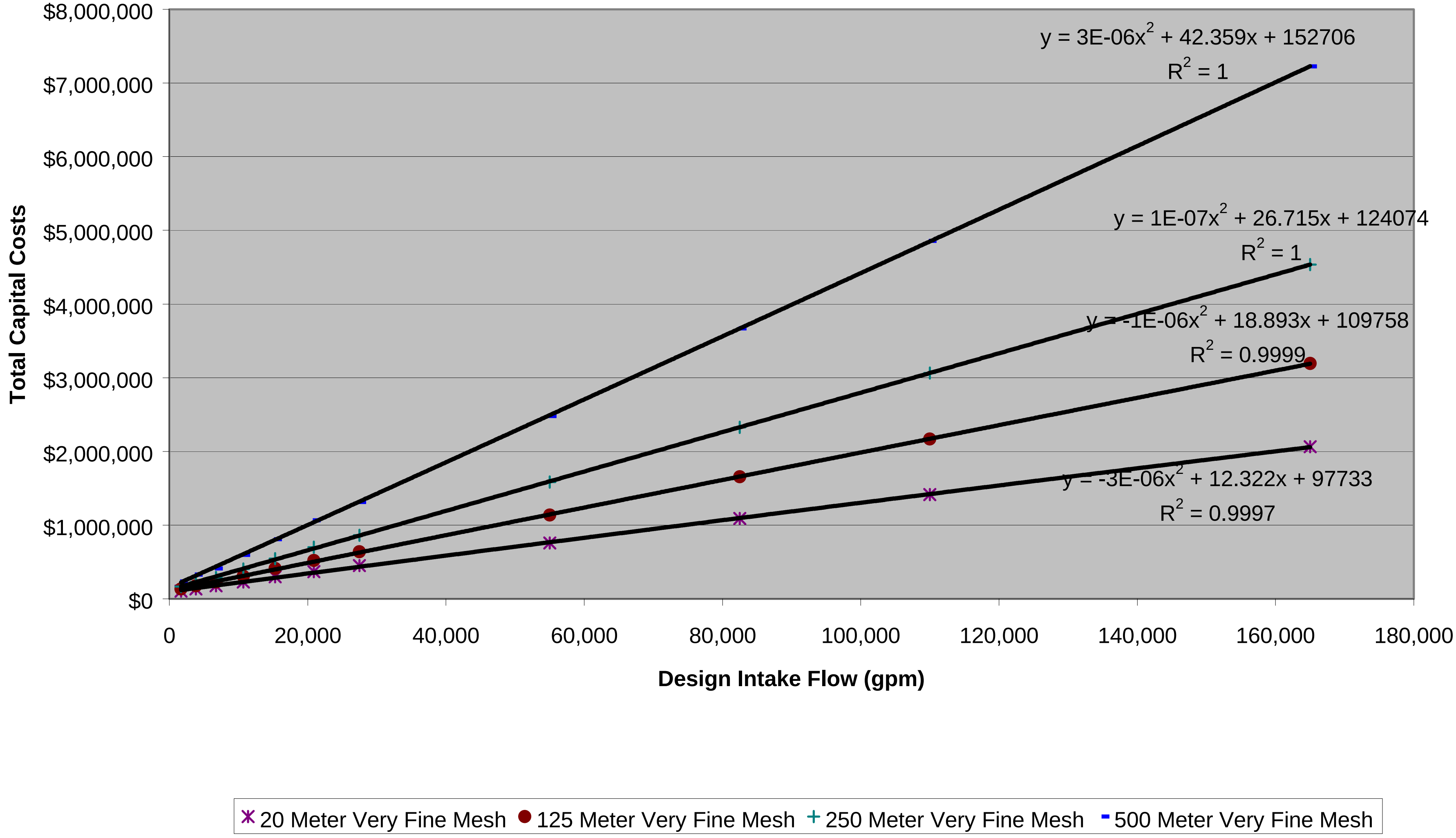


Figure 1-16
Total O&M Cost for Fine Mesh Passive Screen Existing Offshore with Airburst Backwash

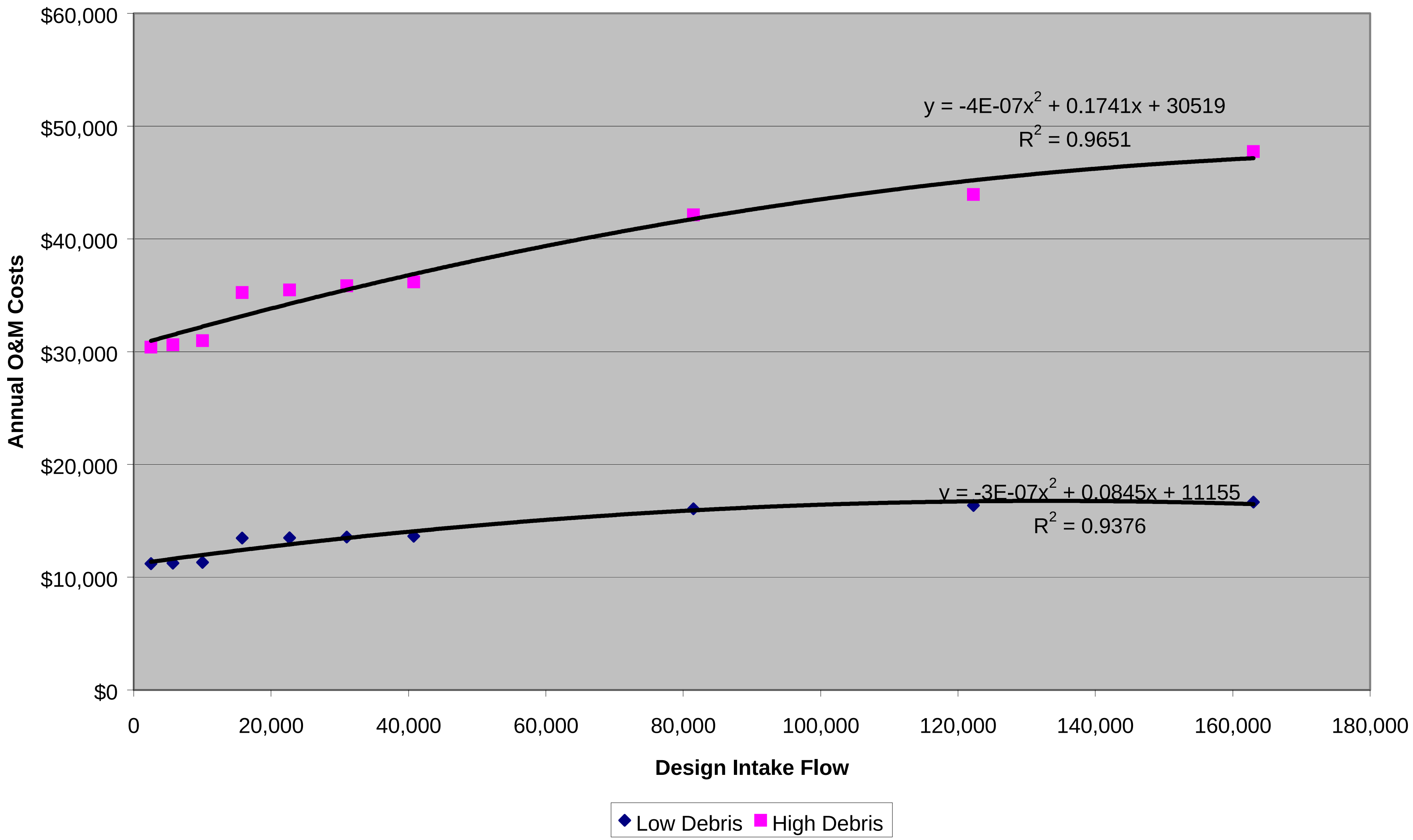
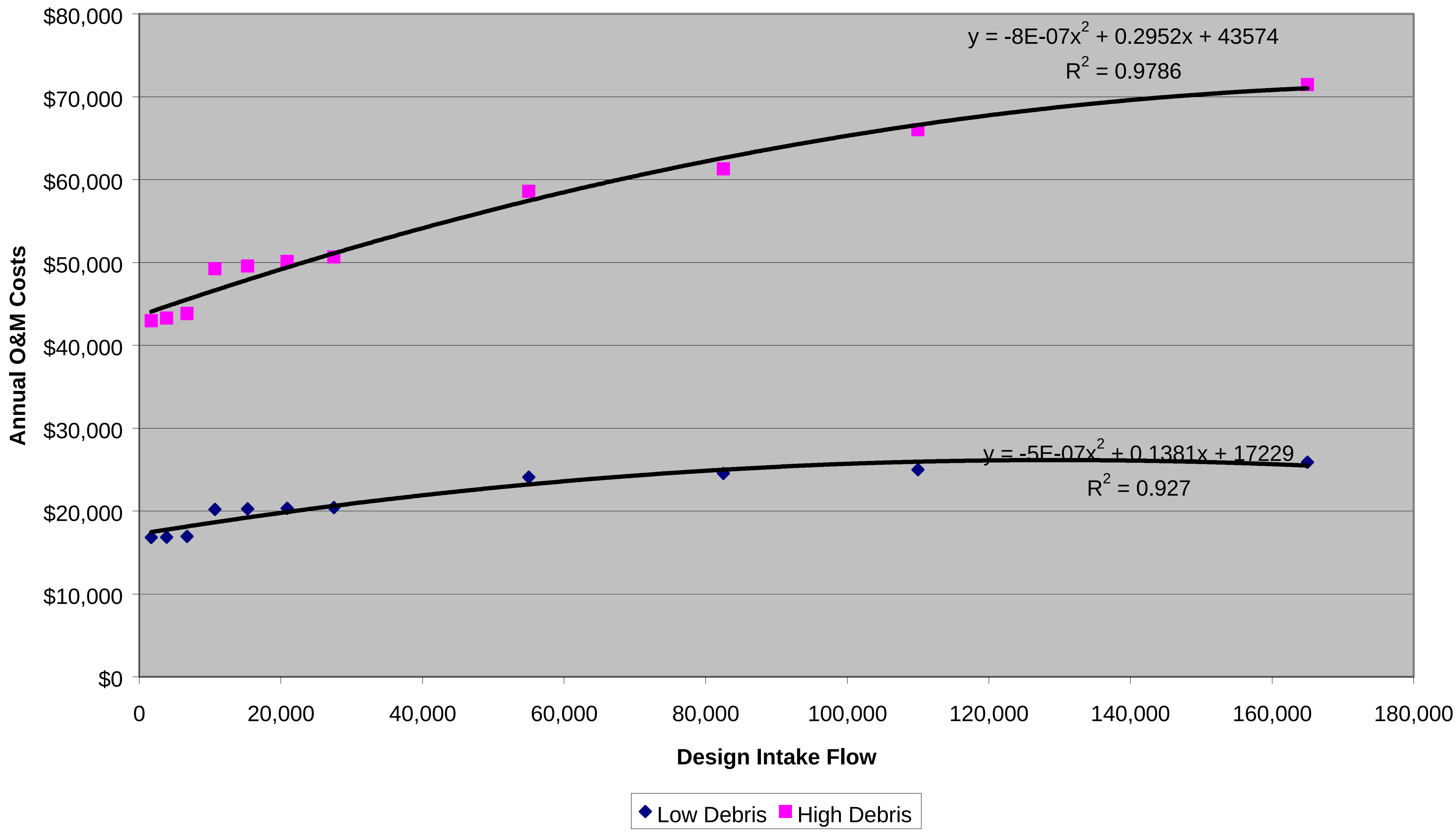


Figure 1-17
Total O&M Cost for Very Fine Mesh Passive Screen Existing Offshore with Airburst Backwash



2.0 IMPROVEMENTS TO EXISTING SHORELINE INTAKES WITH TRAVELING SCREENS

2.1 REPLACE EXISTING TRAVELING SCREENS WITH NEW TRAVELING SCREEN EQUIPMENT

The methodology described below is based on data, where available, from the Detailed Technical Questionnaires. Where certain facility data are unavailable (e.g., Short Technical Questionnaire facilities), the methodology generally uses statistical values (e.g., median values). The costs for traveling screen improvements described below are for installation in an existing or newly built intake structure. Where the existing intake is of insufficient design or size, construction costs for increasing the intake size are developed in a separate cost module and the cost for screen modification/installation at both the existing and/or new intake structure(s) are applied according to the estimated size of each.

Estimating Existing Intake Size

The capital cost of traveling screen equipment is highly dependent on the size and surface area of the screens employed. In developing compliance costs for existing facilities in Phase I, a single target, through-screen velocity was used. This decision ensured the overall screen area of the units being costed was a direct function of design flow. Thus, EPA could rely on a cost estimating methodology for traveling screens that focused primarily on design flow. In the Phase I approach, a single screen width was chosen for a given flow range. Variations in cost were generally based on differences in screen well depth. Where the flow exceeded the maximum flow for the largest screen costed, multiples of the largest (14 ft wide) screens were costed. Because, in this instance, EPA was applying it's cost methodology to hypothetical facilities, screen well depth could be left as a dependent variable. However, for existing facilities this approach is not tenable because existing screen velocities vary considerably between facilities. Because the size of the screens is very much dependent on design flow and screen velocity, a different approach -- one that first estimates the size of the existing screens -- is warranted.

Estimating Total Screen Width

Available data from the Detailed Questionnaires concerning the physical size of existing intake structures and screens are limited to vertical dimensions (e.g., water depth, distance of water surface to intake deck, and intake bottom to water surface). Screen width dimensions (parallel to shore) are not provided. For each model facility EPA has developed data concerning actual and estimated design flow. Through-screen velocity is available for most facilities--even those that completed only the Short Technical Questionnaire. Given the water depth, intake flow, and through screen velocity, the aggregate width of the intake screens can be estimated using the following equation:

Screen Width (Ft) = Design Flow (cfs) / (Screen Velocity (fps) x Water Depth (Ft) x Open Area (decimal %))

The variables "design Flow," "screen velocity," and "water depth" can be obtained from the database for most facilities that completed the Detailed Technical Questionnaire. These database values may not always correspond to the same waterbody conditions. For example, the screen velocity may correspond to low flow conditions while the water depth may represent average conditions. Thus, calculated screen widths may differ from actual values, but likely represents a reasonable estimate, especially given the limited available data. EPA considers the above equation to be a reasonable method for estimating the general size of the existing intake for cost estimation purposes. Determining the value for water depth at the intake, where no data is available, is described below.

The last variable in the screen width equation is the percent open area, which is not available in the database. However, the majority of the existing traveling screens are coarse mesh screens (particularly those requiring equipment upgrades). In most cases (at least for power plants), the typical mesh size is 3/8 inch (Petrovs 2002, Gathright 2002). This mesh size corresponds to an industry standard that states the mesh size should be half the diameter of the downstream heat exchanger tubes. These tubes are typically around 7/8 inch in diameter for power plant steam condensers. For a mesh size of 3/8 inch, the corresponding percent open area for a square mesh screen using 14 gauge wire is 68%. This combination was reported as "typical" for coarse mesh screens (Gathright 2002). Thus, EPA will use an assumed percent open area value of 68% in the above equation.

At facilities where the existing through-screen velocity has been determined to be too high for fine mesh traveling screens to perform properly, a target velocity of 1.0 fps was used in the above equation to estimate the screen width that would correspond to the larger size intake that would be needed.

Screen Well Depth

The costs for traveling screens are also a function of screen well depth, which is not the same as the water depth. The EPA cost estimates for selected screen widths have been derived for a range of screen well depths ranging from 10 feet to 100 feet. The screen well depth is the distance from the intake deck to the bottom of the screen well, and includes both water depth and distance from the water surface to the deck. For those facilities that reported "distance from intake bottom to water surface" and "distance from water surface to intake top," the sum of these two values can be used to determine actual screen well depth. For those Phase II facilities that did not report this data, statistical values such as the median were used. The median value of the ratio of the water depth to the screen well depth for all facilities that reported such data was 0.66. Thus, based on median reported values, the screen well depth can be estimated by assuming it is 1.5 times the water depth where only water depth is reported. For those Phase II facilities that reported water depth data, the median water depth at the intake was 18.0 ft.

Based on this discussion, screen well depth and intake water depth are estimated using the following hierarchy:

- If "distance from intake bottom to water surface" plus "distance from water surface to intake top" are reported, then the sum of these values are used for screen well depth
- If only the "distance from intake bottom to water surface" and/or the "depth of water at intake" are reported, one of these values (if both are known, the former selected is over the latter) is multiplied by a factor of 1.5
- If no depth data are reported, this factor is applied to the median water depth value of 18 feet (i.e., 27 feet) and this value is used.

This approach leaves open the question of which costing scenario well depth should be used where the calculated or estimated well depth does not correspond to the depths selected for cost estimates. EPA has selected a factor of 1.2 as the cutoff for using a shallower costing well depth. Table 2-1 shows the range of estimated well depths that correspond to the specific well depths used for costing.

Table 2-1
Guidance for Selecting Screen Well Depth for Cost Estimation

Calculated or Estimated Screen Well Depth (Ft)	Well Depth to be Costed
0-12 ft	10 ft
>12-30 ft	25 ft
>30-60 ft	50 ft
>60-90 ft	75 ft

Traveling Screen Replacement Options

Compliance action requirements developed for each facility may result in one of the following traveling screen improvement options:

- No Action.
- Add Fine Mesh Only (improves entrainment performance).
- Add Fish Handling Only (improves impingement performance).
- Add Fine Mesh and Fish Handling (improves entrainment and impingement performance).

Table 2-2 shows potential combinations of existing screen technology and replacement technologies that are applied to these traveling screen improvement options. In each case, there are separate costs for freshwater and saltwater environments.

Areas highlighted in grey in Table 2-2 indicate that the compliance scenario is not compatible with the existing technology combination. The table shows there are three possible technology combination scenarios that for a retrofit involving modifying the existing intake structure only,. Each scenario is described briefly below:

Scenario A - Add fine mesh only

This scenario involves simply purchasing a separate set of fine mesh screen overlay panels and installing them in front of the existing coarse mesh screens. This placement may be performed on a seasonal basis. This option is not considered applicable to existing screens without fish handling and return systems, since the addition of fine mesh will retain additional aquatic organisms that would require some means for returning them to the waterbody. Corresponding compliance O&M costs include seasonal placement and removal of fine mesh screen overlay panels.

Table 2-2
Compliance Action Scenarios and Corresponding Cost Components

Compliance Action	Cost Component Included in EPA Cost Estimates	Existing Technology	
		Traveling Screens Without Fish Return	Traveling Screens With Fish Return
Add Fine Mesh Only (Scenario A)	New Screen Unit	NA	No
	Add Fine Mesh Screen Overlay	NA	Yes
	Fish Buckets	NA	No
	Add Spray Water Pumps	NA	No
	Add Fish Flume	NA	No
Add Fish Handling Only (Scenario B)	New Screen Unit[1]	Yes	NA
	Add Fine Mesh Screen Overlay[2]	No	NA
	Fish Buckets	Yes	NA
	Add Spray Water Pumps	Yes	NA
	Add Fish Flume	Yes	NA
Add Fine Mesh With Fish Handling (Scenario C and Dual-Flow Traveling Screens)	New Screen Unit	Yes	NA
	Add Fine Mesh Screen Overlay	Yes[3]	NA
	Fish Buckets	Yes	NA
	Add Spray Water Pumps	Yes	NA
	Add Fish Flume	Yes	NA

[1] Replace entire screen unit, includes one set of smooth top or fine mesh screen.
[2] Add fine mesh includes costs for a separate set of overlay fine mesh screen panels that can be placed in front of coarser mesh screens on a seasonal basis.
[3] Does not include initial installation labor for fine mesh overlays. Seasonal deployment and removal of fine mesh overlays is included in O&M costs.

Scenario B - Add fish handling and return

This scenario requires the replacement of all of the traveling screen units with new ones that include fish handling features, but no specific mesh requirements are included. Mesh size is assumed to be 1/8-inch by ½-inch smooth top. A less costly option would be to retain and retrofit portions of the existing screen units. However, vendors noted that approximately 75% of the existing screen components would require replacement and it would be more prudent to replace the entire screen unit (Gathright 2002, Petrovs 2002). Costs for additional spray water pumps and a fish return flume are included. Capital and O&M costs do not include any component for seasonal placement of fine mesh overlays.

Scenario C - Add fine mesh with fish handling and return

This scenario requires replacement of all screen units with units that include fish handling and return features plus additional spray water pumps and a fish return flume. Costs for a separate set of fine mesh screen overlay panels with seasonal placement are included.

Double Entry-Single Exit (Dual-Flow) Traveling Screens

The conditions for scenario C also apply to dual-flow traveling screens described separately below.

Fine Mesh Screen Overlay

Several facilities that have installed fine mesh screens found that during certain periods of the year the debris loading created operating problems. These problems prompted operators to remove fine mesh screens and replace them with coarser screens for the duration of the period of high and/or troublesome debris. As a high-side approach, when fine mesh screens replace coarse mesh screens (Scenarios A and C), EPA has decided to include costs for using two sets of screens (one coarser mesh screen such as 1/8-inch by 1/4-inch smooth top and one fine mesh overlay) with annual placement and removal of the fine mesh overlay. This placement of fine mesh overlay can occur for short periods when sensitive aquatic organisms are present or for longer periods being removed only during a the period when troublesome debris is present. Fine mesh screen overlays are also included in the costs for dual-flow traveling screens described separately below.

Mesh Type

In general three different types of mesh are considered here. One is the coarse mesh which is typical in older installations. Coarse mesh is considered to be the baseline mesh type and the typical mesh size is 3/8 inch square mesh. When screens are replaced, two types of mesh are considered. One is fine mesh, which is assumed to have openings in the 1 to 2 mm range. The other mesh type is the smooth top mesh. Smooth top mesh has smaller openings (at least in one dimension) than coarse mesh (e.g., 1/8-inch by ½-inch is a common size) and is manufactured in a way that reduces the roughness that is associated with coarse mesh. Smooth top mesh is used in conjunction with screens that have fish handling and return systems. The roughness of standard coarse mesh has been blamed for injuring (descaling) fish as they are washed over the screen surface when they pass from the fish bucket to the return trough during the fish wash step. Due to the tighter weave of fine mesh screens, roughness is not an issue when using fine mesh.

2.1.1 TRAVELING SCREEN CAPITAL COSTS

The capital cost of traveling screen equipment is generally based on the size of the screen well (width and depth), construction materials, type of screen baskets, and ancillary equipment requirements. While EPA has chosen to use the same mix of standard screen widths and screen well depths as were developed for the new facility Phase I effort, as described above, the corresponding water depth, design flow, and through-screen velocities in most cases differ. As presented in Table 2-2, cost estimates do not need to include a compliance scenario where replacement screen units without fish handling and return equipment are installed. Unlike the cost methodology developed for Phase I, separate costs are developed in Phase II costing for equipment suitable for freshwater and saltwater environments. Costs for added spray water pumps and fish return flumes are described below, but unlike the screening equipment are generally a function of screen width only.

Screen Equipment Costs

EPA contacted traveling screen vendors to obtain updated costs for traveling screens with fine mesh screens and fish handling equipment for comparison to the 1999 costs developed for Phase I. Specifically, costs for single entry-single exit (through-flow) screens with the following attributes were requested:

- -Spray systems
- -Fish trough
- -Housings and transitions
- -Continuous operating features
- -Drive unit
- -Frame seals
- -Engineering
- -Freshwater versus saltwater environments.

Only one vendor provided comparable costs (Gathright 2002). The costs for freshwater environments were based on equipment constructed primarily of epoxy-coated carbon steel with stainless steel mesh and fasteners. Costs for saltwater and brackish water environments were based on equipment constructed primarily of 316 stainless steel with stainless steel mesh and fasteners.

EPA compared these newly obtained equipment costs to the costs for similar freshwater equipment developed for Phase I, adjusted for inflation to July 2002 dollars. EPA found that the newly obtained equipment costs were lower by 10% to 30%. In addition, a comparison of the newly obtained costs for brackish water and freshwater screens showed that the costs for saltwater equipment were roughly 2.0 times the costs for freshwater equipment. This factor of approximately 2.0 was also suggested by a separate vendor (Petrovs 2002). Rather than adjust the Phase I equipment costs downward, EPA chose to conclude that the Phase I freshwater equipment costs adjusted to 2002 were valid (if not somewhat overestimated), and that a factor of 2.0 would be reasonable for estimating the cost of comparable saltwater/brackish water equipment. Tables 2-3 and 2-4 present the Phase I equipment costs, adjusted for inflation to July 2002 dollars, for freshwater and saltwater environments respectively.

Table 2-3
Equipment Costs for Traveling Screens with Fish Handling for Freshwater Environments
2002 Dollars

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$69,200	$80,100	$102,500	$147,700
25	$88,600	$106,300	$145,000	$233,800
50	$133,500	$166,200	$237,600	$348,300
75	$178,500	$228,900	$308,500	$451,800
100	$245,300	$291,600	$379,300	$549,900

Table 2-4
Equipment Costs for Traveling Screens with Fish Handling for Saltwater Environments
2002 Dollars

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$138,400	$160,200	$205,000	$295,400
25	$177,200	$212,600	$290,000	$467,600
50	$267,000	$332,400	$475,200	$696,600
75	$357,000	$457,800	$617,000	$903,600
100	$490,600	$583,200	$758,600	$1,099,800

Costs for fine mesh screen overlay panels were cited as approximately 8% to 10% of the total screen unit costs (Gathright 2002). The EPA cost estimates for fine mesh overlay screen panels are based on a 10% factor applied to the screen equipment costs shown in Tables 2-3 and 2-4. Note that if the entire screen basket required replacement, then the costs would increase to about 25% to 30% of the screen unit costs (Gathright 2002, Petrovs 2002). However, in the scenarios considered here, basket replacement would occur only when fish handling is being added. In those scenarios, EPA has chosen to assume that the entire screen unit will require replacement. The cost of new traveling screen units with smooth top mesh is only about 2% above that for fine mesh (Gathright 2002). EPA has concluded that the cost for traveling screen units with smooth top mesh is nearly indistinguishable from that for fine mesh. Therefore, EPA has not developed separate costs for each.

Screen Unit Installation Costs

Vendors indicated that the majority of intakes have stop gates or stop log channels that enable the isolation and dewatering of the screen wells. Thus, EPA assumes, in most cases, screens can be replaced and installed in dewatered screen wells without the use of divers. When asked whether most screens were accessible by crane, a vendor did note that about 70% to 75% may have problems accessing the intake screens by crane from overhead. In such cases, the screens are dismantled (screen panels are removed, chains are removed and screen structure is removed in sections that key into each other). Such overhead access problems may be due to structural cover or buildings, and access is often through the side wall. According to one vendor, this screen dismantling requirement may add 30% to the installation costs. For those installations that do not need to dismantle screens, these costs typically are $15,000 to $30,000 per unit (Petrovs 2002). Another vendor cited screen installation costs as +/- $45,000 per screen giving an example of

$20,000 for a 15-foot screen plus the costs of a crane and forklift ($15,000 - $20,000 divided between screens) (Gathright 2002). Note that these installation costs are for the typical range of screen sizes; vendors noted that screens in the range of the 100-foot well depth are rarely encountered.

Table 2-5 presents the installation costs developed from vendor supplied data. These costs include crane and forklift costs and are presented on a per screen basis. Phase I installation costs included an intake construction component not included in Phase II costs. The costs shown here assume the intake structure and screen wells are already in-place. Therefore, installation involves removing existing screens and installing new screens in their place. Any costs for increasing the intake size are developed as a separate module. Vendors indicated costs for disposing of the existing screens were minimal. The cost of removal and disposal of old screens, therefore, are assumed to be included in the Table 2-5 estimates.

Table 2-5
Traveling Screen Installation Costs

Well Depth	Basket Screening Panel Width (Ft)			
(Ft)	2	5	10	14
10	$15,000	$18,000	$21,000	$25,000
25	$22,500	$27,000	$31,500	$37,000
50	$30,000	$36,000	$42,000	$50,000
75	$37,500	$45,000	$52,500	$62,500
100	$45,000	$54,000	$63,000	$75,000

Installation of Fine Mesh Screen Panel Overlays

Screen panel overlay installation and removal costs are based on an estimate of the amount of labor required to replace each screen panel. Vendors provided the following estimates for labor to replace screen baskets and panels (Petrovs 2002, Gathright 2002):

- 1.0 hours per screen panel overlay (1.5 hours to replace baskets and panel)
- Requires two-man team for small screen widths (assumed to be 2- and 5-foot wide screens)
- Requires three-man team for large screen widths (assumed to be 10- and 14-foot wide screens)
- Number of screen panels is based on 2-foot tall screen panels on front and back extending 6 feet above the deck. Thus, a screen for a 25-foot screen well is estimated to have 28 panels.

Labor costs are based on a composite labor rate of $41.10/hr (See O&M cost section).

These assumptions apply to installation costs for Scenario A. These same assumptions also apply to O&M costs for fine mesh screen overlay in Scenarios A and C, where it is applied twice for seasonal placement and removal.

Indirect Costs Associated with Replacement of Traveling Screens

EPA noted that equipment costs (Tables 2-3 and 2-4) included the engineering component and that installation costs (Table 2-5) included costs for contractor overhead and profit. Because the new screens are designed to fit the existing screen well channels and the existing structure is of a known design, contingency and allowance costs should be minimal. Also, no costs for sitework were included because existing intakes, in most cases, should already have provisions for equipment access. Because inflation-adjusted equipment costs exceeded the recently obtained equipment vendor quotation by 10% to 30%, EPA has concluded any indirect costs are already included in the equipment cost component.

Combining Per Screen Costs with Total Screen Width

As noted above, total screen costs are estimated using a calculated screen width as the independent variable. In many cases, this calculated width will involve using more than one screen, particularly if the width is greater than 10 to 14 feet. Vendors have indicated there is a general preference for using 10-foot wide screens over 14-foot screens, but that 14-foot screens are more economical (reducing civil structure costs) for larger installations. The screen widths and corresponding number and screens used to plot screen cost data and develop cost equations are as follows:

2 ft	=	a single	2-ft screen
5 ft	=	a single	5-ft screen
10 ft	=	a single	10-ft screen
20 ft	=	two	10-ft screens
30 ft	=	three	10-ft screens
40 ft	=	four	10-ft screens
50 ft	=	five	10-ft screens
60 ft	=	six	10-ft screens
70 ft	=	five	14-ft screens
84 ft	=	six	14-ft screens
98 ft	=	seven	14-ft screens
112 ft	=	eight	14-ft screens
126 ft	=	nine	14-ft screens
140 ft	=	ten	14-ft screens.

Any widths greater than 140 feet are divided and the costs for the divisions are summed.

Ancillary Equipment Costs for Fish Handling and Return System

When adding a screen with a fish handling and return system where no fish handling system existed before, there are additional requirements for spray water and a fish return flume. The equipment and installation costs for the fish troughs directly adjacent to the screen and spray system are included in the screen unit and installation costs. However, the costs for pumping additional water for the new fish spray nozzles and the costs for the fish return flume from the end of the intake structure to the discharge point are not included. Fish spray and flume volume requirements are based solely on screen width and are independent of depth.

Pumps for Spray Water

Wash water requirements for the debris wash and fish spray were obtained from several sources. Where possible, the water volume was divided by the total effective screen width to obtain the unit flow requirements (gpm/ft). Total unit flow requirements for both debris wash and fish spray combined ranged from 26.7 gpm/ft to 74.5 gpm/ft. The only data with a breakdown between the two uses reported a flow of 17.4 gpm/ft for debris removal and 20.2 gpm/ft for fish spray, with a total of 37.5 gpm/ft (Petrovs 2002). Based on these data, EPA assumed a total of 60 gpm/ft with each component being equal at 30 gpm/ft. These values are near the high end of the ranges reported and were selected to account for additional water needed at the upstream end of the fish trough to maintain a minimum depth.

Because the existing screens already have pumps to provide the necessary debris spray flow, only the costs for pumps sized to deliver the added fish spray are included in the capital cost totals. Costs for the added fish spray pumps are based on the installed equipment cost estimates developed for Phase I, adjusted to July 2002 dollars. These costs already include an engineering component. An additional 10% was added for contingency and allowance. Also, 20% was added to theses costs to account for any necessary modifications to the existing intake (based on BPJ). Table 2-6 presents the costs for adding pumps for the added fish spray volume.

The costs in Table 2-6 were plotted and a best-fit, second-order equation derived from the data. Pump costs were then projected from this equation for the total screen widths described earlier.

Table 2-6
Fish Spray Pump Equipment and Installation Costs

Centrifugal Pump Flow (gpm)	Costs for Centrifugal Pumps - Installed (1999 Dollars)	Pump Costs Adjusted to July 2002	Retrofit Cost & Indirect Costs	Total Installed Cost
10	$800	$872	$262	$1,134
50	$2,250	$2,453	$736	$3,189
75	$2,500	$2,725	$818	$3,543
100	$2,800	$3,052	$916	$3,968
500	$3,700	$4,033	$1,210	$5,243
1,000	$4,400	$4,796	$1,439	$6,235
2,000	$9,000	$9,810	$2,943	$12,753
4,000	$18,000	$19,620	$5,886	$25,506

Fish Return Flume

In the case of the fish return flume, the total volume of water to be carried was assumed to include both the fish spray water and the debris wash water. A total unit flow of 60 gpm/ft screen width was assumed as a conservative value for estimating the volume to be conveyed. Return flumes may take the form of open troughs or closed pipe and are often constructed of reinforced fiberglass (Gathright 2002, Petrovs 2002). The pipe diameter is based on an assumed velocity of 1.5 fps, which is at the low end of the range of pipe flow velocities. Higher velocities will result in smaller pipes. Actual velocities may be much higher in order to ensure fish are transported out of the pipe. With lower velocities fish can continually swim upstream. Vendors have noted that the pipes do not tend to flow full, so basing the cost on a larger pipe sized on the basis of a low velocity is a reasonable approach.

Observed flume return lengths varied considerably. In some cases, where the intake is on a tidal waterbody, two return flumes may be used alternately to maintain the discharge in the downstream direction of the receiving water flow. A traveling screen vendor suggested lengths of 75 to 150 feet (Gathright 2002). EPA reviewed facility description data and found example flume lengths ranging from 30 ft to 300 ft for intakes without canals, and up to several thousand feet for those with canals. For the compliance scenario typical flume length, EPA chose the upper end of the range of examples for facilities without intake canals (300 ft). For those intakes located at the end of a canal, the cost for the added flume length to get to the waterway (assumed equal to canal length) is estimated by multiplying an additional unit cost-per-ft times the canal length. This added length cost is added to the non-canal facility total cost.

To simplify the cost estimation approach, a unit pipe/support structure cost ($/inch-diameter/ft-length) was developed based on the unit cost of a 12-inch reinforced fiberglass pipe at $70/ft installed RS Means 2001) and the use of wood pilings at 10-foot intervals as the support structure. Piling costs assume that the average piling length is 15 feet and unit cost for installed pilings is $15.80/ft (RS Means 2001). The unit costs already include the indirect costs for contractor overhead and profit. Additional costs include 10% for engineering, 10% for contingency and allowance, and 10% for sitework. Sitework costs are intended to cover preparation and restoration of the work area adjacent to the flume. Based on these cost applied to an assumed 300-foot flume, a unit cost of $10.15/India./ft was derived. Flume costs for the specific total screen widths were then derived based on a calculated flume diameter (using the assumed flow volume of 60 gpm/ft, the 1.5-fps velocity when full) times the unit cost and the length.

EPA was initially concerned whether there would be enough vertical head available to provide the needed gradient, particularly for the longer applications. In a typical application, the upstream end of the flume is located above the intake deck and the water flows down the flume to the water surface below. A vendor cited a minimum gradient requirement in the range of 0.001 to 0.005 ft drop/ft length. For a 300-foot pipe, the needed vertical head based on these gradients is only 0.3 feet to 1.5 feet. The longest example fish return length identified by EPA was 4,600 feet at the Brunswick, SC plant. The head needed for that return, based on the above minimum gradient range, is 4.6 feet to 23 feet. Based on median values from the Phase II data base, intake decks are often about half the intake water depth above the water surface, EPA has concluded in most cases there was more than enough gradient available. Indeed, the data suggest if the return length is too short, there may be a potential problem from too great a gradient producing velocities that could injure fish.

Table 2-7 presents the added spray water pumps costs, 300-foot flume costs and the unit cost for additional flume length above 300 feet. Note that a feasibility study for the Drayton Point power plant cited an estimated flume unit cost of $100/ft which does not include indirect costs but is still well below comparable costs shown in Table 2-7.

Table 2-7

Spray Pump and Flume Costs

Total Screen Width (ft)		2	5	10	20	30	40	50	60	70	84	98	112	126	140
Fish Spray Flow at 30 gpm/ft (gpm)		60	150	300	600	900	1200	1500	1800	2100	2520	2940	3360	3780	4200
Pump Costs		$3,400	$3,900	$4,400	$5,500	$6,700	$8,100	$9,500	$11,100	$12,800	$15,300	$18,000	$21,000	$24,100	$27,500
Total Wash Flow at 60 gpm/ft (gpm)		120	300	600	1200	1800	2400	3000	3600	4200	5040	5880	6720	7560	8400
Pipe Dia at 1.5 fps (In)		6.0	8.0	12.0	16.0	20.0	23.0	25.0	28.0	30.0	33.0	35.0	38.0	40.0	42.0
Flume Costs at	$10.15	$18,272	$24,362	$36,543	$48,724	$60,905	$70,041	$76,131	$85,267	$91,358	$100,493	$106,584	$115,720	$121,810	$127,901
Flume Cost per Ft Added		$61	$81	$122	$162	$203	$233	$254	$284	$305	$335	$355	$386	$406	$426

Total Capital Costs

Indirect costs such as engineering, contractor overhead and profit, and contingency and allowance have been included in the individual component costs as they apply. Tables 2-8 through 2-13 (at the end of this section) present the total capital costs for compliance scenarios A, B, and C for both freshwater and saltwater environments. These costs are then plotted in Figures 2-1 through 2-6, which also include the best-fit, second-order equations of the data. These equations are used in the estimation of capital costs for the various technology applications.

2.1.2 DOWNTIME REQUIREMENTS

Placement of the fine screen overlay panels (Scenario A & C) can be done while the screen is operating. The screens are stopped during the placement and, between the placement of each panel, the screen rotated once. Installation of the ancillary equipment for the fish return system can be performed prior to screen replacement. Only the step of replacing the screen units would require shutdown of that portion of the intake. Vendors have reported that it would take from one to three days to replace traveling screen units where fish troughs and new spray piping are needed. The total should be no more than two weeks for multiple screens (Gathright 2002). If necessary, facilities with multiple screens and pumps could operate at the reduced capacity associated with taking a single pump out of service. However, it would be more prudent to schedule the screen replacement during a scheduled maintenance shutdown which typically occurs on an annual basis. Even at the largest installations with numerous screens, there should be sufficient time during the scheduled maintenance period to replace the screens and install controls and piping. Therefore, EPA is not including any monetary consideration for unit downtime associated with screen replacement or installation. Downtime for modification or addition to the intake structure to increase its size are discussed in a separate cost module.

Nuclear Facilities

Costs for nuclear facilities are not presented here. However, these costs were estimated applying a 1.8 cost factor to the applicable non-nuclear facility costs (see passive screen module for discussion).

2.1.3 O&M COST DEVELOPMENT

In general, O&M costs for intake system retrofit involve calculating the net difference between the existing system O&M costs and the new system O&M costs. The Phase I O&M cost estimates for traveling screens were generally derived as a percentage of the capital costs. This approach, however, does not lend itself well to estimating differences in operating costs for retrofits that involve similar equipment but have different operating and maintenance requirements such as changes in the duration of the screen operation. Therefore, a more detailed approach was developed.

The O&M costs developed here include only those components associated with traveling screens. Because cooling water flow rates are assumed not to change as a result of the retrofit, the O&M costs associated with the intake pumps are not considered. For traveling screens, the O&M costs are broken down into three components: labor, power requirements, and parts replacement. The basis and assumptions for each are described below.

Labor Requirements

The basis for estimating the total annual labor cost is based on labor hours as described below. In each baseline and compliance scenario the estimated number of hours is multiplied times a single hourly rate of $41.10/hour. This rate was derived by first estimating the hourly rate for a manager and a technician. The estimated management and technician rates were based on Bureau of

Labor Statistics hourly rates for management and electrical equipment technicians. These rates were multiplied by factors that estimate the additional costs of other compensation (e.g., benefits) to yield estimates of the total labor costs to the employer. These rates were adjusted for inflation to represent June 2002 dollars (see Daley 2002 for details). The two labor category rates were combined into one compound rate using the assumption that 90% of the hours applied to the technicians and 10% to management. A 10% management component was considered as reasonable because the majority of the work involves physical labor, with managers providing oversight and coordination with the operation of the generating units.

A vendor provided general guidelines for estimating basic labor requirements for traveling screens as averaging 200 hours and ranging from 100 to 300 hours per year per screen for coarse mesh screens without fish handling and double that for fine mesh screens with fish handling (Gathright 2002). The lower end of the range corresponds to shallow narrow screens and the high end of the range corresponds to the widest deepest screens. Tables 2-14 and 2-15 present the estimated annual number of labor hours required to operate and maintain a "typical" traveling screen.

Table 2-14
Basic Annual O&M Labor Hours for
Coarse Mesh Traveling Screens Without Fish Handling

Well Depth	Basket Screening Panel Width			
feet	2	5	10	14
10	100	150	175	200
25	120	175	200	225
50	130	200	225	250
75	140	225	250	275
100	150	250	275	300

Table 2-15
Basic Annual O&M Labor Hours for
Traveling Screens With Fish Handling

Well Depth	Basket Screening Panel Width (Ft)			
feet	2	5	10	14
10	78	78	117	117
25	168	168	252	252
50	318	318	477	477
75	468	468	702	702
100	618	618	927	927

When fine mesh screens are added as part of a compliance option, they are included as a screen overlay. EPA has assumed when sensitive aquatic organisms are present these fine mesh screens will be in place. EPA also assumes during times when levels of troublesome debris are present the facility will remove the fine mesh screen panels leaving the coarse mesh screen panels in place. The labor assumptions for replacing the screen panels are described earlier, but in this application the placement and removal steps occur once each per year. Table 2-16 presents the estimated annual labor hours for placement and removal of the fine mesh overlay screens.

Table 2-16
Total Annual O&M Hours for Fine Mesh Overlay Screen Placement and Removal

Well Depth	Basket Screening Panel Width			
feet	2	5	10	14
10	78	78	117	117
25	168	168	252	252
50	318	318	477	477
75	468	468	702	702
100	618	618	927	927

Operating Power Requirement

Power is needed to operate the mechanical equipment, specifically the motor drives for the traveling screens and the pumps that deliver the spray water for both the debris wash and the fish spray.

<u>Screen Drive Motor Power Requirement</u>

Coarse mesh traveling screens without fish handling are typically operated on an intermittent basis. When debris loading is low the screens may be operated several times per day for relatively short durations. Traveling screens with fish handling and return systems, however, must operate continuously if the fish return system is to function properly.

A vendor provided typical values for the horsepower rating for the drive motors for traveling screens which are shown in Table 2-17. These values were assumed to be similar for all of the traveling screen combinations considered here. Different operating hours are assumed for screens with and without fish handling. This is due to the fact that screens with fish handling must be operated continuously. A vendor estimated that coarse mesh screens without fish handling are typically operated for a total of 4 to 6 hrs/day (Gathright 2002). The following assumptions apply:

- The system will be shut down for four weeks out of the year for routine maintenance
- For fine mesh, operating hours will be continuous (24 hrs/day)
- For coarse mesh, operating hours will be an average of 5 hours/day (range of 4 to 6)
- Electric motor efficiency of 90%
- Power cost of $0.04/kWh for power plants.

<u>Wash Water and Fish Spray Pump Power Requirement</u>

As noted previously, spray water is needed for both washing debris off of the screens (which occurs at all traveling screens) and for a fish spray (which is needed for screens with fish handling and return systems). The nozzle pressure for the debris spray can range from 80 to 120 psi. A value of 120 psi was chosen as a high value which would include any static pressure component. The following assumptions apply:

- Spray water pumps operate for the same duration as the traveling screen drive motors
- Debris wash requires 30 gpm/ft screen length
- Fish spray requires 30 gpm/ft screen length
- Pumping pressure is 120 psi (277 ft of water) for both
- Combined pump and motor efficiency is 70%
- Electricity cost is $0.04/KWh for power plants.

The pressure needed for fish spray is considerably less than that required for debris, but it is assumed that all wash water is pumped to the higher pressure and regulators are used to step down the pressure for the fish wash. Tables 2-18 and 2-19 present the power costs for the spray water for traveling screens without and with fish handling, respectively. Spray water requirements depend on the presence of a fish return system but are assumed to otherwise be the same regardless of the screen mesh size.

Table 2-17
Screen Drive Motor Power Costs

				Power Costs - Fine Mesh			Power Costs - Coarse Mesh		
Screen Width	Well Depth	Motor Power	Electric Power	Operating Hours	Annual Power	Annual Power Costs at $/Kwh of	Operating Hours	Annual Power	Annual Power Costs at $/Kwh of
Ft	Ft	Hp	Kw		Kwh	$0.04		Kwh	$0.04
2	10	0.5	0.414	8,064	3,342	$134	1,680	696	$28
2	25	1	0.829	8,064	6,684	$267	1,680	1,393	$56
2	50	2.7	2.210	8,064	17,824	$713	1,680	3,713	$149
2	75	5	4.144	8,064	33,421	$1,337	1,680	6,963	$279
2	100	6.7	5.512	8,064	44,450	$1,778	1,680	9,260	$370
5	10	0.75	0.622	8,064	5,013	$201	1,680	1,044	$42
5	25	1.5	1.243	8,064	10,026	$401	1,680	2,089	$84
5	50	4	3.316	8,064	26,737	$1,069	1,680	5,570	$223
5	75	7.5	6.217	8,064	50,131	$2,005	1,680	10,444	$418
5	100	10.0	8.268	8,064	66,674	$2,667	1,680	13,891	$556
10	10	1	0.829	8,064	6,684	$267	1,680	1,393	$56
10	25	3.5	2.901	8,064	23,395	$936	1,680	4,874	$195
10	50	10	8.289	8,064	66,842	$2,674	1,680	13,925	$557
10	75	15	12.433	8,064	100,262	$4,010	1,680	20,888	$836
10	100	20.0	16.536	8,064	133,349	$5,334	1,680	27,781	$1,111
14	10	2	1.658	8,064	13,368	$535	1,680	2,785	$111
14	25	6.25	5.181	8,064	41,776	$1,671	1,680	8,703	$348
14	50	15	12.433	8,064	100,262	$4,010	1,680	20,888	$836
14	75	20	16.578	8,064	133,683	$5,347	1,680	27,851	$1,114
14	75	26.6	22.048	8,064	177,799	$7,112	1,680	37,041	$1,482

Table 2-18
Wash Water Power Costs
Traveling Screens Without Fish Handling

						Fine Mesh			Coarse Mesh		
Screen Width	Flow Rate	Total Head	Hydraulic-Hp	Brake-Hp	Power Requirement	Annual Hours	Annual Power	Total Costs at $/Kwh of	Annual Hours	Annual Power	Total Costs at $/Kwh of
ft	gpm	ft	Hp	Hp	Kw	hr	Kwh	$0.04	hr	Kwh	$0.04
2	60	277	4.20	6.0	4.5	8064	36,072	$1,443	1680	7,515	$301
5	150	277	10.49	15.0	11.2	8064	90,179	$3,607	1680	18787	$751
10	300	277.1	20.98	30.0	22.4	8064	180,359	$7,214	1680	37575	$1,503
14	420	277	29.37	42.0	31.3	8064	252,502	$10,100	1680	52605	$2,104

Table 2-19
Wash Water and Fish Spray Power Costs
Traveling Screens With Fish Handling

						Fine Mesh			Coarse Mesh		
Screen Width	Flow Rate	Total Head	Hydraulic-Hp	Brake-Hp	Power Requirement	Annual Hours	Annual Power	Total Costs at $/Kwh of	Annual Hours	Annual Power	Total Costs at $/Kwh of
ft	gpm	ft	Hp	Hp	Kw	hr	Kwh	$0.04	hr	Kwh	$0.04
2	120	277	8.39	12.0	8.9	8064	72,143	$2,886	1680	15,030	$601
5	300	277	20.98	30.0	22.4	8064	180,359	$7,214	1680	37575	$1,503
10	600	277	41.97	60.0	44.7	8064	360,717	$14,429	1680	75149	$3,006
14	840	277	58.76	83.9	62.6	8064	505,004	$20,200	1680	105209	$4,208

A vendor estimated that the cost of parts replacement for coarse mesh traveling screens without fish handling would be approximately 15% of the equipment costs every 5 years (Gathright 2002). For traveling screens with fish handling, the same 15% would be replaced every 2.5 years. EPA has assumed for all screens that the annual parts replacement costs would be 6% of the equipment costs for those operating continuously and 3% for those operating intermittently. These factors are applied to the equipment costs in Table 2-3 and 2-4. Traveling screens without fish handling (coarse mesh) operate fewer hours (estimated at 5 hrs/day) and should therefore experience less wear on the equipment. While the time of operation is nearly five times longer for continuous operation, the screen speed used is generally lower for continuous operation. Therefore, the wear and tear, hence O&M costs, are not directly proportional.

Baseline and Compliance O&M Scenarios

Table 2-20 presents the six baseline and compliance O&M scenario cost combinations developed by EPA.

For the few baseline operations with fine mesh, nearly all had fish returns and or low screen velocities, indicating that such facilities will likely not require compliance action. Thus, there is no baseline cost scenario for traveling screens with fine mesh without fish handling and return. Tables 2-21 through -26 (at the end of this section) present the O&M costs for the cost scenarios shown in Table 2-20. Figures 2-7 through 2-12 present the graphic plots of the O&M costs shown in these tables with best-fit, second-order equations of the plots. These equations are used in the estimation of O&M costs for the various technology applications.

Table 2-20
Mix of O&M Cost Components for Various Scenarios

	Baseline Without Fish Handling	**Baseline Without Fish Handling**	**Baseline with Fish Handling & Scenario B Compliance**	**Baseline with Fish Handling & Scenario B Compliance**	**Scenario A & C Compliance**	**Scenario A & C Compliance**
Mesh Type	Coarse	Coarse	Coarse or Smooth Top	Coarse or Smooth Top	Smooth Top & Fine	Smooth Top & Fine
Fish Handling	None	None	Yes	Yes	Yes	Yes
Water Type	Freshwater	Saltwater	Freshwater	Saltwater	Freshwater	Saltwater
Screen Operation	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Basic Labor	100-300 hrs	100-300 hrs	200-600 hrs	200-600 hrs	200-600 hrs	200-600 hrs
Screen Overlay Labor	None	None	None	None	Yes	Yes
Screen Motor Power	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Debris Spray Pump Power	5 hrs/day	5 hrs/day	Continuous	Continuous	Continuous	Continuous
Fish Spray Pump Power	None	None	Continuous	Continuous	Continuous	Continuous
Parts Replacement - % Equipment Costs	3%	3%	6%	6%	6%	6%

O&M for Nuclear Facilities

Unlike the assumption for capital costs, the O&M costs for nuclear facilities consider the differences in the component costs. The power cost component is assumed to be the same. The equipment replacement cost component uses the same annual percentage of equipment cost factors, but is increased by the same factor as the capital costs (2.0). A Bureau of Labor Statistics document (BLS 2002) reported that the median annual earnings of a nuclear plant operator were $57,220 in 2002 compared to $46,090 for power plant operators in general. Thus, nuclear operators earnings were 24% higher than the industry average. No comparable data were available for maintenance personnel. This factor of 24% is used for estimating the increase in labor costs for nuclear facilities. This factor may be an overestimation: nuclear plant operators require a proportionally greater amount of training and the consequences of their actions engender greater overall risks than the intake maintenance personnel. EPA recalculated the O&M costs using the revised equipment replacement and labor costs. EPA found that the ratio of non-nuclear to nuclear O&M costs did not vary much for each scenario and water depth. Therefore, EPA chose to use the factor derived from the average ratio (across total width values) of estimated nuclear facility O&M to non-nuclear facility O&M for each scenario and well depth to estimate the nuclear facility O&M costs. Table 2-27 presents the cost factors to be used to estimate nuclear facility O&M costs for each cost scenario and well depth using the non-nuclear O&M values as the basis.

Table 2-27
Nuclear Facility O&M Cost Factors

Well Depth	Baseline O&M Traveling Screens Without Fish Handling	Baseline O&M Traveling Screens Without Fish Handling	Baseline & Scenario B Compliance O&M Traveling Screens With Fish Handling	Baseline & Scenario B Compliance O&M Traveling Screens With Fish Handling	Scenario A & C Compliance O&M Traveling Screens With Fish Handling	Scenario A & C Compliance O&M Traveling Screens With Fish Handling
Ft	Freshwater	Saltwater	Freshwater	Saltwater	Freshwater	Saltwater
10	1.32	1.41	1.29	1.40	1.28	1.39
25	1.35	1.46	1.33	1.46	1.32	1.44
50	1.39	1.51	1.39	1.53	1.36	1.49
75	1.41	1.53	1.43	1.57	1.38	1.51
100	1.42	1.55	1.45	1.60	1.40	1.53

2.1.4 DOUBLE ENTRY-SINGLE EXIT (DUAL-FLOW) TRAVELING SCREENS

Another option for replacing coarse mesh single entry-single exit (through-flow) traveling screens is to install double entry-single exit (dual-flow) traveling screens. Such screens are designed and installed to filter water continuously, using both upward and downward moving parts of the screen. The interior space between the upward and downward moving screen panels is closed off on one side (oriented in the upstream direction), while screened water exits towards the pump well through the open end on the other side.

One major advantage of dual-flow screens is that the direction of flow through the screen does not reverse as it does on the back side of a through-flow screen. As such, there is no opportunity for debris stuck on the screen to dislodge on the downstream side. In through-flow screens, debris that fails to dislodge as it passes the spray wash can become dislodged on the downstream side (essentially bypassing the screen). Such debris continues downstream where it can plug condenser tubes or require more frequent cleaning of fixed screens set downstream of the intake screen to prevent condenser tube plugging. Such maintenance typically requires the shut down of the generating units. Since dual-flow screens eliminate the opportunity for debris carryover, the spray water pressure requirements are reduced with dual-flow screens requiring a wash water spray pressure of 30 psi compared to 80 to 120 psi for through-flow screens (Gathright 2002). Dual-flow screens are oriented such that the screen face is parallel to the direction of flow. By extending the screen width forward (perpendicular to the flow) to a size greater than one half the screen well width, the total screen surface area of a dual-flow screen can exceed that of a through-flow screen in the same application. Therefore, if high through-screen velocities are affecting the survival of impinged organisms in existing through-flow screens, the retrofit of dual-flow screens may help alleviate this problem. The degree of through-screen velocity reduction will be dependent on the space constraints of the existing intake configuration. In new intake construction, dual-flow screens can be installed with no walls separating the screens.

Retrofitting existing intakes containing through-flow screens with dual-flow screens can be performed with little or minor modifications to the existing intake structure. In this application, the dual-flow screens are constructed such that the open outlet side will align with the previous location of the downstream side of the through-flow screen. The screen is constructed with supports that slide into the existing screen slots and with “gull wing” baffles that close off the area between the screens downstream end and the screen well walls. The baffles are curved to better direct the flow. For many existing screen structures, the opening where the screen passes through the intake deck (including the open space in front of the screen) is limited to a five-foot opening front to back which limits the equivalent total overall per screen width of just under 10 ft for dual-flow retrofit screens. Because dual-flow screens filter on both sides the effective width is twice that of one screen panel. However, a vendor indicated, in many instances the screen well opening can be extended forward by demolishing a portion of the concrete deck at the front end. The feasibility and extent of such a modification (such as maximum width of the retrofit screen) is dependent on specific design of the existing intake, particularly concerning the proximity of obstructions upstream of the existing screen units. Certainly, most through-flow screens of less than 10 ft widths could be retrofitted with dual-flow screens that result in greater effective screen widths. Those 10 ft wide or greater that have large deck openings and/or available space could also install dual-flow screens with greater effective screen widths.

Capital Cost for Dual-Flow Screens

A screen vendor provided general guidance for both capital and O&M costs for dual-flow screens (Gathright 2002). The cost of dual-flow screens with fish handling sized to fit in existing intake screen wells could be estimated using the following factors applied to the costs of a traveling screen with fish handling that fit the existing screen well:

- For a screen well depth of 0 to <20 ft add 15% to the cost of a similarly sized through-flow screen.
- For a screen well depth of 20 ft to <40 ft add 10% to the cost of a similarly sized through-flow screen.
- For a screen well depth of greater than 40 ft add 5% to the cost of a similarly sized through-flow screen.

Installation costs are assumed to be similar to that for through-flow screens. The above factors were applied to the total installed cost of similarly sized through-flow screens, However, an additional 5% was added to the above cost factors to account for modifications that may be necessary to accommodate the new dual-flow screens such as demolition of a portion of the deck area. It is assumed that dual-flow screens can be installed in place of most through-flow screens but the benefit of lower through screen velocities may be limited for larger width (e.g., 14-ft) existing screens. The dual-flow screens are assumed to include fine mesh overlays and fish return systems, so the cost factors are applied to the scenario C through-flow screens only. The costs for dual-flow screens are not presented here but can be derived by applying the factor shown in Table 2-28 below

The capital costs for adding fine mesh overlays to existing dual-flow screens (scenario A) is assumed to be the same as for through-flow screens. This assumption is based on the fact that installation labor is based on the number of screen panels and should be the nearly the same and that the cost of the screen overlays themselves should be nearly the same. The higher equipment costs for dual-flow screens is mostly due to the equipment and equipment modifications located above the deck.

Table 2-28
Capital Cost Factors for Dual-Flow Screens

Screen Depth	Capital Cost Factor[1]
10 Ft	1.2
25 Ft	1.15
50 Ft	1.1
75 Ft	1.1

[1] Applied to capital costs for similarly sized through-flow screens derived from equations shown in Figures 2-5 and 2-6 (Scenario C freshwater and saltwater)

O&M Costs for Dual-Flow Screens

A vendor indicated that a significant benefit of dual-flow screens is reduced O&M costs compared to similarly sized through-flow screens. O&M labor was reported to be as low as one tenth that for similarly sized through-flow traveling screens (Bracket Green 2002). Also, wash water flow is nearly cut in half and the spray water pressure requirement drops from 80 to 120 psi for through-flow screens to about 30 psi. Examples were cited where dual-flow retrofits paid for themselves in a two to five year period. Using an assumption of 90% reduction in routine O&M labor combined with an estimated reduction of 70% in wash water energy requirements (based on combined reduction in flow and pressure), EPA calculated that the O&M costs for dual-flow screens would be equal approximately 30% of the O&M costs for similarly sized through-flow screens with fine mesh overlays and fish handling and return systems. O&M costs for dual-flow screens were calculated as 30% of the O&M costs for similarly sized through-flow screens derived from the equations shown in Figures 2-9 and 2-10 (Scenario C freshwater and saltwater).

The O&M costs for adding fine mesh overlays to existing dual-flow screens (scenario A) is assumed to be the same as the net difference between through-flow screens with fish handling with and without fine mesh overlays (net O&M costs for scenario A versus scenario B). The majority of the net O&M costs are for deployment and removal of the fine mesh overlays.

Downtime for Dual-Flow Screens

As with through-flow screens dual-flow screens can be retrofitted with minimal generating unit downtime and can be scheduled to occur during routine maintenance downtime. While there may be some additional deck demolition work, this effort should add no more than one week to the two week estimate for multiple through-flow screens described above.

Technology Application

Capital Costs

The cost scenarios included here assume that the existing intake structure is designed for and includes through-flow (single entry, single exit) traveling screens, either with or without fish handling and return. For those systems with different types of traveling screens or fixed screens, the cost estimates derived here may also be applied. However, they should be viewed as a rough estimate for a retrofit that would result in similar performance enhancement. The cost scenario applied to each facility is based on the compliance action required and whether or not a fish handling and return system is in place. For those facilities with acceptable through-screen velocities no modification, other than described above, is considered as necessary. For those with high through-screen velocities that would result in unacceptable performance, costs for modifications/additions to the existing intake are developed through another cost module. The costs for new screens to be installed in these new intake structures will be based on the design criteria of the new structure.

Capital costs are applied based on waterbody type with costs for freshwater environments being applied to facilities in freshwater rivers/streams, lakes/reservoirs and the Great Lakes, and costs for saltwater environments being applied to facilities in estuaries/tidal rivers and oceans.

No distinction is being made here for freshwater environments with Zebra mussels. A vendor indicated that the mechanical movement and spray action of the traveling screens tend to prevent mussel attachment on the screens.

For facilities with intake canals, an added capital cost component for the additional length of the fish return flume (where applicable) are added. Where the canal length is not reported. The median canal length for other facilities with the same waterbody type are used.

O&M Costs

The compliance O&M costs are calculated as the net difference between the compliance scenario O&M costs and the baseline scenario O&M costs. For compliance scenarios that start with traveling screens where the traveling screens are then rendered unnecessary (e.g., relocating a shoreline intake to submerged offshore), the baseline scenario O&M costs presented here can be used to determine the net O&M cost difference for those technologies.

2.2 NEW LARGER INTAKE STRUCTURE FOR DECREASING INTAKE VELOCITIES

The efficacy of traveling screens can be affected by both through-screen and approach velocities. Through-screen velocity affects: the rate of debris accumulation; the potential for entrainment and impingement of swimming organisms; and the amount of injury that may occur when organisms become impinged and a fish return system is in use. Performance, with respect to impingement and entrainment, generally tends to deteriorate as intake velocities increase. For older intake structures, the primary function of the screen was to ensure downstream cooling system components continued to function without becoming plugged with debris. The design often did not take into consideration the effect of through-screen velocity on entrainment and impingement of aquatic organisms. For these older structures, the standard design value for through-screen velocity was in the range of 2.0 to 2.5 fps (Gathright 2002). These design velocities were based on the performance of coarse mesh traveling screens with respect to their ability to remove debris as quickly as it collected on the screen surface. As demonstrated in the Facility Questionnaire database, actual velocities may be even higher than standard design values. These higher velocities may result from cost-saving, site-specific designs or from an increased withdrawal rate compared to the original design.

As described previously, solutions considered for reducing entrainment on traveling screens are to replace the coarse mesh screens with finer mesh screens or to install fine mesh screen overlays. However, a potential problem with replacing the existing intake screens with finer mesh screens is that a finer mesh will accumulate larger quantities of debris. Thus, retrofitting existing coarse mesh screens with fine mesh may affect the ability of screens to remove debris quickly enough to function properly. Exacerbating this potential problem is finer mesh may result in slightly higher through-screen velocities (Gathright 2002). If the debris problems associated with using fine mesh occur on a seasonal basis, then one possible solution (see Section 2.1, above) is to use fine mesh overlays during the period when sensitive aquatic organisms are present. This solution is predicated on the assumption that the period of high debris loading does not substantially coincide with the period when sensitive aquatic organisms are most prevalent. When such an approach is not feasible, some means of decreasing the intake velocities may be necessary.

The primary intake attributes that determine intake through-screen velocities are the flow volume, effective screen area, and percent open area of the screen. The primary intake attributes that determine approach velocity are flow volume and cross-sectional area of the intake. In instances where flow volume cannot be reduced, a reduction in intake velocities can only be obtained in two ways: for through-screen velocities, an increased screen area and/or percent open area, or for approach velocity, an increased intake cross-sectional area. In general, there are practical limits regarding screen materials and percent open area. These limits prevent significant modification of this attribute to reduce through-screen velocities. Thus, an increase in the screen area and/or intake cross-sectional area generally must be accomplished in order to reduce intake velocities. Passive screen technology (such as T-screens) relies on lower screen velocities to improve performance with respect to impingement and entrainment and to reduce the rate of debris accumulation. For technology options that rely on the continued use of traveling screens, a means of increasing the effective area of the screens is warranted. EPA has researched this problem and has identified the following three approaches to increasing the screen size:

- Replace existing through flow (single entry-single exit) traveling screens with dual-flow (double entry-double exit) traveling screens. Dual-flow screens can be placed in the same screen well as existing through flow screens. However, they are oriented perpendicular to the orientation of the original through-flow screens and extend outward towards the front of the intake. Installation may require some demolition of the existing intake deck. This solution may work where screen velocities do not need to be reduced appreciably. This technology has a much improved performance with respect to debris carry over and is often selected based on this attribute alone (Gathright 2002; see also Section 2.1.4).

- Replace the function of the existing intake screen wells with larger wells constructed in front of the existing intake and hydraulically connected to the intake front opening. This approach retains the use and function of the existing intake pumps and pump wells with little or no modification to the original structure. A concern with this approach (besides construction costs) is whether the construction can be performed without significant downtime for the generating units.

- Add a new intake structure adjacent to, or in close proximity to, the existing intake. The old intake remains functional, but with the drive system for the existing pumps modified to reduce the flow rate. The new structure will include new pumps sized to pump an additional flow. The new structure can be built without a significant shutdown of the existing intake. Shutdown would only be required at the final construction step, where the pipes from new pumps are connected to the existing piping and the pumps and/or pump drives for the existing pumps are modified or replaced. In this case, generating downtime is minimized. However, the need for new pumps, and the modification to existing pumps that reduce their original flow, entail significant additional costs.

Option 3 is a seemingly simple solution where the addition of new intake bays adjacent or in close proximity to the existing intake would add to the total intake and screen cross-sectional area. A problem with this approach is that the current pumping capacity needs to be distributed between the old and new intake bays. Utilizing the existing pump wells and pumps is desirable to help minimize costs. However, where the existing pumps utilize single speed drives, the distribution of flow to the new intake bays would require either an upstream hydraulic connection or a pump system modification. Where the existing intake has only one or two pump wells a hydraulic connection with a new adjacent intake bay could be created through demolition of a sidewall downstream of the traveling screen. While this approach is certainly feasible in certain instances, the limitations regarding intake configurations prevents EPA from considering this a viable regulatory compliance alternative for all but a few existing systems. A more widely applicable solution would be to reduce pump flow rate of the existing pumps either by modifying the pump drive to a multi-speed or variable speed drive system, or by replacing the existing pumps with smaller ones. The new intake bays would be constructed with new smaller pumps that produce lower flow rates. The combined flows of the new and older, modified pumps satisfies the existing intake flow requirement. The costs of modifying existing pumps, plus the new pumps and pump wells, represents a substantial cost component.

Option 2 does not require modifications or additions to the existing pumping equipment. In this approach a new intake structure to house more and/or larger screen wells would be constructed in front of the existing intake. The old and new intake structures could then be hydraulically connected by closing off the ends with sheet pile walls or similar structures. EPA is not aware of any installations that have performed this retrofit but it was proposed as an option in the Demonstration Study for the Salem Nuclear Plant (PSE&G 2001). In that proposal the new screens were to be dual-flow screens but the driving factor for the new structure was a need to increase the intake size.

EPA initially developed rough estimates of the comparative costs of applying option 2 versus option 3 (in the hypothetical case the intake area was doubled in size). The results indicated that adding a new screen well structure in front of the existing intake was less costly and therefore, this option was selected for consideration as a compliance technology option. This cost efficiency is primarily due to the reuse of the existing intake in a more cost efficient manner in option 2. However, option 2 has one important drawback: it may not be feasible where sufficient space is not available in front of the existing intake. To minimize construction downtime, EPA assumes the new intake structure is placed far enough in front of the existing intake to allow the existing intake to continue functioning until construction of the structure is completed. As a result of the need for sufficient space in front of the intake, the Agency has applied the technology in appropriate circumstances in developing model facility costs.

Scenario Description

In this scenario, modeled on option 2 described above, a new reinforced concrete structure is designed for new through-flow or dual-flow intake screens. This structure will be built directly in front of the existing intake. The structure will be built inside a temporary sheet pile coffer dam. Upon completion of the concrete structure, the coffer dam will be removed. A permanent sheet pile wall will be installed at both ends, connecting the rear of the new structure to the front of the old intake structure hydraulically. Such a configuration has the advantage of providing for flow equalization between multiple new intake screens and multiple existing pumps. The construction includes costs for site development for equipment access. Capital costs were developed for the same set of screen widths (2 feet through 140 feet) and depths (10 feet through 100 feet) used in the traveling screen cost methodology. Best-fit, second-order equations were used to estimated costs for each different screen well depth, using total screen width as the independent variable. Construction duration is estimated to be nine months.

Capital Costs

Capital costs were derived for different well depths and total screen widths based on the following assumptions.

<u>Design Assumptions - On-shore Activities</u>

- Clearing and grabbing: this is based on clearing with a dozer, and clearing light to medium brush to 4" diameter; clearing assumes a 40 feet width for equipment maneuverability near the shore line and 500 feet accessibility lengthwise at $3,075/acre (R S Means 2001); surveying costs are estimated at $1,673/ acre (R S Means 2001), covering twice the access area.
- Earth work costs: these include mobilization, excavation, and hauling, etc., along a water front width, with a 500-foot inland length; backfill with structural sand and grave (backfill structural based on using a 200 HP bulldozer, 300-foot haul, sand and gravel; unit earthwork cost is $395/ cu yd (R S Means 2001)
- Paving and surfacing, using concrete 10" thick; assuming a need for a 20-foot wide and 2- foot long equipment staging area at a unit cost of $33.5/ sq yd (R S Means 2001)
- Structural cost is calculated @ $1250/CY (R S Means 2001),assuming two wing walls 1.5 feet thick and 26 feet high, with 10 feet above ground level, and 36 feet long with 16 feet onshore (these walls are for tying in the connecting sheet pile walls).
- Sheet piling, steel, no wales, 38 psf, left in place; these are assumed to have a width twice the width of the screens + 20 feet, with onshore construction distance, and be 30 feet deep, at $24.5/ sq ft (R S Means 2001).

<u>Design Assumptions - Offshore Components</u>

- Structure width is 20% greater than total screen width and 20 ft front to back
- Structural support consists of the equivalent of four 3-foot by 3-foot reinforced concrete columns at $935/ cu yd (R S Means 2001) plus two additional columns for each additional screen well (a 2-foot wide screen assumes an equivalent of 2-foot by 2 feet columns)
- Overall structure height is equal to the well depth plus 10%
- The elevated concrete deck is 1.5 ft thick at $48/ cu yd (R S Means 2001)
- Dredging mobilization is $9,925 if total screen width is less than 10 feet; is $25,890 if total screen width is 10 feet to 25 feet; and is $52,500 if total screen width is greater than 25 ft (R S Means 2001)
- The cost of dredging in the offshore work area is $23/cu yd to a depth of 10 feet
- The cost of the temporary coffer dam for the structure is $22.5/ sq ft (R S Means 2001), with total length equal to the structure perimeter times a factor of 1.5 and the height equal to 1.3 times well depth.

<u>Field Project Personnel Not Included in Unit Costs</u>:

- Project Field Manager at $2,525 per week (R S Means 2001)
- Project Field Superintendent at $2,375 per week (R S Means 2001)
- Project Field Clerk at $440 per week (R S Means 2001).

The above cost components were estimated and summed and the costs were expanded using the following cost factors.

<u>Add-on and Indirect Costs</u>:

- Construction Management is 4.5% of direct costs
- Engineering and Architectural fees for new construction is 17% of direct costs

- Contingency is 10% of direct costs
- Overhead and profit is 15% of direct costs
- Permits are 2% of direct costs
- Metalwork is 5% of direct costs
- Performance bond is 2.5% of direct costs
- Insurance is 1.5% of direct costs.

The total capital costs were then adjusted for inflation from 2001 dollars to July 2002 dollars using the ENR Construction Cost Index. Table 2-29 presents the total capital costs for various screen well depths and total screen widths. No distinction was made between freshwater and brackish or saltwater environments. Figure 13 plots the data in Table 2-29 and presents the best-fit cost equations. The shape of these curves indicates a need for separate equations for structures with widths less than and greater than 10 feet. In general, however, the Phase II compliance applications of this technology option included only new structures greater than 10 feet wide.

Table 2-29
Total Capital Costs for Adding New Larger Intake Screen Well Structure in Front of Existing Shoreline Intake

Well Depth	10 Ft	25 Ft	50 Ft	75 ft	100 Ft
Width (Ft)					
2	$ 291,480	$ 562,140	$ 1,176,330	$ 1,842,570	$ 2,581,680
5	$ 333,120	$ 624,600	$ 1,290,840	$ 1,998,720	$ 2,800,290
10	$ 916,080	$ 1,957,080	$ 4,361,790	$ 6,922,650	$ 9,806,220
20	$ 1,051,410	$ 2,175,690	$ 4,757,370	$ 7,484,790	$ 10,545,330
30	$ 1,270,020	$ 2,487,990	$ 5,236,230	$ 8,130,210	$ 11,378,130
40	$ 1,426,170	$ 2,727,420	$ 5,642,220	$ 8,713,170	$ 12,138,060
50	$ 1,582,320	$ 2,977,260	$ 6,058,620	$ 9,306,540	$ 12,908,400
60	$ 1,748,880	$ 3,227,100	$ 6,485,430	$ 9,899,910	$ 13,689,150
70	$ 1,925,850	$ 3,487,350	$ 6,922,650	$ 10,503,690	$ 14,469,900
84	$ 2,165,280	$ 3,851,700	$ 7,536,840	$ 11,367,720	$ 15,583,770
98	$ 2,425,530	$ 4,236,870	$ 8,161,440	$ 12,242,160	$ 16,718,460
112	$ 2,696,190	$ 4,622,040	$ 8,994,240	$ 13,127,010	$ 17,863,560
126	$ 2,977,260	$ 5,028,030	$ 9,462,690	$ 14,032,680	$ 19,029,480
140	$ 3,268,740	$ 5,444,430	$ 10,139,340	$ 14,948,760	$ 20,205,810

O&M Costs

No separate O&M costs were derived for the structure itself since the majority of the O&M activities are covered in the O&M costs for the traveling screens to be installed in the new structure.

Construction Downtime

As described above, this scenario is modeled after an option described in a 316b Demonstration Study for the Salem Nuclear Plant (PSE&G 2001). In that scenario which applies to a very large nuclear facility, the existing intake continues to operate during the construction of the offshore intake structure inside the sheet pile cofferdam. Upon completion of the offshore structure and removal of the cofferdam, the final phase on the construction requires the shut down of the generating units for the placement of the sheet pile end walls. The feasibility study states that units 1 and 2 would be required to shut down for one month each. Based on this estimate and the size of the Salem facility (average daily flow of over 2 million gpm), EPA has concluded that a total construction downtime estimate in the range of 6 to 8 weeks is reasonable. EPA did not select a single downtime for all facilities installing an offshore structure. Instead, EPA applied a six- to eight-week downtime duration based on variations in project size, using design flow as a measure of size. EPA assumed a total downtime of six weeks for facilities with intake flow volumes of less than 400,000 gpm; seven weeks for facilities with intake flow volumes greater than 400,000 gpm but less than 800,000 gpm; and eight weeks for facilities with intake flow volumes greater than 800,000 gpm.

Application

The input value for the cost equation is the screen well depth and the total screen width (see Section 1.1 for a discussion of the methodology for determining the screen well depth). The width of the new larger screen well intake structure was based on the design flow, and an assumed through-screen velocity of 1.0 fps and a percent open area of 50%. The 50 % open area value used is consistent with the percent open area of a fine mesh screen. The same well depth and width values are used for estimating the costs of new screen equipment for the new structure. New screen equipment consisted of fine mesh dual flow (double entry single exit) traveling screens with fish handling and return system.

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Table 2-8
Total Capital Costs for Scenario A - Adding Fine Mesh Without Fish Handling
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$7,989	$9,079	$11,853	$23,706	$35,559	$47,412	$59,265	$71,117	$81,865	$98,237	$114,610	$143,806	$147,356	$163,729
25'-0	$11,162	$12,932	$17,952	$35,905	$53,857	$71,810	$89,762	$107,714	$134,162	$160,994	$187,827	$242,278	$241,492	$268,324
50'-0	$17,707	$20,977	$30,295	$60,590	$90,885	$121,180	$151,475	$181,769	$206,825	$248,189	$289,554	$383,198	$372,284	$413,649
75'-0	$24,262	$29,302	$40,467	$80,935	$121,402	$161,870	$202,337	$242,804	$273,987	$328,784	$383,582	$515,318	$493,177	$547,974
100'-0	$32,997	$37,627	$50,630	$101,260	$151,890	$202,520	$253,150	$303,779	$338,450	$406,139	$473,829	$643,118	$609,209	$676,899

Table 2-9
Total Capital Costs for Scenario A - Adding Fine Mesh Without Fish Handling
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$14,909	$17,089	$22,103	$44,206	$66,309	$88,412	$110,515	$132,617	$155,715	$186,857	$218,000	$249,143	$280,286	$311,429
25'-0	$20,022	$23,562	$32,452	$64,905	$97,357	$129,810	$162,262	$194,714	$251,062	$301,274	$351,487	$401,699	$451,912	$502,124
50'-0	$31,057	$37,597	$54,055	$108,110	$162,165	$216,220	$270,275	$324,329	$380,975	$457,169	$533,364	$609,559	$685,754	$761,949
75'-0	$42,112	$52,192	$71,317	$142,635	$213,952	$285,270	$356,587	$427,904	$499,887	$599,864	$699,842	$799,819	$899,797	$999,774
100'-0	$57,527	$66,787	$88,560	$177,120	$265,680	$354,240	$442,800	$531,359	$613,400	$736,079	$858,759	$981,439	$1,104,119	$1,226,799

Table 2-10
Total Capital Costs for Scenario B - Adding Fish Handling and Return
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$105,872	$126,362	$164,443	$301,224	$438,105	$572,141	$703,131	$837,367	$967,658	$1,151,993	$1,333,484	$1,518,320	$1,700,210	$1,882,401
25'-0	$132,772	$161,562	$217,443	$407,224	$597,105	$784,141	$968,131	$1,155,367	$1,460,658	$1,743,593	$2,023,684	$2,307,120	$2,587,610	$2,868,401
50'-0	$185,172	$230,462	$320,543	$613,424	$906,405	$1,196,541	$1,483,631	$1,773,967	$2,095,658	$2,505,593	$2,912,684	$3,323,120	$3,730,610	$4,138,401
75'-0	$237,672	$302,162	$401,943	$776,224	$1,150,605	$1,522,141	$1,890,631	$2,262,367	$2,675,658	$3,201,593	$3,724,684	$4,251,120	$4,774,610	$5,298,401
100'-0	$311,972	$373,862	$483,243	$938,824	$1,394,505	$1,847,341	$2,297,131	$2,750,167	$3,228,658	$3,865,193	$4,498,884	$5,135,920	$5,770,010	$6,404,401

Table 2-11
Total Capital Costs for Scenario B - Adding Fish Handling and Return
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$175,072	$206,462	$266,943	$506,224	$745,605	$982,141	$1,215,631	$1,452,367	$1,706,158	$2,038,193	$2,367,384	$2,699,920	$3,029,510	$3,359,401
25'-0	$221,372	$267,862	$362,443	$697,224	$1,032,105	$1,364,141	$1,693,131	$2,025,367	$2,629,658	$3,146,393	$3,660,284	$4,177,520	$4,691,810	$5,206,401
50'-0	$318,672	$396,662	$558,143	$1,088,624	$1,619,205	$2,146,941	$2,671,631	$3,199,567	$3,837,158	$4,595,393	$5,350,784	$6,109,520	$6,865,310	$7,621,401
75'-0	$416,172	$531,062	$710,443	$1,393,224	$2,076,105	$2,756,141	$3,433,131	$4,113,367	$4,934,658	$5,912,393	$6,887,284	$7,865,520	$8,840,810	$9,816,401
100'-0	$557,272	$665,462	$862,543	$1,697,424	$2,532,405	$3,364,541	$4,193,631	$5,025,967	$5,978,158	$7,164,593	$8,348,184	$9,535,120	$10,719,110	$11,903,401

Table 2-12
Total Capital Costs for Scenario C - Adding Fine Mesh with Fish Handling and Return
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$112,772	$134,362	$174,743	$321,824	$469,005	$613,341	$754,631	$899,167	$1,041,658	$1,240,793	$1,437,084	$1,636,720	$1,833,410	$2,030,401
25'-0	$141,672	$172,162	$231,943	$436,224	$640,605	$842,141	$1,040,631	$1,242,367	$1,577,658	$1,883,993	$2,187,484	$2,494,320	$2,798,210	$3,102,401
50'-0	$198,572	$247,062	$344,343	$661,024	$977,805	$1,291,741	$1,602,631	$1,916,767	$2,269,658	$2,714,393	$3,156,284	$3,601,520	$4,043,810	$4,486,401
75'-0	$255,572	$325,062	$432,843	$838,024	$1,243,305	$1,645,741	$2,045,131	$2,447,767	$2,901,658	$3,472,793	$4,041,084	$4,612,720	$5,181,410	$5,750,401
100'-0	$336,472	$403,062	$521,143	$1,014,624	$1,508,205	$1,998,941	$2,486,631	$2,977,567	$3,503,658	$4,195,193	$4,883,884	$5,575,920	$6,265,010	$6,954,401

Table 2-13
Total Capital Costs for Scenario C - Adding Fine Mesh with Fish Handling and Return
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10'-0	$188,872	$222,462	$287,543	$547,424	$807,405	$1,064,541	$1,318,631	$1,575,967	$1,854,158	$2,215,793	$2,574,584	$2,936,720	$3,295,910	$3,655,401
25'-0	$239,172	$289,062	$391,443	$755,224	$1,119,105	$1,480,141	$1,838,131	$2,199,367	$2,863,658	$3,427,193	$3,987,884	$4,551,920	$5,113,010	$5,674,401
50'-0	$345,472	$429,862	$605,743	$1,183,824	$1,762,005	$2,337,341	$2,909,631	$3,485,167	$4,185,158	$5,012,993	$5,837,984	$6,666,320	$7,491,710	$8,317,401
75'-0	$451,972	$576,862	$772,243	$1,516,824	$2,261,505	$3,003,341	$3,742,131	$4,484,167	$5,386,658	$6,454,793	$7,520,084	$8,588,720	$9,654,410	$10,720,401
100'-0	$606,272	$723,862	$938,343	$1,849,024	$2,759,805	$3,667,741	$4,572,631	$5,480,767	$6,528,158	$7,824,593	$9,118,184	$10,415,120	$11,709,110	$13,003,401

Table 2-21
Baseline O&M Costs for Traveling Screens Without Fish Handling
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$5,419	$8,103	$10,223	$20,445	$30,668	$40,891	$51,113	$61,336	$62,805	$75,367	$87,928	$100,489	$113,050	$125,611
25	$6,433	$9,499	$11,880	$23,760	$35,640	$47,520	$59,400	$71,280	$75,667	$90,800	$105,933	$121,067	$136,200	$151,333
50	$7,591	$11,483	$14,741	$29,482	$44,223	$58,964	$73,705	$88,446	$89,781	$107,737	$125,693	$143,650	$161,606	$179,562
75	$8,786	$13,687	$16,865	$33,729	$50,594	$67,458	$84,323	$101,187	$101,216	$121,459	$141,702	$161,946	$182,189	$202,432
100	$10,597	$15,833	$18,985	$37,970	$56,956	$75,941	$94,926	$113,911	$112,279	$134,735	$157,191	$179,647	$202,103	$224,558

Table 2-22
Baseline O&M Costs for Traveling Screens Without Fish Handling
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 f	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$6,400	$9,247	$11,694	$23,388	$35,083	$46,777	$58,471	$70,165	$73,433	$88,120	$102,806	$117,493	$132,179	$146,866
25	$7,577	$10,971	$13,842	$27,684	$41,526	$55,368	$69,210	$83,052	$92,834	$111,401	$129,968	$148,535	$167,101	$185,668
50	$9,389	$13,772	$18,175	$36,349	$54,524	$72,698	$90,873	$109,047	$113,498	$136,186	$158,884	$181,582	$204,279	$226,977
75	$11,238	$16,957	$21,116	$42,231	$63,347	$84,462	$105,578	$126,693	$129,829	$155,794	$181,760	$207,726	$233,691	$259,657
100	$14,357	$20,084	$24,054	$48,107	$72,161	$96,215	$120,269	$144,322	$144,979	$173,975	$202,971	$231,967	$260,963	$289,958

Table 2-23
Baseline & Scenario B Compliance O&M Totals for Traveling Screens With Fish Handling
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$15,391	$24,551	$35,231	$70,462	$105,693	$140,924	$176,155	$211,386	$230,185	$276,221	$322,258	$368,295	$414,332	$460,369
25	$18,333	$28,378	$40,504	$81,009	$121,513	$162,018	$202,522	$243,027	$271,971	$326,365	$380,759	$435,154	$489,548	$543,942
50	$22,295	$34,696	$49,853	$99,707	$149,560	$199,413	$249,267	$299,120	$328,293	$393,952	$459,611	$525,269	$590,928	$656,587
75	$26,441	$41,449	$57,499	$114,998	$172,498	$229,997	$287,496	$344,995	$376,302	$451,563	$526,823	$602,084	$677,344	$752,605
100	$31,712	$47,927	$65,126	$130,251	$195,377	$260,503	$325,628	$390,754	$424,831	$509,797	$594,763	$679,729	$764,695	$849,661

Table 2-24
Baseline & Scenario B Compliance O&M Totals for Traveling Screens With Fish Handling
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$19,543	$29,357	$41,381	$82,762	$124,143	$165,524	$206,905	$248,286	$274,495	$329,393	$384,292	$439,191	$494,090	$548,989
25	$23,649	$34,756	$49,204	$98,409	$147,613	$196,818	$246,022	$295,227	$342,111	$410,533	$478,955	$547,378	$615,800	$684,222
50	$30,305	$44,668	$64,109	$128,219	$192,328	$256,437	$320,547	$384,656	$432,783	$519,340	$605,897	$692,453	$779,010	$865,567
75	$37,151	$55,183	$76,009	$152,018	$228,028	$304,037	$380,046	$456,055	$511,842	$614,211	$716,579	$818,948	$921,316	$1,023,685
100	$46,430	$65,423	$87,884	$175,767	$263,651	$351,535	$439,418	$527,302	$589,801	$707,761	$825,721	$943,681	$1,061,641	$1,179,601

Table 2-25
Scenario A & C Compliance O&M Totals for Traveling Screens With Fish Handling
Freshwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$17,529	$26,688	$38,437	$76,874	$115,311	$153,747	$192,184	$230,621	$246,214	$295,456	$344,699	$393,942	$443,184	$492,427
25	$22,936	$32,982	$47,409	$94,819	$142,228	$189,637	$237,046	$284,456	$306,495	$367,794	$429,093	$490,392	$551,691	$612,990
50	$31,008	$43,409	$62,923	$125,846	$188,769	$251,693	$314,616	$377,539	$393,642	$472,371	$551,099	$629,828	$708,556	$787,285
75	$39,264	$54,272	$76,734	$153,468	$230,202	$306,936	$383,670	$460,404	$472,476	$566,972	$661,467	$755,962	$850,458	$944,953
100	$48,645	$64,861	$90,525	$181,051	$271,576	$362,102	$452,627	$543,153	$551,830	$662,195	$772,561	$882,927	$993,293	$1,103,659

Table 2-26
Scenario A & C Compliance O&M Totals for Traveling Screens With Fish Handling
Saltwater Environments

Total Width	2	5	10	20	30	40	50	60	70	84	98	112	126	140
Well Depth (Ft)	One 2 ft	One 5 ft	One 10 ft	Two 10 ft	Three 10 ft	Four 10 ft	Five 10 ft	Six 10 ft	Five 14 ft	Six 14 ft	Seven 14 ft	Eight 14 ft	Nine 14 ft	Ten 14 ft
10	$21,681	$31,494	$44,587	$89,174	$133,761	$178,347	$222,934	$267,521	$290,524	$348,628	$406,733	$464,838	$522,942	$581,047
25	$28,252	$39,360	$56,109	$112,219	$168,328	$224,437	$280,546	$336,656	$376,635	$451,962	$527,289	$602,616	$677,943	$753,270
50	$39,018	$53,381	$77,179	$154,358	$231,537	$308,717	$385,896	$463,075	$498,132	$597,759	$697,385	$797,012	$896,638	$996,265
75	$49,974	$68,006	$95,244	$190,488	$285,732	$380,976	$476,220	$571,464	$608,016	$729,620	$851,223	$972,826	$1,094,430	$1,216,033
100	$63,363	$82,357	$113,283	$226,567	$339,850	$453,134	$566,417	$679,701	$716,800	$860,159	$1,003,519	$1,146,879	$1,290,239	$1,433,599

Figure 2-1. Scenario A - Capital Cost - Add Fine Mesh Replacement Screen Panels Freshwater

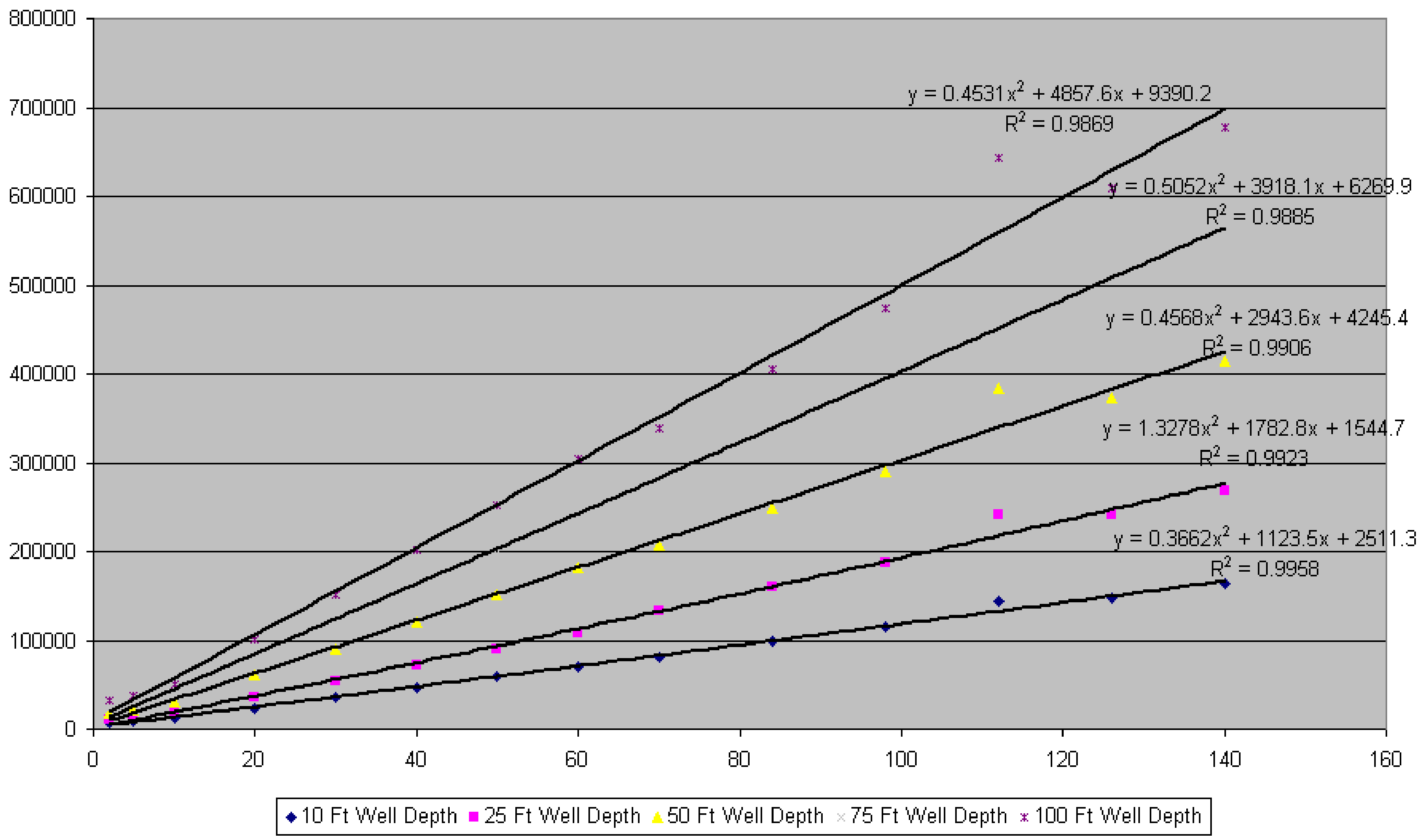
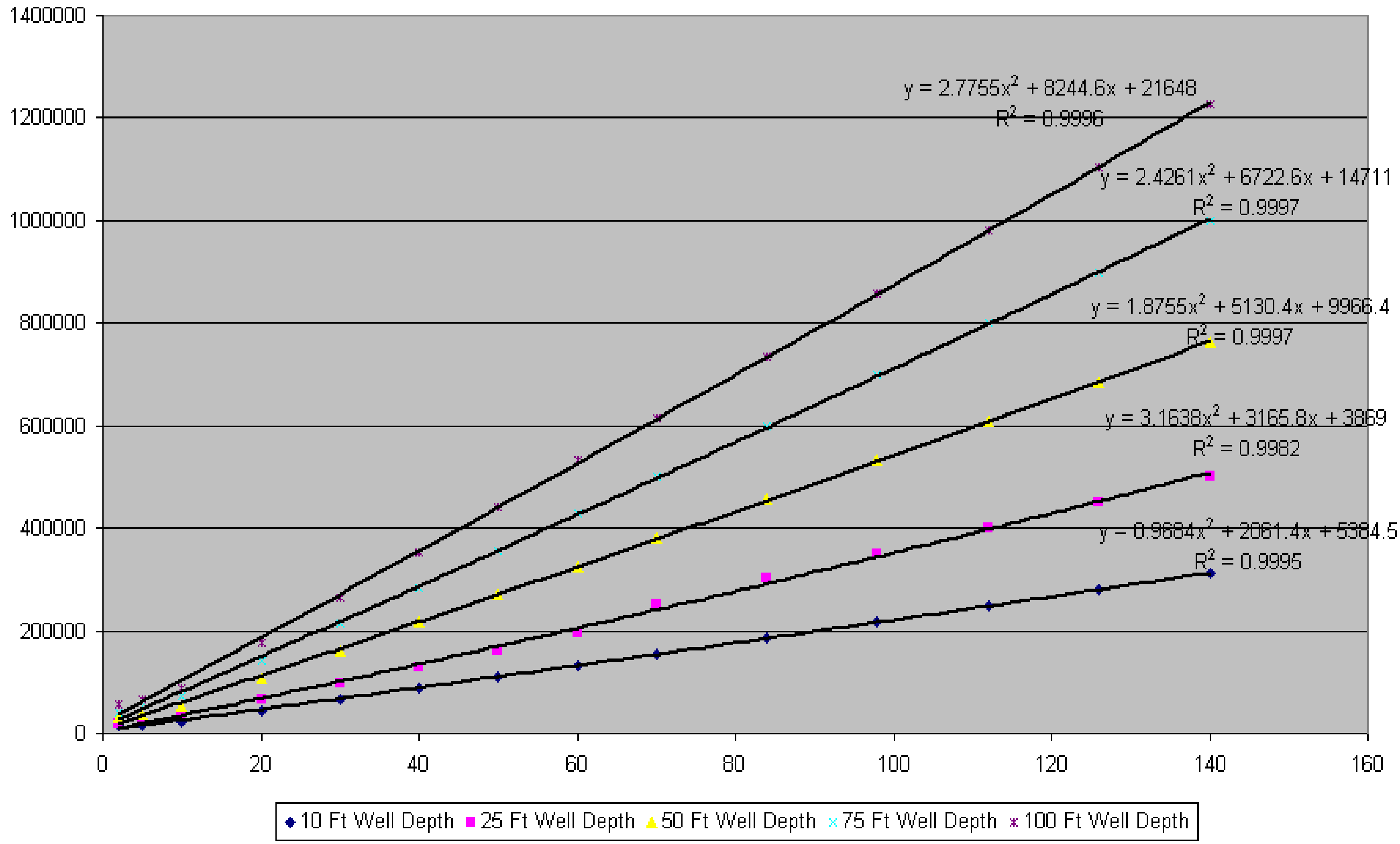


Figure 2-2. Scenario A - Capital Cost - Add Fine Mesh Replacement Screen Panels Saltwater



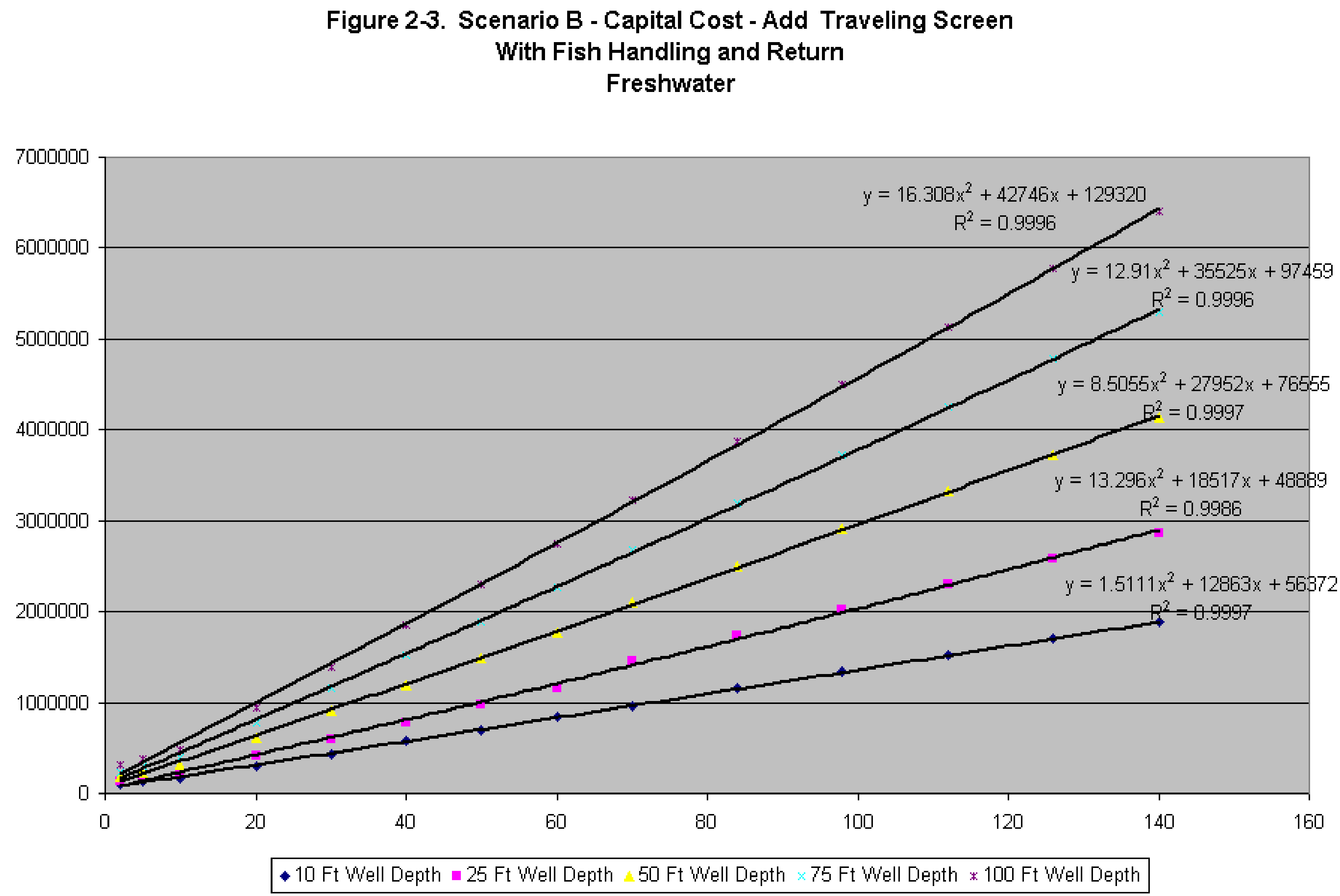


Figure 2-3. Scenario B - Capital Cost - Add Traveling Screen
With Fish Handling and Return
Freshwater
y = 16.308x2 + 42746x + 129320
R2 = 0.9996
y = 12.91x2 + 35525x + 97459
R2 = 0.9996
y = 8.5055x2 + 27952x + 76555
R2 = 0.9997
y = 13.296x2 + 18517x + 48889
R2 = 0.9986
y = 1.5111x2 + 12863x + 56372
R2 = 0.9997
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
0
20
40
60
80
100
120
140
160
10 Ft Well Depth
25 Ft Well Depth
50 Ft Well Depth
75 Ft Well Depth
100 Ft Well Depth

Figure 2-4. Scenario B - Capital Cost - Add Traveling Screen With Fish Handling and Return Saltwater

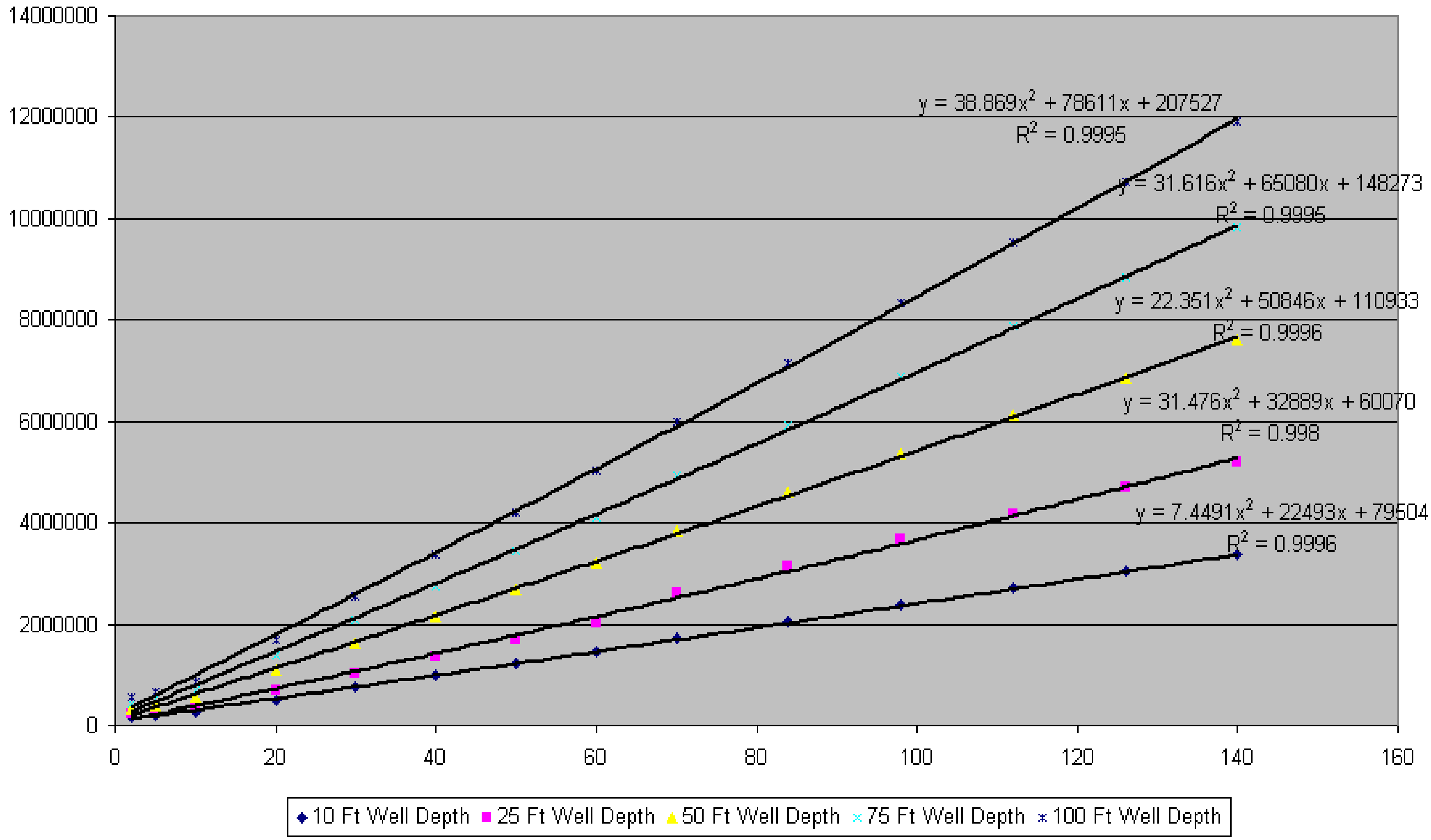
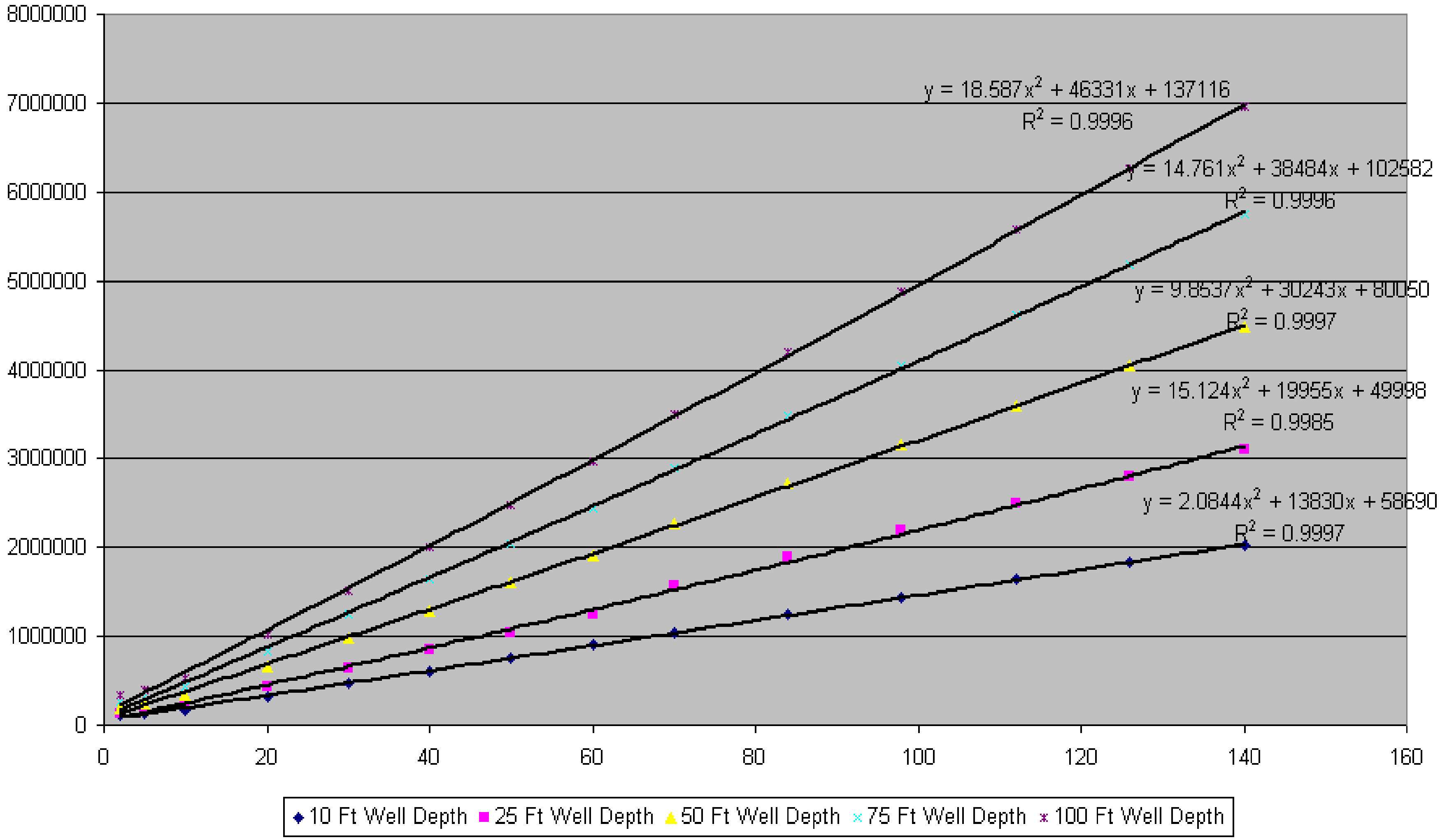


Figure 2-5. Scenario C - Capital Cost - Add Fine Mesh Traveling Screen With Fish Handling and Return Freshwater



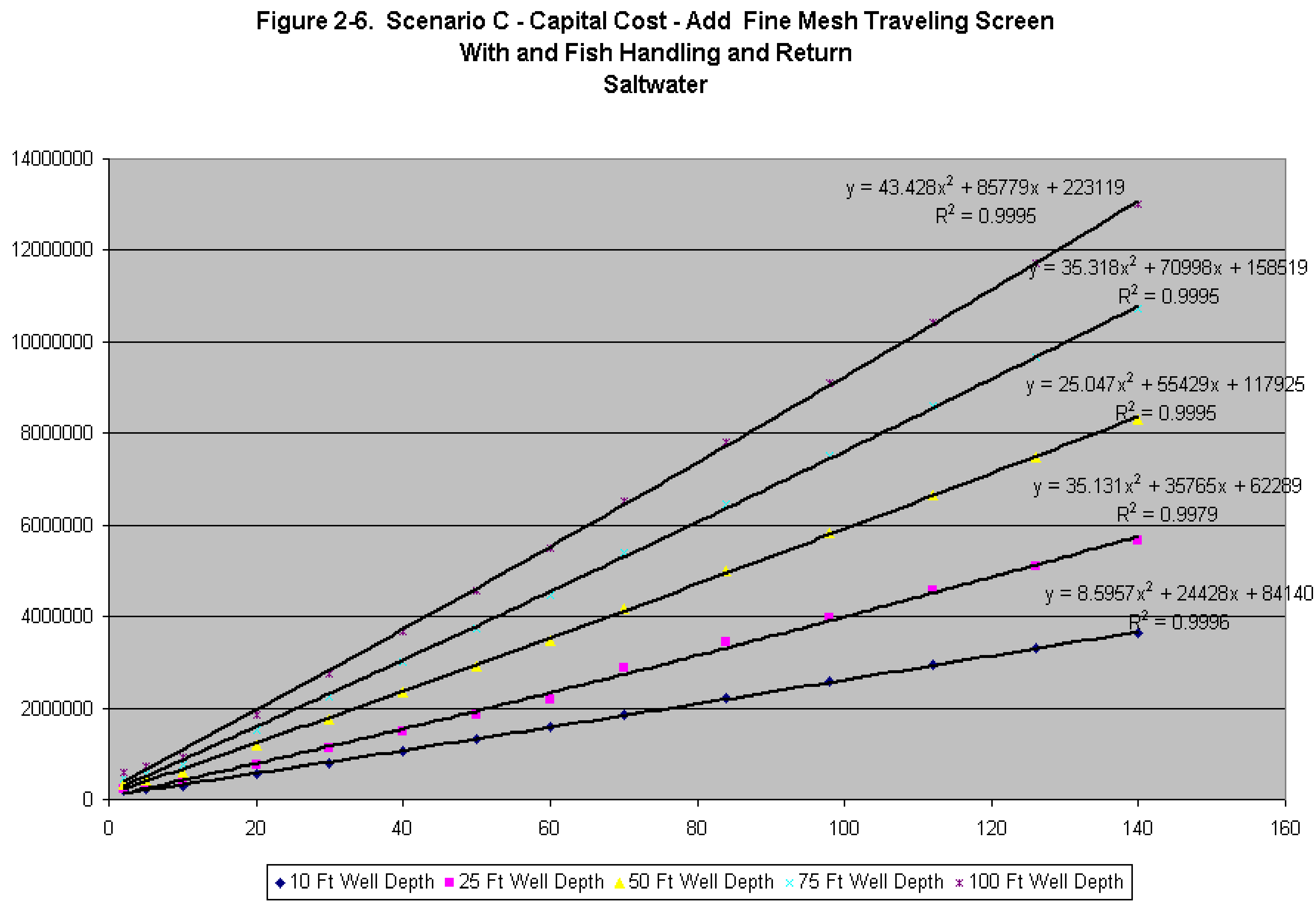


Figure 2-6. Scenario C - Capital Cost - Add Fine Mesh Traveling Screen
With and Fish Handling and Return
Saltwater
y = 43.428x2 + 85779x + 223119
R2 = 0.9995
y = 35.318x2 + 70998x + 158519
R2 = 0.9995
y = 25.047x2 + 55429x + 117925
R2 = 0.9995
y = 35.131x2 + 35765x + 62289
R2 = 0.9979
y = 8.5957x2 + 24428x + 84140
R2 = 0.9996
14000000
12000000
10000000
8000000
6000000
4000000
2000000
0
0
20
40
60
80
100
120
140
160
10 Ft Well Depth
25 Ft Well Depth
50 Ft Well Depth
75 Ft Well Depth
100 Ft Well Depth

Figure 2-7. Baseline O&M Costs For Traveling Screens Without Fish Handling Freshwater Environments

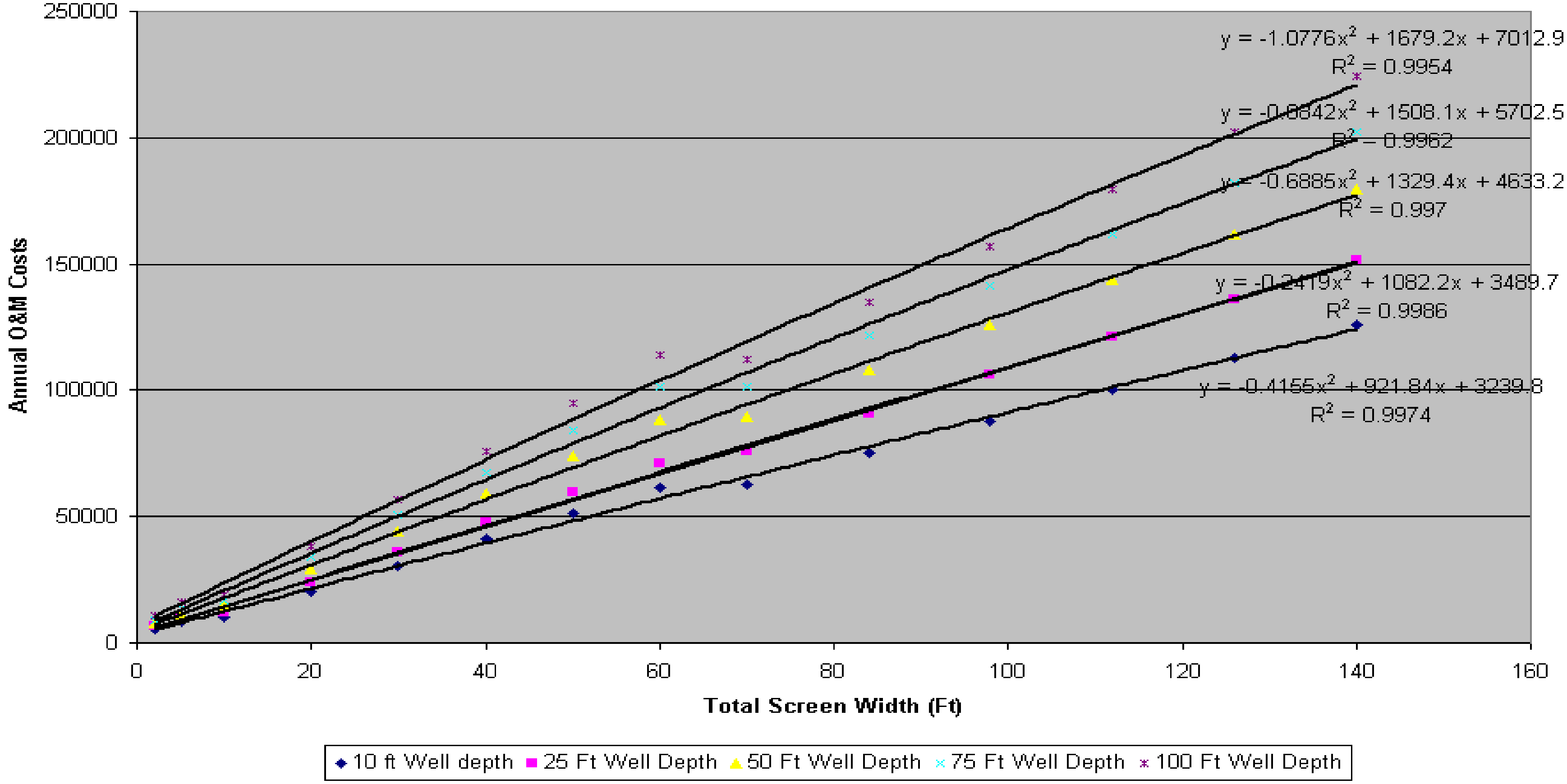


Figure 2-8. Baseline O&M Costs For Traveling Screens Without Fish Handling Saltwater Environments

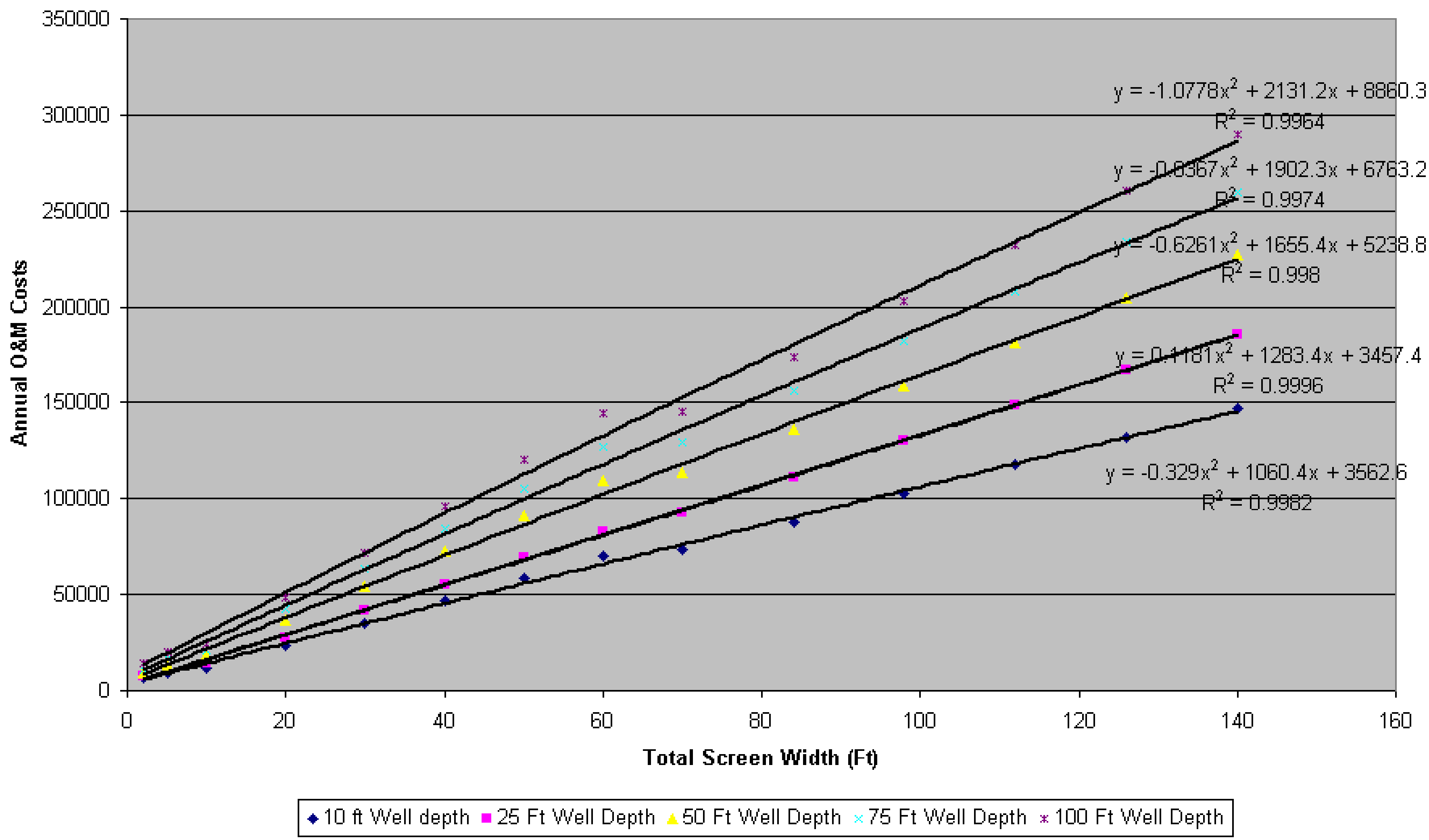


Figure 2-9. Scenarios A & C Compliance O&M Total Costs For Traveling Screens With Fish Handling Freshwater Environments

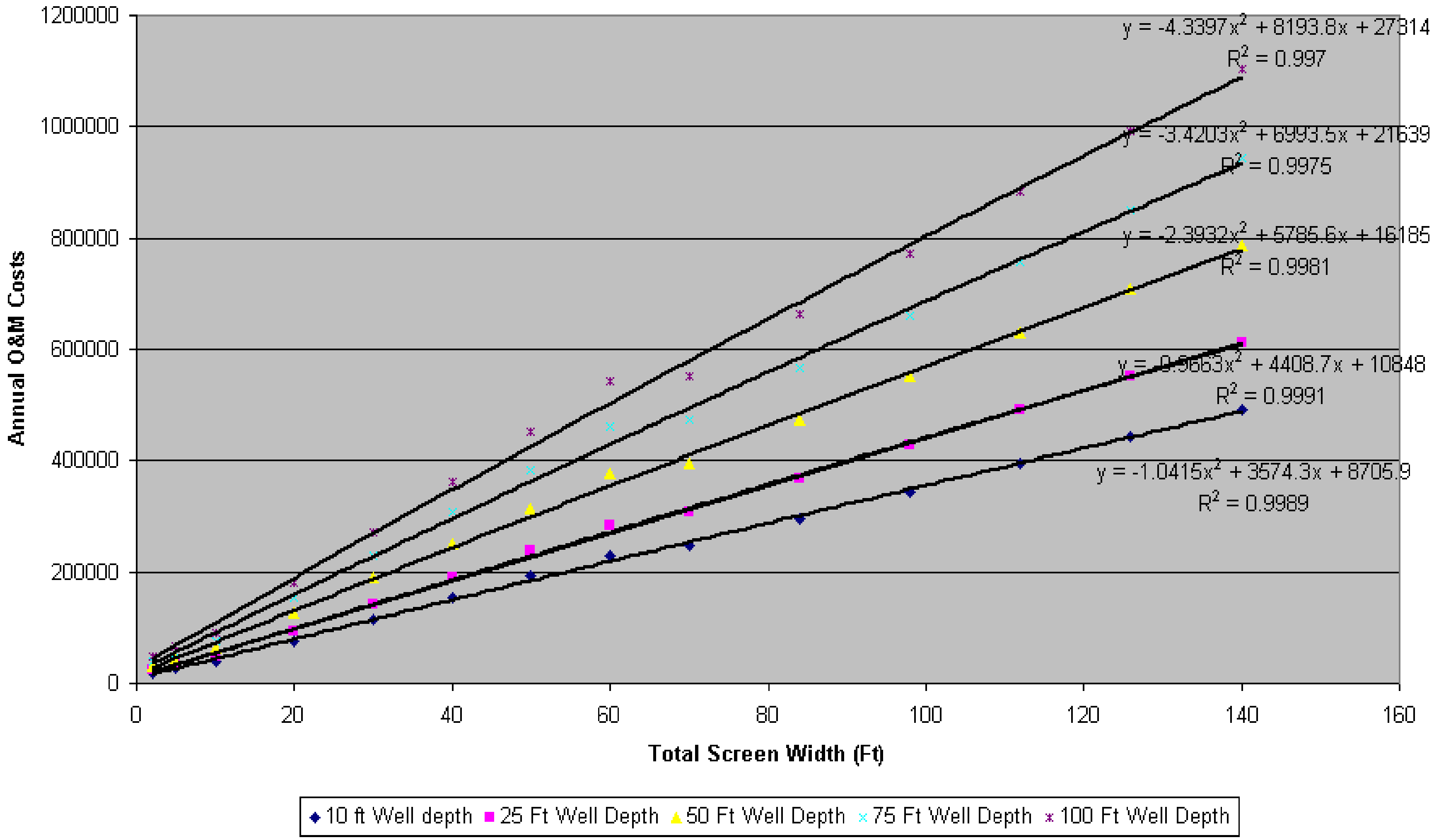


Figure 2-10. Scenarios A & C Compliance O&M Total Costs For Traveling Screens With Fish Handling Saltwater Environments

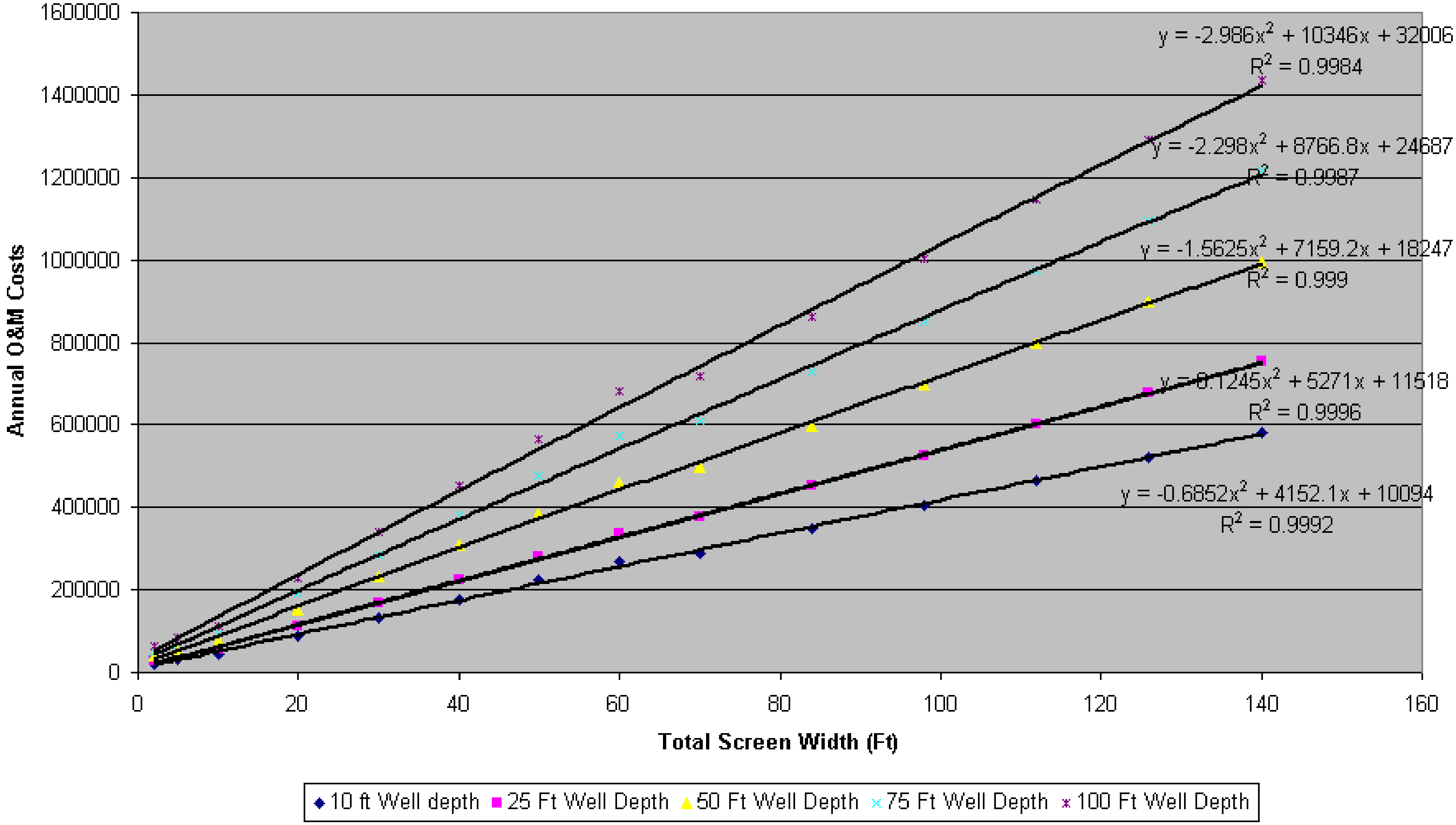


Figure 2-11. Baseline & Scenario B Compliance O&M Total Costs For Traveling Screens With Fish Handling Freshwater Environments

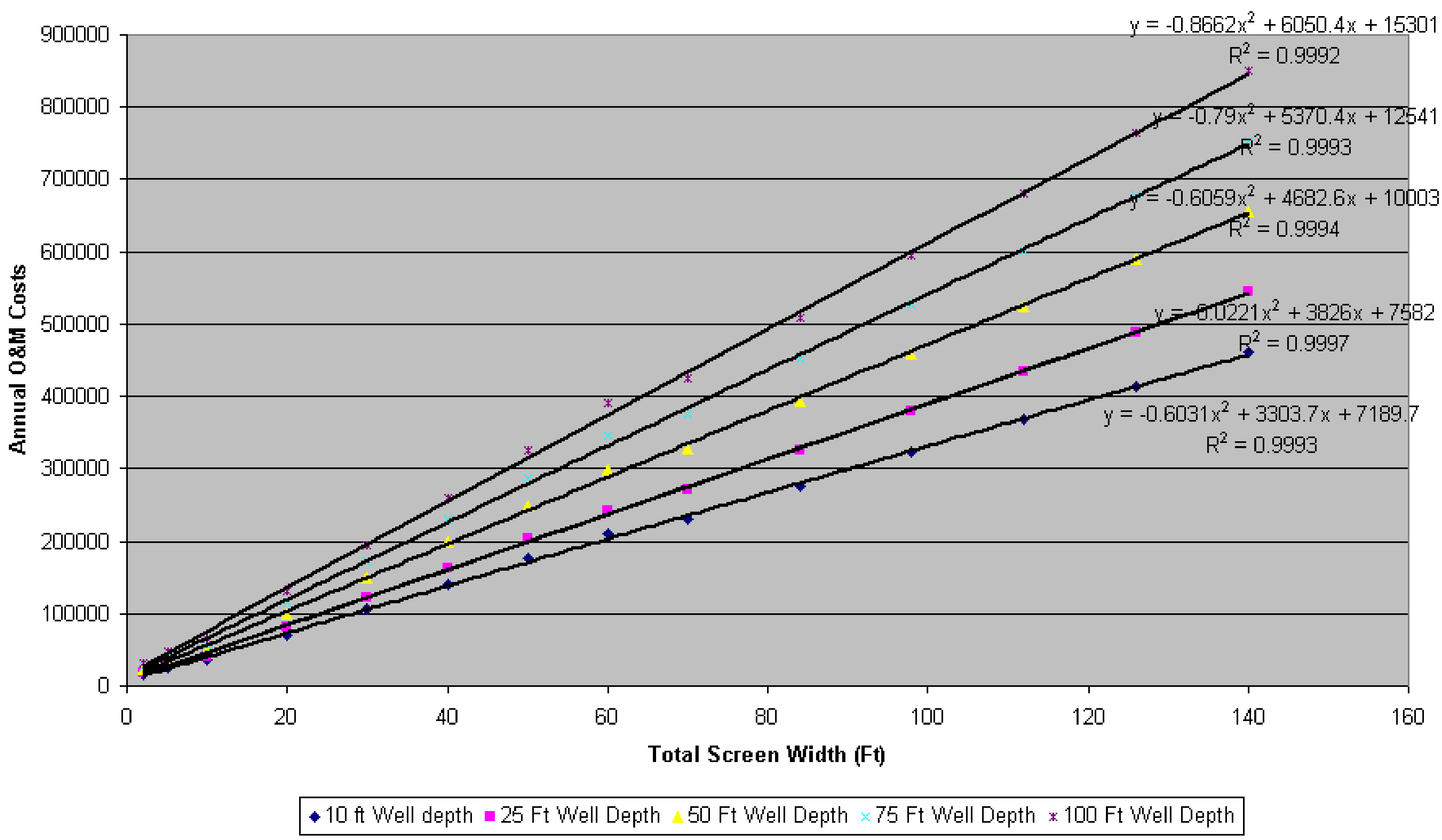


Figure 2-12. Baseline & Scenario B Compliance O&M Total Costs For Traveling Screens With Fish Handling Saltwater Environments

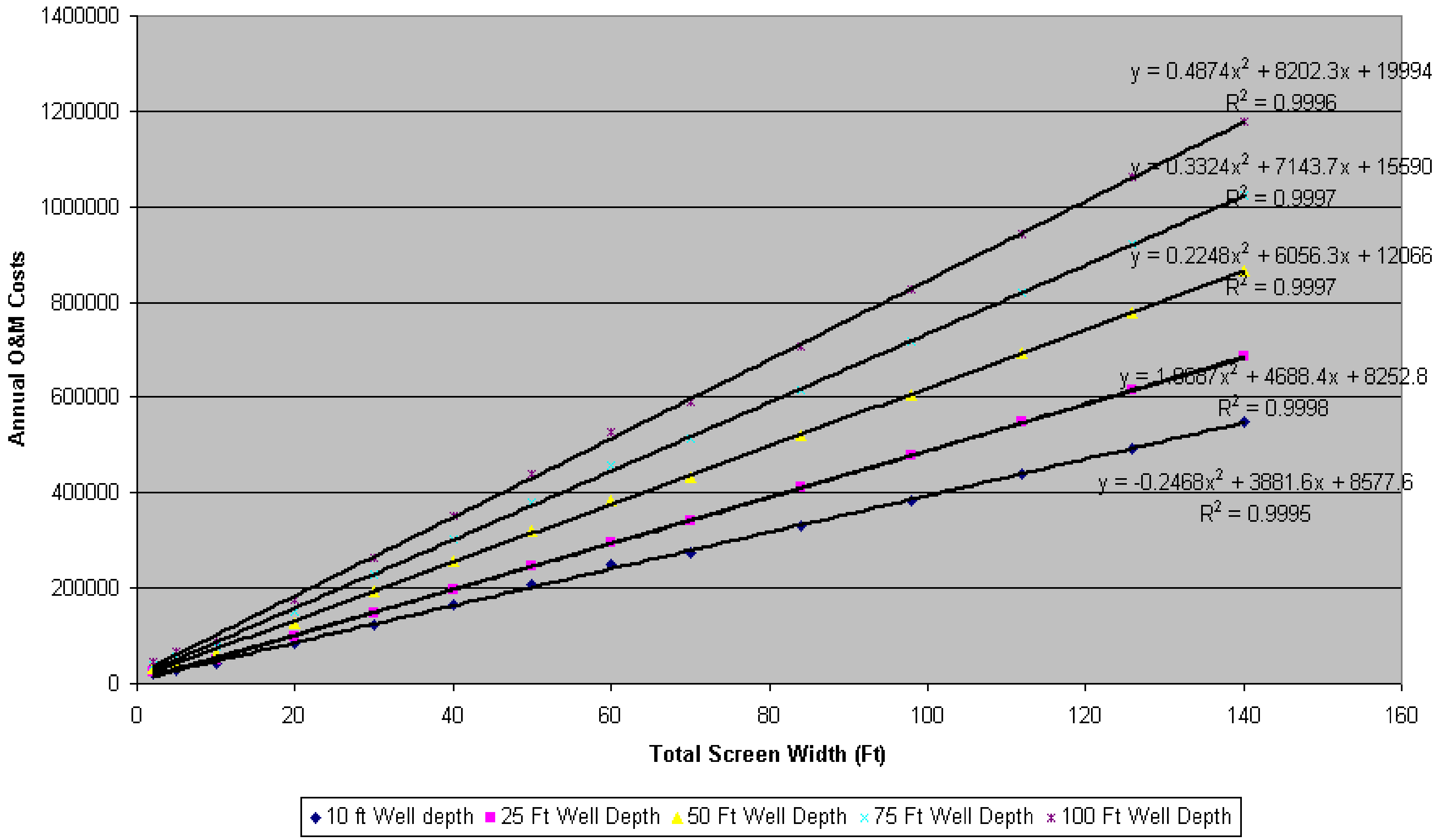
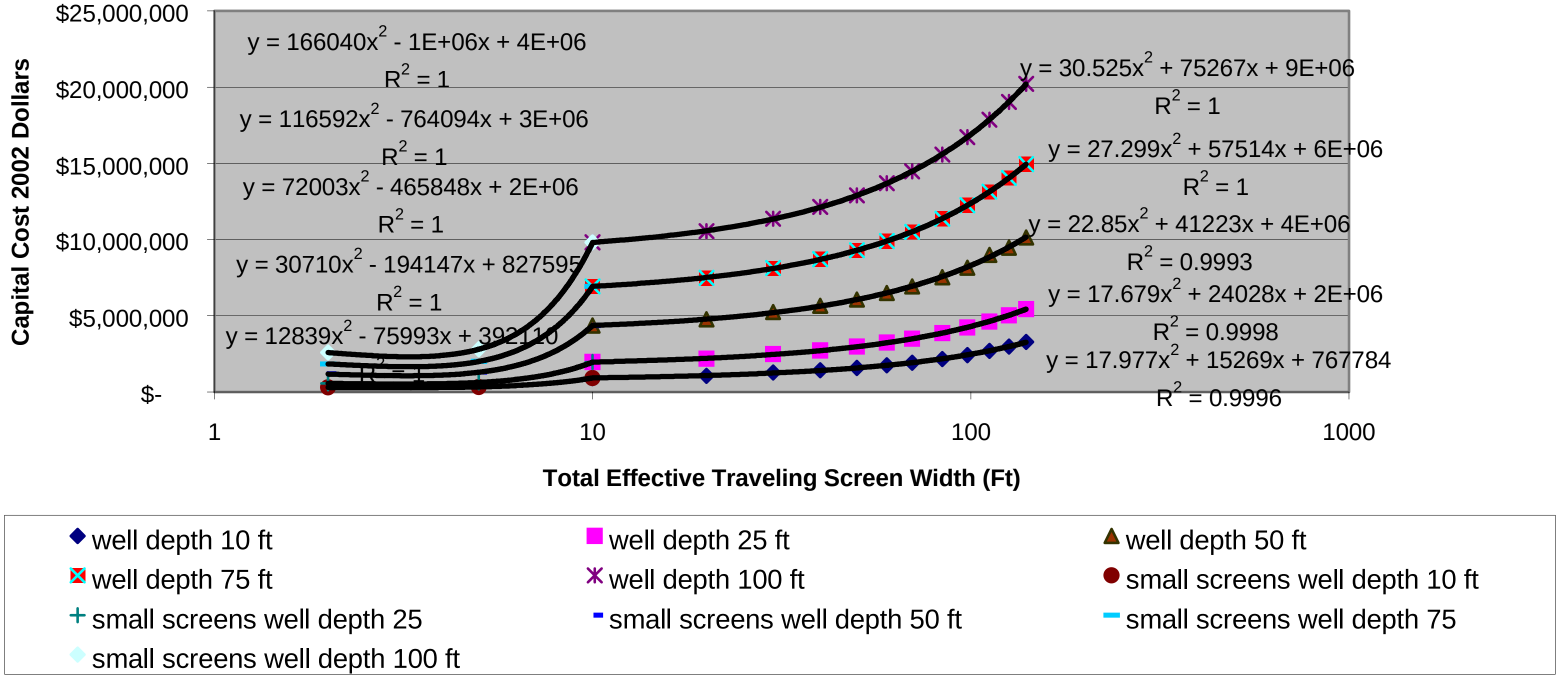


Figure 2-13
Total Capital Costs of New Larger Intake Structure



3.0 EXISTING SUBMERGED OFFSHORE INTAKES - ADD VELOCITY CAPS

Velocity caps are applicable to submerged offshore intakes. Adding velocity caps to facilities with existing or new submerged offshore intakes can provide appreciable impingement reduction. Therefore, this module may be most applicable when the compliance option only requires impingement controls and the intake requires upgrading. However depending on site-specific conditions, velocity caps could conceivably be used in conjunction with onshore screening systems tailored for entrainment reduction.

Research on velocity cap vendors identified only one vendor, which is located in Canada. (A possible reason for this scarcity in vendors is that many velocity caps are designed and fabricated on a site-specific basis, often called "intake cribs".) This vendor manufactures a velocity cap called the "Invisihead," and was contacted for cost information (Elarbash 2002a and 2002b). The Invisihead is designed with a final entrance velocity of 0.3 fps and has a curved cross-section that gradually increases the velocity as water is drawn farther into the head. The manufacturer states the gradual increase in velocity though the velocity cap minimizes entrainment of sediment and suspended matter and minimizes inlet pressure losses (Elmosa 2002). All costs presented below are in July 2002 dollars.

3.1 CAPITAL COSTS

The vendor provided information for estimating retrofit costs for velocity caps manufactured both from carbon steel and from stainless steel. Stainless steel construction is recommended for saltwater conditions to minimize corrosion. Carbon steel is recommended for freshwater systems. Due to the rather large opening, Invisihead performance is not affected by the attachment of Zebra mussels, so no special materials of construction are required where Zebra mussels are present.

Installation costs include the cost for a support vessel and divers to cut, weld and/or bolt the fitting flange for the velocity cap; make any needed minor reinforcements of the existing intake; and install the cap itself. Installation was said to take between two and seven days, depending on the size and number of heads in addition to the retrofit steps listed above. Costs also include mobilization and demobilization of the installation personnel, barge, and crane. The vendor indicated these costs included engineering and contractor overhead and profit, but did not provide break-outs or percentages for these cost components. EPA has concluded that the installation costs for adding a velocity cap on a new intake (relocated offshore) and on an existing offshore intake should be similar because most of the costs involve similar personnel and equipment. (See the "Application" section below for a discussion of new/existing submerged offshore intake cost components.)

Table 3-1 presents the component (material, installation, and mobilization/demobilization) and total capital costs for stainless steel and carbon steel velocity caps provided by the vendor (Elarbash 2002a and 2002b) . Data are presented for flows ranging from 5,000 gpm to 350,000 gpm. Figure 3-1 presents a plot of these data. The upper end of this flow range covers existing submerged pipes up to 15 feet in diameter at pipe velocities of approximately 5 fps. Second-order polynomial equations provided the best fit to the data and were used to produce cost curves. These cost curves serve as the basis for estimating capital costs for installing velocity caps on existing or new intakes submerged offshore at Phase II facilities. When applying these cost curves, if the intake flow exceeds 350,000 gpm plus 10% (385,000 gpm), the flow is divided into equal increments and these lower flows costed. The costs for these individual incremental flows are summed to estimate total capital cost. In these cases, costs are assumed to be applied to multiple intake pipes. If the intake flow is less than 5,000 gpm, the capital cost for 5,000 gpm will be used rather than extrapolating beyond the bottom end of the cost curve.

3.2 O&M COSTS

For velocity caps, O&M costs generally include routine inspection and cleaning of the intake head. As noted above, biofouling does not affect velocity cap performance, so rigorous cleaning is not necessary. The vendor stated that their equipment is relatively maintenance free. However, O&M costs based on an annual inspection and cleaning of offshore intakes by divers were cited by facilities with existing offshore intakes, including some with velocity caps and especially those with bar racks at the intake. Therefore, estimated O&M costs are presented for an annual inspection and cleaning by divers because EPA believes this is common practice for submerged offshore intakes of all types.

Table 3-2 presents the component and total O&M costs for the diver inspection and cleaning, for one to four days (Paroby 1999). In general, O&M costs are based on less than one day per head for inspection and cleaning of smaller intake heads and one day per head for the largest intake head. There is a minimum of one day for each inspection event. Inspection and cleaning events are assumed to occur once per year. Figure 3-2 presents the plot of the O&M costs by flow. A second-order polynomial equation provided the best fit to this data and serves as the basis for estimating the O&M costs.

Figure 3-2 also shows data for two facilities that reported actual O&M costs based on diver inspection and cleaning of submerged offshore intakes. While these two facilities use different intake technologies (passive screens for the smaller flow and bar rack type intakes for the larger flow), the inspection and cleaning effort should be similar for all three types of intakes. For both facilities, the actual reported O&M costs were less than the costs estimated using the cost curves, indicating that the estimated O&M costs should be considered as high-side estimates.

3.3 APPLICATION

As Retrofit of Existing Offshore Intake

Adding velocity caps to facilities with existing offshore intakes will provide impingement reduction only. For facilities withdrawing from saltwater/brackish waters (ocean and estuarine/tidal rivers), the capital cost curve for stainless steel caps will be applied. For the remaining facilities withdrawing freshwater (freshwater rivers/streams, reservoirs/lakes, Great Lakes), the capital cost curve for carbon steel caps will be applied. The same O&M cost curve will be used for both freshwater and saltwater systems. It is assumed that the existing intake is in a location that will provide sufficient clearance and is away from damaging wave action.

As Component of Relocating Existing Shoreline Intake to Submerged Offshore

These same velocity cap retrofit costs can be incorporated into retrofits where an existing shoreline intake is relocated to submerged offshore. In this application, some of the same equipment and personnel used in velocity cap installation may also be used to install other intake components, such as the pipe. Therefore, the mobilization/demobilization component could be reduced if these tasks are determined to occur close together in time. However, a high-side costing approach would be to cost each step separately, using the same velocity cap costs for both new and existing offshore intake pipes. In this case, the installation costs for velocity caps at existing offshore intakes (which include costs for cutting, and welding and/or bolting the velocity cap in place) are assumed to also cover costs of installing connection flanges at new offshore intakes. Costs for other components of relocating existing shoreline intakes to submerged offshore are developed as a separate cost module associated with passive screens. The compliance cost estimates did not include this scenario.

REFERENCES

Elarbash, M. Elmosa Canada. email correspondence with John Sunda, SAIC concerning cost and technical data for Invisihead velocity caps. August 9, 2002a

Elarbash, M. Elmosa Canada. email correspondence with John Sunda, SAIC concerning cost and technical data for Invisihead velocity caps. August 19, 2002b

Elmosa. Website at http://www.imasar.com/elmosa/invisiheaddetails.htm accessed May 9, 2002.

Paroby, Rich. Personal communication between Rich Paroby, District Sales Manager, Water Process Group and Deborah Nagle, USEPA E-mail dated May 12, 1999.

Table 3-1

Velocity Cap Retrofit Capital and O&M Costs (2002 $)

Flow (gpm)	# Heads	Material Costs - Stainless Steel /Head	Material Costs - Stainless Steel Total	Material Costs - Carbon Steel /Head	Material Costs - Carbon Steel Total	Installation	Mobilization/ Demobilization	Total Capital Costs - Stainless Steel	Total Capital Costs - Carbon Steel	Total O&M
Water Type	All	Saltwater	Saltwater	Freshwater	Freshwater	All	All	Saltwater	Freshwater	All
5,000	1	$30,000	$30,000	$22,500	$22,500	$25,000	$10,000	$65,000	$57,500	$5,260
10,000	1	$30,000	$30,000	$22,500	$22,500	$30,000	$15,000	$75,000	$67,500	$5,260
25,000	1	$40,000	$40,000	$30,000	$30,000	$35,000	$15,000	$90,000	$80,000	$5,260
50,000	2	$35,000	$70,000	$26,250	$52,500	$49,000	$25,000	$144,000	$126,500	$7,250
100,000	2	$80,000	$160,000	$60,000	$120,000	$49,000	$25,000	$234,000	$194,000	$7,250
200,000	4	$80,000	$320,000	$60,000	$240,000	$98,000	$30,000	$448,000	$368,000	$11,230
350,000	4	$106,000	$424,000	$79,500	$318,000	$98,000	$30,000	$552,000	$446,000	$11,230

Note: Vendor indicated installation took 2 to 7 days

Note: Installation includes retrofit activities such as cutting pipe and & attaching connection flange on intake inlet pipe.

Table 3-2

Installation and Maintenance Diver Team Costs

Item	Daily Cost*	One Time Cost*	Total	Adjusted Total			
Duration			One Day	One Day	Two Day	Three Day	Four Day
Cost Year			1999	2002	2002	2002	2002
Supervisor	$575		$575	$627	$1,254	$1,880	$2,507
Tender	$200		$200	$218	$436	$654	$872
Diver	$375		$750	$818	$1,635	$2,453	$3,270
Air Packs	$100		$100	$109	$218	$327	$436
Boat	$200		$200	$218	$436	$654	$872
Mob/Demob		$3,000	$3,000	$3,270	$3,270	$3,270	$3,270
Total			$4,825	$5,260	$7,250	$9,240	$11,230

***Source: Paroby 1999 (cost adjusted to 2002 dollars).**

Figure 3-1

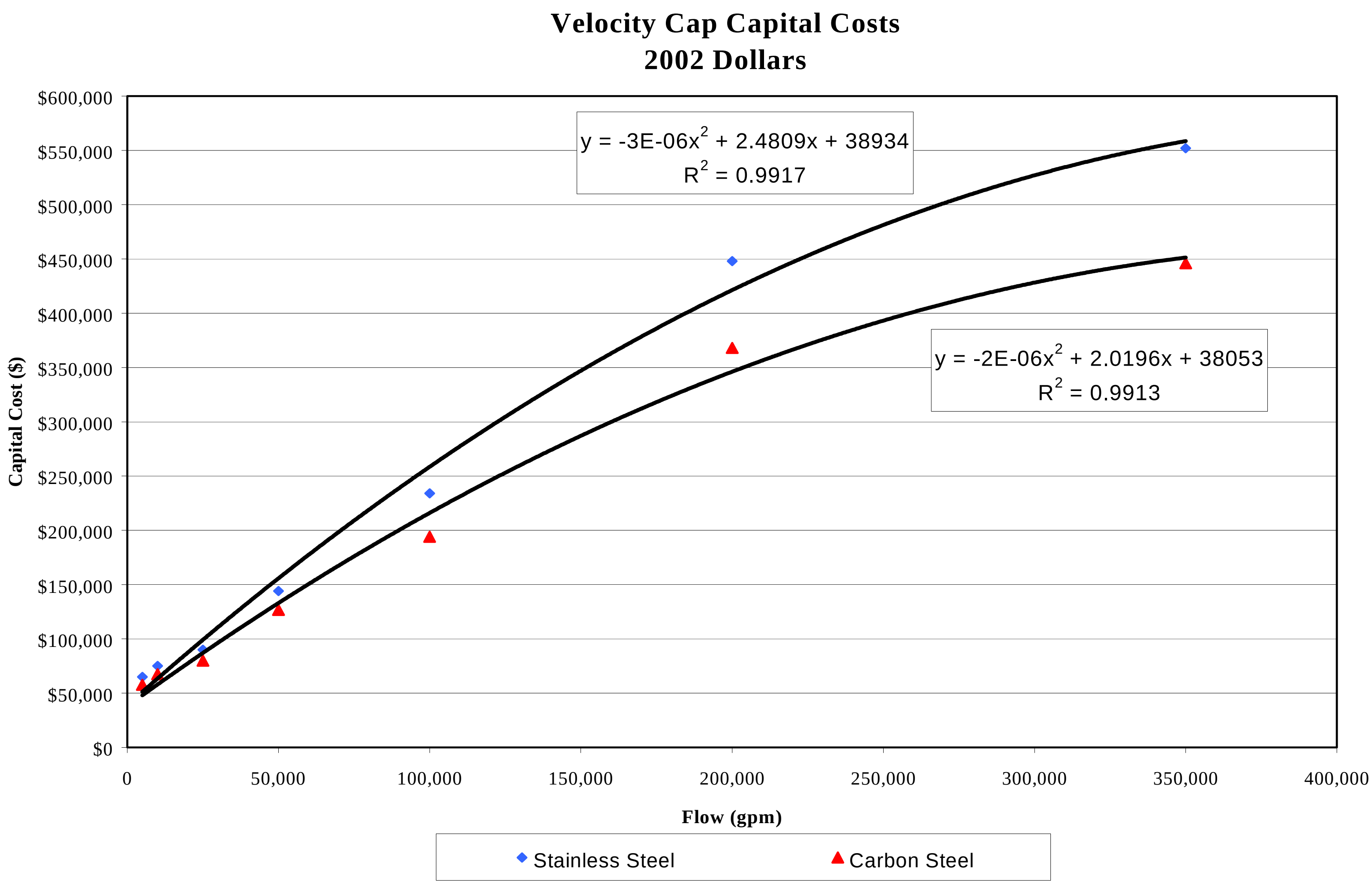
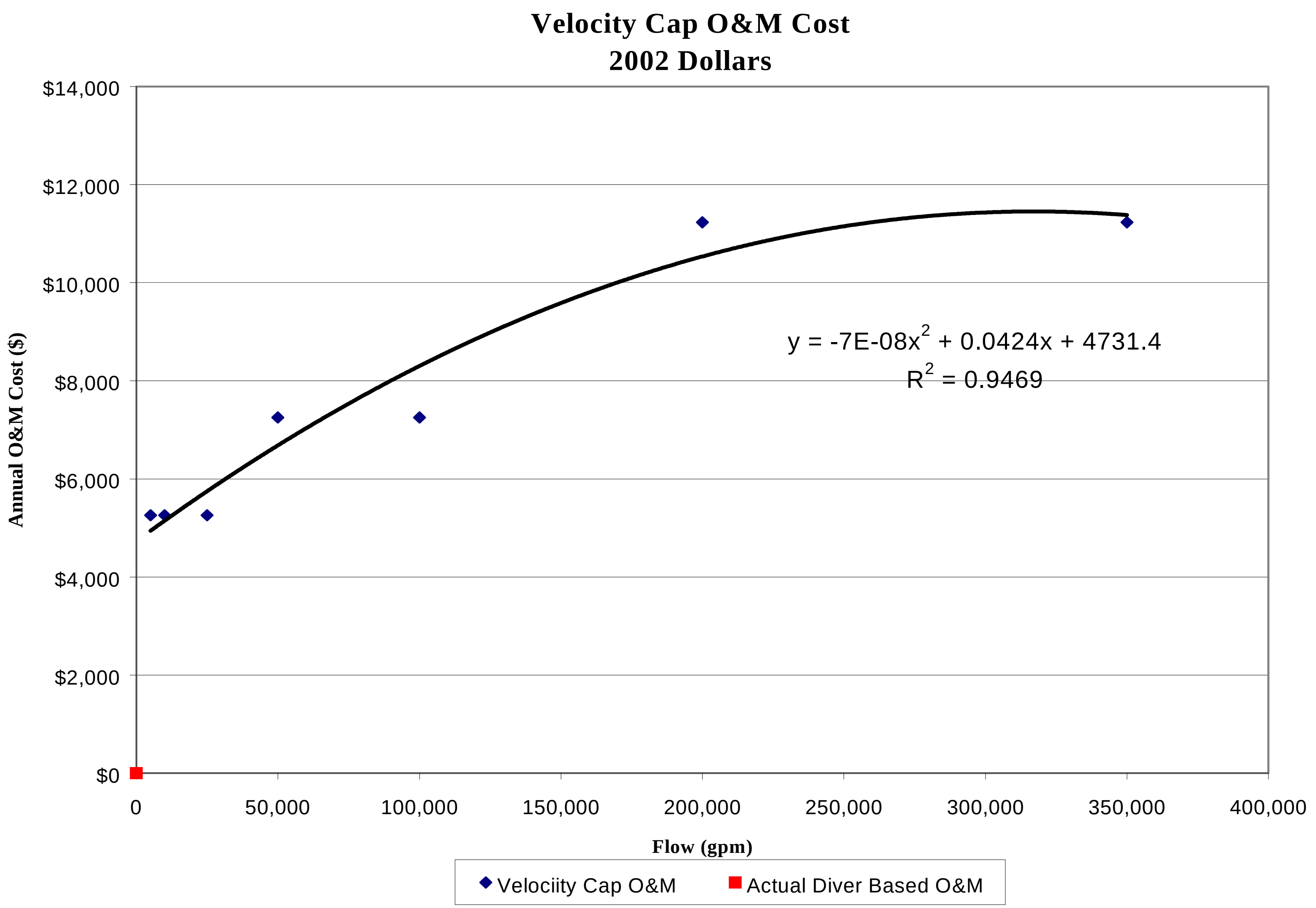

Velocity Cap Capital Costs
2002 Dollars
y = -3E-06x2 + 2.4809x + 38934
R2 = 0.9917
y = -2E-06x2 + 2.0196x + 38053
R2 = 0.9913
Capital Cost ($)
$600,000
$550,000
$500,000
$450,000
$400,000
$350,000
$300,000
$250,000
$200,000
$150,000
$100,000
$50,000
$0
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Flow (gpm)
Stainless Steel
Carbon Steel

Figure 3-2


Velocity Cap O&M Cost
2002 Dollars
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
Annual O&M Cost ($)
0
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
Flow (gpm)
y = -7E-08x2 + 0.0424x + 4731.4
R2 = 0.9469
Velociity Cap O&M
Actual Diver Based O&M

4.0 FISH BARRIER NETS

Fish barrier net can be used where improvements to impingement performance is needed. Because barrier nets can be installed independently of intake structures, there is no need to include any costs for modifications to the existing intake or technology employed. Costs are assumed to be the same for both new and existing facilities. Barrier nets can be installed while the facility is operating. Thus, there is no need to coordinate barrier net installation with generating unit downtime .

Fish Barrier Net Questionnaire

EPA identified seven facilities from its database that employed fish barrier nets and sent them a brief questionnaire requesting barrier net design and cost data (EPA 2002). The following four facilities received but did not submit a response:

Bethlehem Steel - Sparrows Point
Consumers Energy Co. - J.R. Whiting Plant
Exelon Corp. (formerly Commonwealth Edison) - LaSalle County Station
Southern Energy - Bowline Generating Station

The following three facilities submitted completed questionnaires:

Entergy Arkansas, Inc. - Arkansas Nuclear One
Potomac Electric Power Co. - Chalk Point
Minnesota Power - Laskin Energy Center

Net Velocity

An important design criterion for determining the size of fish barrier nets is the velocity of the water as it passes through the net. Net velocity (which is similar to the approach velocity for a traveling screen) determines how quickly debris will collect on the nets. Net velocity also determines the force exerted on the net, especially if it becomes clogged with debris. For facilities that supplied technical data, Table 4-1 presents the design intake flow (estimated by EPA) and facility data reported in the Barrier Net Questionnaire. These data include net size, average daily intake flow, and calculated net velocities based on average and design flows. Note that the Chalk Point net specifications used for purchasing the net, indicated a net width of 27 ft (Langley 2002) while the Net Questionnaire reported a net width of 30 ft. A net width of 27 ft was used for estimating net velocities and unit net costs The two larger facilities have similar design net velocity values that, based on design flow, is equal to 0.06 feet per second (fps). This values are roughly an order of magnitude lower than compliance velocities used for rigid screens in the Phase I Rule as well as design velocities recommended for passive screens. There are two reasons for this difference. One difference is rigid screens can withstand greater pressure differentials because they are firmly held in place. The second is rigid screens can afford to collect debris at a more rapid rate because they have an active means for removing debris collected on the surface.

Based on the data presented in Table 4-1, EPA has selected a net velocity of 0.06 fps (using the design flow) as the basis for developing compliance costs for fish barrier nets. Nets tested at a high velocity (> 1.3 fps) at a power plant in Monroe Michigan clogged and collapsed. Velocities higher than 0.06 fps may be acceptable at locations where the debris loading is low or where additional measures are taken to remove debris. While tidal locations can have significant water velocities, the periodic reversal of flow direction can help dislodge some of the debris that collects on the nets. The technology scenario described below, for tidal waterbodies, is designed to accommodate significant debris loading through the use of dual nets and frequent replacement with cleaned nets.

Table 4-1
Net Velocity Data Derived from Barrier Net Questionnaire Data

Facility Owner	Facility Name	Depth*	Length*	Area	EPA Design Flow	Net Velocity at Design Flow	Average Daily Flow*	Net Velocity at Daily Flow
		Ft	Ft	sq ft	gpm	fps	gpm	fps
PEPCO	Chalk Point	27	1000	27,000	762,500	0.06	500,000	0.04
Entergy	Arkansas Nuclear One	20	1500	30,000	805,600	0.06	593,750	0.04
Minn. Power	Laskin Energy Center	16	600	9,600	101,900	0.02	94,250	0.02

* Source: 2002 EPA Fish Barrier Net Questionnaire and Langley 2002

Mesh Size

Mesh size determines the fish species and juvenile stages that will be excluded by the net. While smaller mesh size has the ability to exclude more organisms, it will plug more quickly with debris. The Chalk Point facility tried to use 0.5-inch stretch mesh netting and found that too much debris collected on the netting; it instead uses 0.75 inch stretch (0.375 inch mesh) netting (Langley 2002). Unlike rigid screens, fish nets are much more susceptible to lateral forces which can collapse the net.

Mesh size is specified in one of two ways, either as a "bar" or "stretch" dimension. A "stretch" measurement refers to the distance between two opposing knots in the net openings when they are stretched apart. Thus, assuming a diamond shaped netting, when the netting is relaxed the distance between two opposing sides of an opening will be roughly ½ the stretch diameter. A "bar" measurement is the length of one of the four sides of the net opening and would be roughly equal to ½ the stretch measurement. The term "mesh size" as used in this document refers to either ½ the "stretch" measurement or is equal to the "bar" measurement

Table 4-2 presents reported mesh sizes from several power plant facilities that either now or in the past employed fish barrier nets. An evaluation report of the use of barrier fish nets at the Bowline Plant in New York cited that 0.374 inch mesh was more effective than 0.5 inch mesh at reducing the number of fish entering the plant intake (Hutcheson 1988). Both fish barrier net cost scenarios described below are based on nets with a mesh size of 0.375 in. (9.5 mm) and corresponds to the median mesh size of those identified by EPA.

Table 4-2
Available Barrier Net Mesh Size Data

Facility	Description	Reported Mesh Size		Type of Measurement and Source	Effective Mesh Size	
		Inch	mm		Inch	mm
Chalk Point	Inner Net	0.75	19	Stretch (1)	0.375	9.5
	Outer Net	1.25	32	Stretch (1)	0.625	15.9
Entergy Arkansas Nuclear One	Low	0.375	10	Mesh (Bar) (1)	0.375	9.5
	High (preferred)	0.5	13	Mesh (Bar) (1)	0.5	12.7
Laskin Energy		0.25	6.4	Mesh (Bar) (1)	0.25	6.4
Bowline Point	More Effective Size	0.374	9.5	Bar (3)	0.374	9.5
J.P. Pulliam		0.25	6.4	Stretch (2)	0.126	3.2
				Median	0.374	9.5

(1): 2002 EPA Fish Barrier Survey
(2):ASCE 1982
(3): Hutcheson 1988

Twine

Twine size mostly determines the strength and weight of the fish netting. Only the Chalk Point facility reported twine size data (#252) knotless nylon netting. Netting #252 is a 75-lb test braided nylon twine in which the twine joints are braided together rather than knotted (Murelle 2002). The netting used at the Bowline Power Plant was cited as multi-filament knotted nylon, chosen because of its low cost and high strength (Hutcheson 1988).

Support/Anchoring System

In general, two different types of support and anchoring systems have been identified by EPA. In the simplest system the nets are held in-place and the bottom is sealed with weights running the length of the bottom usually consisting of a chain or a lead line. The weights may be supplemented with anchors placed at intervals. Vendors indicated the requirement for anchors varies depending on the application and waterbody conditions. The nets are anchored along the shore and generally placed in a semi-circle or arc in front of the intake. The Bowline Facility net used a v-shape configuration with an anchor and buoy at the apex and additional anchors placed midway along the 91 meter length sides. In some applications anchors may not be needed at all. If the nets are moved by current or waves, they can be set back into the proper position using a boat. The nets are supported along the surface with buoys and floats. The buoys may support signs warning boaters of the presence of the net. The required spacing and size of the anchors and buoys is somewhat dependent on the size of the net and lateral water velocities. The majority of facilities investigated used this float/anchor method of installation. This net support configuration, using weights, anchors, floats, and buoys, is the basis for compliance scenario A.

A second method is to support nets between evenly spaced pilings. This method is more appropriate for water bodies with currents. The Chalk Point Power Plant uses this method in a tidal river. The Chalk Point facility uses two concentric nets. Each has a separate set of support pilings with a spacing between pilings of about 18 feet to 20 feet (Langley 2002). Nets are hung on the outside of the pilings with spikes and are weighted on the bottom with galvanized chain. During the winter top of the net is suspended below the water surface to avoid ice damage but generally thick ice does not persist during the winter months at the facility location.

Debris

Debris problems generally come in two forms. In one case large floating debris can get caught in the netting near the surface and result in tearing of the netting. In the other cases, floating and submerged debris can plug the openings in the net. This increases the hydraulic gradient across the net, resulting in net being pulled in the downstream direction. The force can become so great that it can collapse the net, and water flows over the top and/or beneath the bottom. If the net is held in place by only anchors and weights it may be moved out of place. At the Chalk Point facility, debris that catches on the nets mostly comes in the form of jellyfish and colonial hydroids (Langley 2002).
Several solutions are described for mitigating problems created by debris. At the Chalk Point Power Plant two concentric nets are deployed. The outer net has a larger mesh opening designed to capture and deflect larger debris so it does not encounter the inner net, which catches smaller debris. This configuration reduces the debris buildup on any one net extending the time period before net cleaning is required. Growth of algae and colonization with other organisms (biofouling) can also increase the drag force on the nets. Periodic removal and storage out of the water can solve this problem. At Chalk Point both nets are changed out with cleaned nets on a periodic basis. This approach is considered to be appropriate for high debris locations.

Another solution is to periodically lift the netting and manually remove debris. A solution for floating debris is to place a debris boom in front of the net (Hutcheson 1988).

Ice

During the wintertime ice can create problems in that the net can become embedded in surface ice with the net subject to tear forces when the ice breaks up or begins to move. Flowing ice can create similar problems as floating debris. Ice will also affect the ability to perform net maintenance such as debris removal. Solutions include:

- Removing the nets during winter
- Drop the upper end of the net to a submerged location; can only be used with fixed support, such as pilings and in locations where thick ice is uncommon
- Installing an air bubbler below the surface. Does not solve problems with flowing ice.

Net Deployment

EPA assumes that barrier nets will be used to augment performance of the existing shore-based intake technology such as traveling screens. The float/anchor supported nets are assumed to be deployed on a seasonal basis to reduce impingement of fish present during seasonal migration. The Arkansas Energy Arkansas Nuclear One Plant deploys their net for about 120 days during winter months. The Minnesota Power Laskin Energy Center, which is located on a lake, deploys the net when ice has broken up in spring and removes the net in the fall before ice forms. Thus, the actual deployment period will vary depending on presence of ice and seasonal migration of fish. For the compliance scenario that relies upon float/anchor supported nets, a total deployment period of eight months (240 day) is assumed. This is equal to or greater than most of the deployment periods observed by EPA.

EPA notes that the Chalk Point facility currently uses year round deployment and avoids problems with ice in the winter time by lowering the net top to a location below the surface. Prior to devising this approach, nets were remove during the winter months. This option is available because the nets are supported on pilings. Thus, the surface support rope (with floats removed) can be stretched between the pilings several feet below the surface. Therefore, a scenario where nets are supported by pilings may include year round deployment as was the case for the Chalk Point Power Plant. However, in northern climates the sustained presence of thick ice during the winter may prevent net removal and cleaning and therefore, it may still be necessary to remove the nets during this period.

4.1 CAPITAL COST DEVELOPMENT

Compliance costs are developed for the two different net scenarios.

Scenario A Installation at Freshwater Lake Using Anchors and Buoys/Floats

This scenario is intended for application in freshwater waterbodies where low water velocities and low debris levels occur such as lakes and reservoirs. This scenario is modeled on the barrier net data from the Entergy Arkansas Nuclear One facility but has been modified to double the annual deployment period from 120 days to 240 days. Along with doubling the deployment period, the labor costs were increased to include an additional net removal and replacement step midpoint through this period. To facilitate the mid season net replacement, the initial net capital costs will include purchase of a replacement net.

Scenario B Installation Using Pilings.

This scenario is modeled after the system used at Chalk Point. In this case two nets are deployed in concentric semi-circles with the inner net having a smaller mesh (0.375 in) and the outer net having a larger mesh. Deployment is assumed to be year round. A marine contractor performs all O&M, which mostly involves periodically removing and the replacing both nets with nets they have cleaned. The initial capital net costs will include purchase of a set of replacement nets. This scenario is intended for application in waterbodies with low or varying currents such as tidal rivers and estuaries. Two different O&M cost estimates are developed for this scenario. In one the deployment is assumed to be year round as is the case at Chalk Point. In the second, the net is deployed for only 240 days being taken out during the winter months. This would apply to facilities northern regions where ice formation would make net maintenance difficult.

Net Costs

The capital costs for each scenario includes two components, the net and the support. The net portion includes a rope and floats spaced along the top and weights along the bottom consisting of either a "leadline"or chain. If similar netting specifications are used the cost of the netting is generally proportional to the size of the netting and can be expressed in a unitized manner such as "dollars/sq ft." Table 4-3 presents the reported net costs and calculated unit costs. While different water depths will change the general ratio of net area to length of rope/floats and bottom weights , the differences in depth also result in different float and weight requirements. For example, a shallower net will require more length of surface rope and floats and weights per unit net area but a shallower depth net will also exert less force and require smaller floats and weights.

EPA is using the cost of nets in the average depth range of 20 to 30 feet as the basis for costing. This approach is consistent with the median Phase II facility shoreline intake depth of 18 feet and median "average bay depth" of 20 feet. While nets are deployed offshore in water deeper than a shoreline intake, costs are for average depths, which include the shallow sections at the ends, and net placement can be configured to minimize depth. To see how shallower depths may affect unit costs, the costs for a shallower 10-foot net with specifications similar to the Chalk Point net (depth of 27 feet) were obtained from the facility's net supplier. As shown in Table 4-3, the unit cost per square foot for the shallower net was less than the deeper net. Therefore, EPA has concluded that the use of shallower nets does not increase unit costs and has chosen to apply the unit costs, based on the 20-foot and 30-foot depth nets, to shallower depths.

Table 4-3 presents costs obtained for the net portion only from the facilities that completed the Barrier Net Questionnaire. These costs have been increased by 12% over what was reported to include shipping costs. This 12% value was obtained from the Chalk Point net supplier who confirmed that the costs reported by Chalk Point did not include shipping (Murelle 2002) The unit net costs range from $0.17/sq ft to $0.78/sq ft. Consultation with net vendors indicates that the barrier net specifications vary considerably and that there is no standard approach. Although no net specification data (besides mesh size) was submitted with the Laskin Energy Center data, EPA has concluded that the data for this net probably represents lower strength netting which would be suitable for applications where the netting is not exposed to significant forces. Because the compliance cost scenarios will be applied to facilities with a variety net strength requirements, EPA has chosen to use the higher net costs that correspond to higher net strength requirements. As such, EPA has chosen to use the cost data for the Chalk Point and Arkansas Nuclear One facilities as the basis for each scenario.

Table 4-3
Net Size and Cost Data

Facility	Depth	Length	Area	Component	Cost/net	Cost/sq ft
	ft	ft	sq ft			
Chalk Point	27	300	8,100	Replacement Net 0.675 in.*	$4,640	$0.57
	27	300	8,100	Replacement Net 0.375 in.*	$4,410	$0.54
Chalk Point (equivalent	10	300	3,000	Replacement Net*	$1,510	$0.50
Entergy Arkansas	20	250	5,000	Replacement Net*	$3,920	$0.78
Entergy Arkansas	20	1500	30,000	Net & Support Costs**	$36,620	$1.22
Laskin Energy Center	16	600	9,600	Net Costs***	$1,600	$0.17

*Costs include floats and lead line or chain and are based on replacement costs plus 12% shipping.
** Costs include replacement net components plus anchors, buoys & cable plus 12% shipping
***Cost based on reported 1980 costs adjusted to 2002 dollars plus 12% for shipping.

Scenario A Net Costs

In this scenario the net and net support components are included in the unit costs. At the Arkansas Nuclear One facility unitized costs for the net and anchors/buoys are $1.22/sq ft plus $0.78/sq ft for the replacement net, resulting in a total initial unit net costs of $2.00/sq ft for both nets. Because the data in Table 4-3 indicate that, if anything, unit costs for nets may decrease with shallower depths, EPA concluded that this unit cost was representative of most of the deeper nets and may slightly overestimate the costs for shallower nets.

Scenario A Net Installation costs

Installation costs for Arkansas Nuclear One (Scenario A) were reported as $30,000 (in 1999 dollars; $32,700 when adjusted for inflation to 2002 dollars) for the 30,000 sq ft net. This included placement of anchors and cable including labor. In order to extrapolate the installation costs for different net sizes, EPA has assumed that approximately 20% ($6,540) of this installation cost represents fixed costs (e.g., mobilization/demobilization). The remainder ($26,160) divided by the net area results in an installation unit cost of $0.87/sq ft to be added to the fixed cost.

Scenario A Total Capital Costs

Table 4-4 presents the component and total capital costs for Scenario A. Indirect costs are added for engineering (10%) and contingency/allowance (10%). Contractor labor and overhead are already included in the component costs. Because most of the operation occurs offshore no cost for sitework are included.

Table 4-4
Capital Costs for Scenario A Fish Barrier Net With Anchors/Buoys as Support Structure

Flow (gpm)	2,000	10,000	50,000	100,000	250,000	500,000	750,000	1,000,000	1,250,000
Net Area (sq ft)	74	371	1,857	3,714	9,284	18,568	27,852	37,136	46,420
Net Costs	$149	$744	$3,722	$7,445	$18,611	$37,223	$55,834	$74,445	$93,057
Installation Costs Fixed	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540	$6,540
Installation Costs Variable	$65	$324	$1,619	$3,238	$8,096	$16,191	$24,287	$32,383	$40,478
Total Direct Capital Costs	$6,754	$7,608	$11,881	$17,223	$33,247	$59,954	$86,661	$113,368	$140,075
Indirect Costs	$1,351	$1,522	$2,376	$3,445	$6,649	$11,991	$17,332	$22,674	$28,015
Total Capital Costs	$8,104	$9,130	$14,258	$20,667	$39,896	$71,945	$103,993	$136,042	$168,090

Scenario B Net Costs

In this scenario the net costs are computed separately from the net support (pilings) costs. In this scenario there are two separate nets and an extra set of replacement nets for each. This, the unit costs for the nets will be two times the sum of the units net costs for each of the large and small mesh nets. As shown in Table 4-3, the unit costs for each net was $0.57/sq ft and $0.54/sq ft resulting in a total cost for all four nets of $2.24/sq ft for the area of a single net.

Scenario B Installation Costs

Installation costs were not provided for the Chalk Point facility. Initial net installation is assumed to be performed by the O&M contractor and is assumed to be a fixed cost regardless of net size. EPA assumed the initial installation costs to be two-thirds of the contractor, single net replacement job cost of $1,400 or $933 (See O&M Costs - Scenario B).

Scenario B Piling Costs

The cost for the pilings at the Chalk Point facility were not provided. The piling costs for scenario B is based primarily on the estimated cost for installing two concentric set of treated wooden pilings with a spacing of 20 ft between pilings. To see how water depth affects piling costs, separate costs were developed at water depths of 10 feet, 20 feet, and 30 feet. Piling costs are based on the following assumptions:

- Costs for pilings is based on a unit cost of $28.50/ ft of piling (RS Means, 2001)
- Piling installation mobilization costs are equal to $2,325 based on a mobilization rate of $46.50/mile for barge mounted pile driving equipment (RS Meaens 2001) and an assumed distance of 50 miles
- Each pile length includes the water depth plus a 6-foot extension above the water surface plus a penetration depth (at two-thirds the water depth); the calculated length was rounded up to the next even whole number
- The two concentric nets are nearly equal in length with one pile for every 20 feet in length and one extra pile to anchor the end of each net.

Table 4-5 presents the individual pile costs and intake flow for each net section between two pilings (at 0.06 fps).

Table 4-5
Pile Costs and Net Section Flow

Water Depth	Total Pile Length	Cost Per Pile	Flow Per 20 ft Net Section	Fixed Cost Mobilization
Ft	Ft		gpm	
10	24	684	5385.6	2325
20	40	1140	10771.2	2325
30	56	1596	16156.8	2325

Tables 4-6, 4-7, and 4-8 present the total capital costs and cost components for the installed nets and pilings. Indirect costs are added for engineering (10%) and contingency/allowance (10%). Contractor labor and overhead are already included in the component costs. Because most of the operation occurs offshore no cost for sitework are included. The costs were derived for nets with multiple 20 ft sections. Because the net costs are derived such that the cost equations are linear with respect to flow, the maximum number of sections shown are selected so they cover a similar flow range. Values that exceed this range can use the same cost equation.

Table 4-6

Capital Costs for Fish Barrier Net With Piling Support Structure for 10 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75	100	200
Total Number of Pilings	6	10	18	26	52	102	152	202	402
Single Net Length (ft)	40	80	160	240	500	1000	1500	2000	4000
Net Area (sq ft)	400	800	1,600	2,400	5,000	10,000	15,000	20,000	40,000
Flow (gpm)	10,771	21,542	43,085	64,627	134,640	269,280	403,920	538,560	1,077,120
Total Piling Cost	$6,429	$9,165	$14,637	$20,109	$37,893	$72,093	$106,293	$140,493	$277,293
Net Costs	$1,380	$1,827	$2,721	$3,614	$6,519	$12,106	$17,692	$23,279	$45,624
Total Direct Costs	$7,809	$10,992	$17,358	$23,723	$44,412	$84,199	$123,985	$163,772	$322,917
Indirect Costs	$1,562	$2,198	$3,472	$4,745	$8,882	$16,840	$24,797	$32,754	$64,583
Total Capital Costs	$9,371	$13,190	$20,829	$28,468	$53,295	$101,039	$148,782	$196,526	$387,501

Table 4-7
Capital Costs for Fish Barrier Net With Piling Support Structure for 20 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75	100
Total Number of Pilings	6	10	18	26	52	102	152	202
Single Net Length (ft)	40	80	160	240	500	1000	1500	2000
Net Area (sq ft)	800	1600	3200	4800	10000	20000	30000	40000
Flow (gpm)	21,542	43,085	86,170	129,254	269,280	538,560	807,840	1,077,120
Total Piling Cost	$9,165	$13,725	$22,845	$31,965	$61,605	$118,605	$175,605	$232,605
Net Costs	$1,827	$2,721	$4,508	$6,296	$12,106	$23,279	$34,452	$45,624
Total Direct Costs	$10,992	$16,446	$27,353	$38,261	$73,711	$141,884	$210,057	$278,229
Indirect Costs	$2,198	$3,289	$5,471	$7,652	$14,742	$28,377	$42,011	$55,646
Total Capital Costs	$13,190	$19,735	$32,824	$45,913	$88,453	$170,260	$252,068	$333,875

Table 4-8
Capital Costs for Fish Barrier Net With Piling Support Structure for 30 Ft Deep Nets

Number of 20 ft Sections	2	4	8	12	25	50	75
Total Number of Pilings	6	10	18	26	52	102	152
Single Net Length (ft)	40	80	160	240	500	1000	1500
Net Area (sq ft)	1,200	2,400	4,800	7,200	15,000	30,000	45,000
Flow (gpm)	32,314	64,627	129,254	193,882	403,920	807,840	1,211,760
Total Piling Cost	$9,576	$15,960	$28,728	$41,496	$82,992	$162,792	$242,592
Net Costs	$2,274	$3,614	$6,296	$8,977	$17,692	$34,452	$51,211
Total Direct Costs	$11,850	$19,574	$35,024	$50,473	$100,684	$197,244	$293,803
Indirect Costs	$2,370	$3,915	$7,005	$10,095	$20,137	$39,449	$58,761
Total Capital Costs	$14,220	$23,489	$42,029	$60,568	$120,821	$236,692	$352,563

Figure 4-1 presents the total capital costs for scenarios A and B from Tables 4-4 through 4-8, plotted against design flow. Figure 4-1 also presents the best-fit linear equations used top estimate compliance costs. EPA notes that pilings for shallower depths costed out more, due to the need for many more pilings. Scenario B costs for 10-foot deep nets will be applied wherever the intake depth is less than 12 ft. For scenario B applications in water much deeper than 12 feet, EPA will use the cost equation for 20-foot deep nets.

4.2 O&M COSTS DEVELOPMENT

Scenario A O&M Costs - Float/Anchor Supported Nets

Barrier net O&M costs generally include costs for replacement netting, labor for net inspection, repair, and cleaning, and labor for net placement and removal. The Arkansas Nuclear One facility supplied data that estimate all three components for its 1500 ft long by 20 ft deep net located on a reservoir. Net deployment, however, was for only a 120-day period. This net is installed in November and removed in March (in-place for 120 days total). Each year two 250-foot sections of the net (one-third of the total) are replaced due to normal wear and tear.

EPA assumes the labor rate is similar to the estimate for traveling screen maintenance labor ($41.10/hr). The reported Arkansas Nuclear One O&M labor requirements includes 3 hrs per day during the time the net is deployed for inspection & cleaning by personnel on a boat (calculated at $14,800). This involves lifting and partially cleaning the nets on a periodic basis. Labor to deploy and remove the net was reported at 240 hrs (calculated at $9,860). Two sections of the six total net sections were replaced annually at a cost of $7,830 total (including shipping). Total annual O&M costs are calculated to be $32,500.

Because other facilities on lakes reported longer deployment periods (generally when ice is not present), EPA chose to adjust O&M costs to account for longer deployment. EPA chose to base O&M costs for scenario A on a deployment period of 240 days (approximately double the Arkansas Nuclear One facility deployment period). EPA also added costs for an additional net removal and deployment step using the second replacement net midway through the annual deployment period. The result is a calculated annual O&M cost of $57,200.

Scenario B O&M Costs - Piling Supported Nets

Nearly all of the O&M labor for Chalk Point facility is performed by a marine contractor who charges $1,400 per job to simultaneously remove the existing net and replace it with a cleaned net. This is done with two boats where one boat removes the existing net followed quickly by the second that places the cleaned net keeping the open area between nets minimized . The contractors fee includes cleaning the removed nets between jobs. This net replacement is performed about 52 to 54 times per years. It is performed about twice per week during the summer and once every two weeks during the winter. The facility relies upon the contractor to monitor the net. Approximately one third of the nets are replaced each year, resulting in a net replacement cost of $9,050.

Using an average of 53 contractor jobs per year and a net replacement cost of $9,050 the resulting annual O&M cost was $83,250. EPA notes that some facilities that employ scenario B technology may choose to remove the nets during the winter. As such, EPA has also estimated the scenario B O&M costs based on a deployment period of approximately 240 days by reducing the estimated number of contractor jobs from 53 to 43 (deducting 10 jobs using the winter frequency of roughly 1 job every 2 weeks). The resulting O&M costs are shown in Tables 4-9 and 4-10.

EPA notes that other O&M costs reported in literature are often less than what is shown in Table 4-9. For example, 1985 O&M cost estimates for the JP Pulliam plant ($7,500/year, adjusted to 2002 dollars) calculate to $11,800 for a design flow roughly half that of Arkansas Entergy. This suggests the scenario A and B estimates represent the high end of the range of barrier net O&M costs. Other O&M estimates, however, do not indicate the cost components that are included and may not represent all cost components.

In order to extrapolate costs for other flow rates, EPA has assumed that roughly 20% of the Scenario A and B O&M costs represent fixed costs. Table 4-9 presents the fixed and unit costs based on this assumption for both scenarios.

Table 4-9
Cost Basis for O&M Costs

	Deployment	Net Replacement	O&M Labor	Model Facility O&M	Fixed Cost	Variable Costs	Unit Variable O&M Costs
	Days						$/sq ft
Scenario A	240	$7,830	$49,320	$57,150	$11,430	$45,720	$1.52
Scenario B	365	$9,050	$74,200	$83,250	$16,650	$66,600	$2.47
Scenario B	240	$9,050	$60,200	$69,250	$13,850	$55,400	$2.05

Note that Unit Variable O&M Costs are based on a total net area of 30,000 sq ft (Entergy Arkansas) for scenario A and 27,000 sq ft for scenario B (Chalk Point).

Table 4-10 presents the calculated O&M costs based on the cost factors in Table 4-9 and Figure 4-2 presents the plotted O&M costs and the linear equations fitted to the cost estimates.

Table 4-10
Annual O&M Cost Estimates

Flow (gpm)		2,000	10,000	50,000	100,000	250,000	500,000	750,000	1,000,000	1,250,000
Net Area (sq ft)		74	371	1,857	3,714	9,284	18,568	27,852	37,136	46,420
Scenario A	240 days	$11,543	$11,996	$14,260	$17,090	$25,579	$39,728	$53,877	$68,025	$82,174
Scenario B	365 days	$16,833	$17,566	$21,230	$25,810	$39,551	$62,451	$85,352	$108,252	$131,153
Scenario B	240 days	$14,002	$14,612	$17,660	$21,470	$32,899	$51,949	$70,998	$90,048	$109,097

4.3 NUCLEAR FACILITIES

Even though the scenario A costs are modeled after the barriers nets installed at a nuclear facility, the higher unit net costs cited by the Arkansas Nuclear One facility include components that are not included with the non-nuclear Chalk Point nets and thus the differences may be attributed to equipment differences and not differences between nuclear and non-nuclear facilities. In addition, the labor rates used for scenario A and B O&M were for non-nuclear facilities. Because the function of barrier nets is purely for environmental benefit, and not critical to the continued function of the cooling system (as would be technologies such as traveling screens). EPA does not believe that a much more rigorous design is warranted at nuclear facilities. However, higher labor rates plus greater paperwork and security requirements at nuclear facilities should result in higher costs. As such, EPA has concluded that the capital costs for nuclear facilities should be increased by a factor of 1.58 (lower end of range cited in passive screen section). Because O&M costs rely heavily on labor costs, EPA has concluded that the O&M costs should be increased by a factor of 1.24 (based on nuclear vs non-nuclear operator labor costs).

4.4 APPLICATION

Fish barrier net technology will augment, but not replace, the function of any existing technology. Therefore, the calculated net O&M costs will include the O&M costs described here without any deductions for reduction in existing technology O&M costs. Fish barrier nets may not be applicable in locations where they would interfere with navigation channels or boat traffic.

Fish barrier nets require low waterbody currents in order to avoid becoming plugged with debris that could collapse the net. Such conditions can be found in most lakes and reservoirs, as well as some tidal waterbodies such as tidal rivers and estuaries. Placing barrier nets in a location with sustained lateral currents in one direction may cause problems because the section of net facing the current will continually collect debris at higher rate than the remainder of the net. In this case, net maintenance cleaning efforts must be able to keep up with debris accumulation. As such, barrier nets are suitable for intake locations that are sheltered from currents, e.g., locations within an embayment, bay, or cove. On freshwater rivers and streams only those facilities within an embayment, bay, or cove will be considered as candidates for barrier nets.. The sheltered area needs to be large enough for the net sizes described above. The fish barrier net designs considered here would not be suitable for waterbodies with the strong wave action typically found in ocean environments.

Scenario A is most suitable for lakes and reservoirs where water currents are low or almost nonexistent. Scenario B is more suitable for tidal waterbodies and any other location where higher quantities of debris and light or fluctuating currents may be encountered. In northern regions where formation of thick ice in winter would prevent access to the nets, and scenario B may be applied, the scenario B O&M costs for a 240-day deployment should be used. However, because this scenario results in reduced costs, EPA has chose to apply the scenario B 365 days deployment for all facilities in suitable waterbodies.

EPA notes that nets with net velocities higher than 0.07 fps have been successfully employed (EPRI 1985). While such nets will be smaller than those described here, they will accumulate debris at a faster rate. Because the majority of the O&M costs are related to cleaning nets, EPA expects the increase in frequency of cleaning smaller nets will be offset by the smaller net size such that the smaller nets should require similar costs to maintain.

Facilities with Canals

Most facilities with canals have in-canal velocities of between 0.5 and 1 fps based on average flow. These velocities are an order of magnitude greater than the design net velocity used here. If nets with mesh sizes in the range considered here were placed within the canals they will likely experience problems with debris. Therefore, if barrier nets are used at facilities with canals, the net would need to be placed in the waterbody just outside the canal entrance.

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Figure 4-1
Total Capital Costs for Fish Barrier Nets

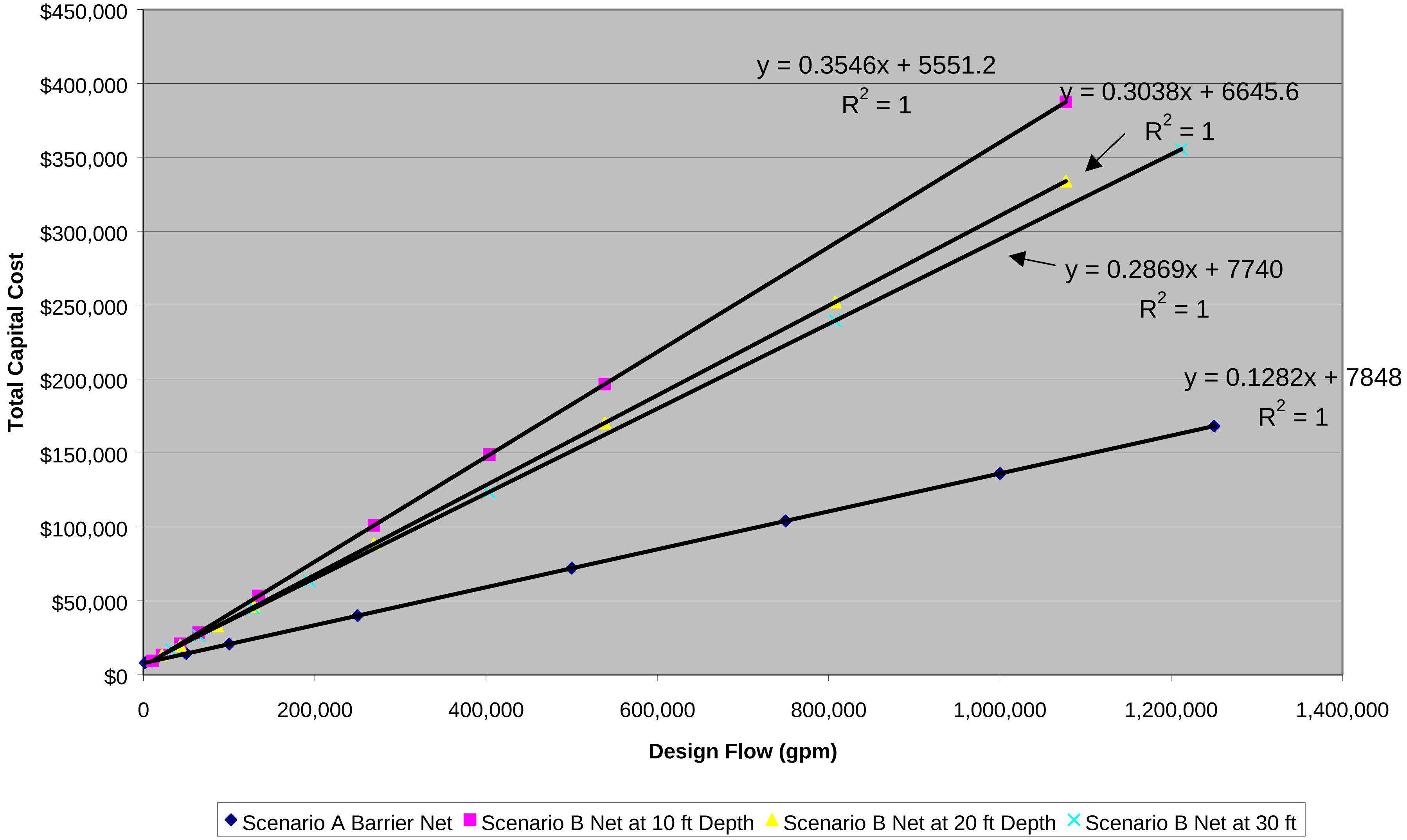
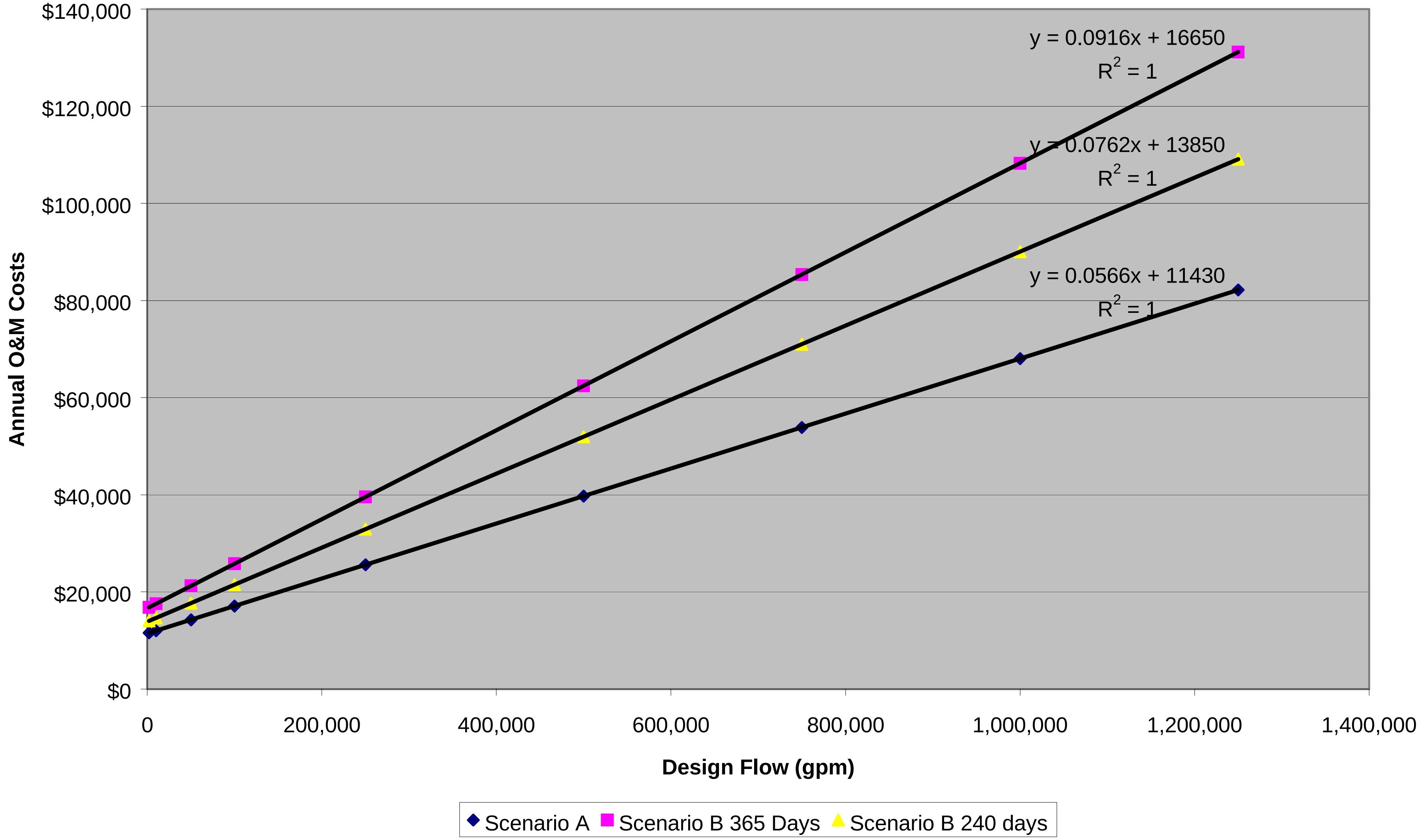


Figure 4-2
Barrier Net Annual O&M Costs



5.0 AQUATIC FILTER BARRIERS

Filter Barrier

Aquatic filter barrier systems are barriers that employ a filter fabric designed to allow passage of water into a cooling water intake structure, while excluding aquatic organisms. One company, Gunderboom, Inc., has a patented system, the Marine/Aquatic Life Exclusion System (MLES)™ that can be deployed as a full-water-depth filter curtain suspended from floating booms extending out in the waterway or supported on a fixed structure as described below. The filter fabric material is constructed of matted unwoven synthetic fibers.

Pore Size and Surface Loading Rate

Filter fabric materials with different pore sizes can be employed depending on performance requirements. In the MLES™ system two layers of fabric are used. Because the material is a fabric and thus the openings are irregular, the measure of the mesh or pore size is determined by an ASTM method that relies on a sieve analysis of the passage of tiny glass beads. The results of this analysis is referred to as apparent opening size. The standard MLES ™ filter fabric material has an apparent opening size (AOS) of 0.15 mm. (McCusker 2003b). Gunderboom can also provides filter fabric material that has been perforated to increase the apparent opening size. Available perforation sizes range from 0.4 mm to 2.0 mm AOS. The "apparent opening size" is referred to as the "pore size" in the discussion below. While smaller pore sizes can protect a greater variety of aquatic organisms, smaller the pore sizes also increase the proportion of suspended solids collected and thus the rate at which it collects. In addition, smaller pore sizes tend to impede the flow of water through the filter fabric which becomes even more pronounced as solids collect on the surface. This impedance of flow results in an increase in the lateral forces acting on the AFB. The filter surface loading rate (gpm/ sq ft) or equivalent approach velocity (fps) determines both the rate at which suspended particles collect on the filter fabric and the intensity of the lateral forces pushing against the AFB. While the airburst system (see description below) is designed to help dislodge and removed such suspended particles, there are practical limits regarding pore size and surface loading rate. For filter fabric of any given pore size, decreasing the surface loading rate will reduce the rate of solids accumulation and the lateral forces acting upon the AFB. Thus, pore size is an important design parameter in that it determines the types of organisms excluded as well as contributes to the selection of an acceptable surface loading rate. The surface loading rate combined with the cooling water intake design flow determines the required AFB surface area. This total filter fabric area requirement when combined with the local bathymetry determines the area that resides within the AFB.

Since the AFB isolates and essentially restricts the function of a portion of the local ecosystem, anything that increases the AFB total surface area will also increase the size of the isolated portion of the ecosystem. As such, there is an environmental trade off between minimizing the pore size to protect small size organisms/lifestages versus minimizing the size of the area being isolated. Additionally, requirements for large AFB surface areas may preclude its use where conflicts with other waterbody uses (e.g., navigation) or where the waterbody size or configuration restricts the area that can be impacted. Vendors can employ portable test equipment or pilot scale installations to test pore size selection and performance which can aid in the selection of the optimal pore size. Acceptable design filter loading rates will vary with the pore size and the amount of sediment and debris present. An initial target loading rate of 3 to 5 gpm/sq ft have been suggested (EPA 2001). This is equivalent to approach or net face velocities of 0.007 to 0.01 fps which is nearly an order of magnitude lower than the 0.06 fps design velocity used by EPA for barrier nets. This difference is consistent with the fact that barrier net use much greater mesh sizes. Use of larger AFB pore sizes can result in greater net velocities. Since the cost estimates as presented here are based on design flow, differences in design filter loading rates will affect the size of the AFB which directly affects the costs. The range between the high and low estimates in capital and O&M costs presented below account at least in part for the differences associated with variations in pore size as well as other design variations that result from differences in site conditions.

Floating Boom

For large volume intakes such as once-through systems, an AFB supported at the top by a floating boom that extends out into the water body and anchored onshore at each end is the most likely design configuration to be employed because of the large surface area required. In this design, a filter fabric curtain is supported by the floating boom at the top and is held against the bottom of the waterbody by weights such as a heavy chain. The whole thing is held in place by cables attached to fixed anchor points placed at regular intervals along the bottom. The Gunderboom MLES design employ a two layer filter fabric curtain that is divided vertically into sections to allow for replacement of an individual sections when necessary. The estimated capital and O&M costs described below are for an AFB using this floating boom-type construction.

Fixed Support

The AFB vendor, Gunderboom Inc., also provides an AFB supported by rigid panels that can be placed across the opening of existing intake structures. This technology is generally applicable to existing intakes where the intake design flow has been substantially reduced such as where once-through systems are being converted to recirculating cooling towers. For other installations, Gunderboom has developed what they refer to as a cartridge-type system which consists of rigid structures surrounded by filter fabric with filtered water removed from the center (McCusker 2003). Costs for either of these rigid type of installation have not been provided.

Air Backwash
The Gunderboom MLES™ employs an automated air burst technology that periodically discharges air bubbles between the two layers of fabric at the bottom of each MLES curtain panel. The air bubbles create turbulence and vibrations that help dislodge particulates that become entrained in the filter fabric. The airburst system can be set to purge individual curtain panels on a sequential basis automatically or can be operated manually. The airburst technology is included in the both the capital and O&M costs provided by the vendor.

5.1 CAPITAL COST DEVELOPMENT

Estimated capital costs were provided by the only known aquatic filter barrier manufacturer, Gunderboom, Inc. Cost estimates were provided for AFBs supported by floating booms representing a range of costs; low, high, and average that may result from differences in construction requirements that result from different site specific requirements and conditions. Such requirements can include whether sheetwall piles or other structures are needed and whether dredging is required which can result in substantial disposal costs. Costs were provided for three design intake flow values: 10,000 gpm, 104,000 gpm, and 347,000 gpm. Theses costs were provided in 1999 dollars and have been adjusted for inflation to July 2002 dollars using the ENR construction cost index. The capital costs are total project costs including installation. Figure 5-1 presents a plot of the data in Table 5-1 along with the second order equation fitted to this data.

The vendor recently provided a total capital cost estimate of 8 to 10 million dollars for full scale MLES™ system at the Arthur Kill Power Station in Staten Island, NY (McCusker 2003a). The vendor is in the process of conducting a pilot study with an estimated cost of $750,000. The NYDEC reported the permitted cooling water flow rate for the Arthur Kill facility as 713 mgd or 495,000 gpm. Applying the cost equations in Figure 5-1 results in a total capital cost of $8.7, $10.1 and $12.4 million dollars for low, average and high costs, respectively. These data indicate that the inflation adjusted cost estimates are consistent with this more recent estimate provided by the vendor. Note that since the Arthur Kill intake flow exceeded the range of the cost equation input values the cost estimates presented above for this facility were derived by first dividing the flow by two and then adding the answer.

Table 5-1
Capital Costs for Aquatic Filter Barrier Provided by Vendor

	Floating Boom		
Flow	Capital Cost (2002 Dollars)		
gpm	Low	High	Average
10,000	$545,000	$980,900	$762,900
104,000	$1,961,800	$2,724,800	$2,343,300
347,000	$6,212,500	$8,501,300	$7,356,900

5.2 O&M COSTS

Estimated O&M costs were also provided by Gunderboom Inc., As with the capital costs the O&M costs provided apply to floating boom type AFBs and include costs to operate an air burst system. Table 5-2 presents a range of O&M costs from low to high and the average which served as the basis for cost estimates. As with the capital costs, the costs presented in Table 5-2 have been adjusted for inflation to July 2002 dollars. Figure 5-1 presents a plot of the data in Table 5-2 along with the second order equation fitted to this data.

Table 5-2
Estimated AFB Annual O&M Costs

Flow	O&M	O&M	O&M
gpm	Low	High	Average
10,000	$109,000	$327,000	$218,000
104,000	$163,500	$327,000	$245,200
347,000	$545,000	$762,900	$653,900

5.3 APPLICATION

Aquatic filter barriers (AFBs) can be used where improvements to impingement performance is needed. Because they can be installed independently of intake structures, there is no need to include any costs for modifications to the existing intake structure or technology employed. Costs are assumed to be the same for both new and existing facilities. AFBs can be installed while the facility is operating. Thus, there is no need to coordinate AFB installation with generating unit downtime. Capital cost estimates used in the economic impact analysis used average costs.

EPA assumed that the existing screen technology would be retained as a backup following the installation of floating boom AFBs. Therefore, as with barrier nets, the O&M costs of the existing technology was not deducted from the estimated net O&M cost used in the Phase II economic impact analysis. Upon further consideration, EPA has concluded that at a minimum there should be a reduction in O&M cost of the existing intake screen technology equivalent to the variable O&M cost component estimated for that technology.

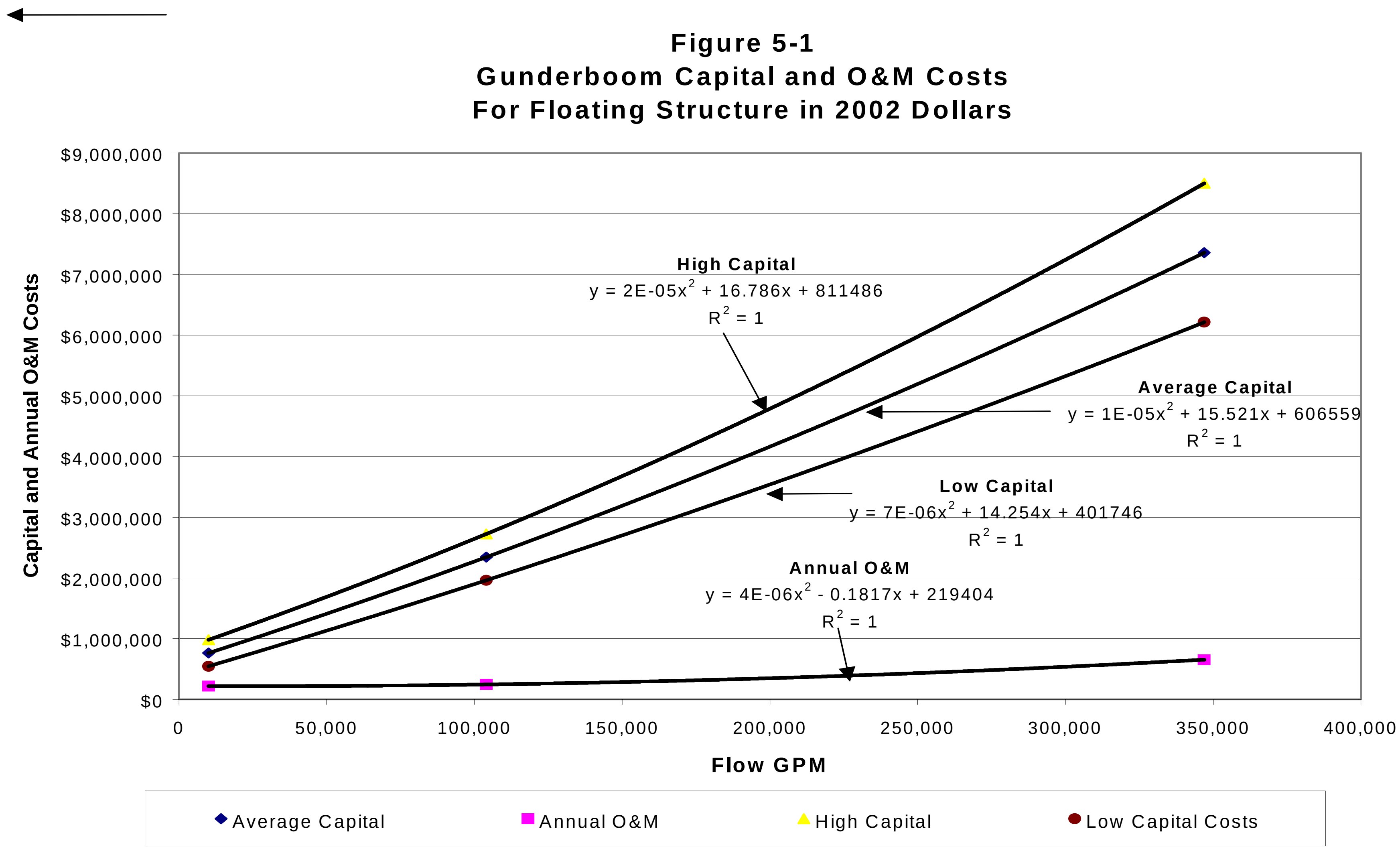
REFERENCES

EPA, Technology Fact Sheet 316(b) Phase I Technical Development Document. (EPA-821-R-01-036). November 2001.

McCusker, A. Gunderboom, Inc., Telephone contact report with John Sunda, SAIC. Regarding MLES system technology. August, 8, 2003a.

McCusker, A. Gunderboom, Inc., email correspondence with John Sunda, SAIC. Regarding MLES system technology pore size and costs. October 2 , 2003b.

Figure 5-1
Gunderboom Capital and O&M Costs For Floating Structure in 2002 Dollars



6.0 DETERMINING FIXED VERSUS VARIABLE O&M COSTS

When developing the annual O&M cost estimates, the underlying assumption was that facilities were operating nearly continuously with the only downtime being periodic routine maintenance. This routine maintenance was assumed to be approximately four weeks per year. The economic model however, considers variations in capacity utilization. Lower capacity utilization factors result in additional generating unit shutdown that may result in reduced O&M costs. However, it is not valid to assume that intake technology O&M costs drop to zero during these additional shutdown periods. Even when the generating unit is shut down, there are some O&M costs incurred. To account for this, total annual O&M costs were divided into fixed and variable components. Fixed O&M costs include items that occur even when the unit is periodically shut down, and thus are assumed to occur year round. Variable O&M costs apply to items that are allocable based on estimated intake operating time. The general assumption behind the fixed and variable determination is that shutdown periods are relatively short (on the order of several hours to several weeks).

6.1 OVERALL APPROACH

The annual O&M cost estimates used in the cost models is the net O&M cost, which is the difference between the estimated baseline and compliance O&M costs. Therefore, the fixed/variable proportions for each facility may vary depending on the mix of baseline and compliance technologies. In order to account for this complexity, EPA calculated the fixed O&M costs separately for both the baseline technology and each compliance technology and then calculated the total net fixed and variable components for each facility/intake.

In order to simplify the methodology (i.e., avoid developing a whole new set of O&M cost equations), a single fixed O&M component cost factor was estimated for each technology application represented by a single O&M cost equation. To calculate fixed O&M factors, EPA first calculated fixed O&M cost factors for the range of data input values, using the assumptions described below, to develop the cost equation . For baseline technologies, EPA selected the lowest value in the range of fixed component factors for each technology application. The lowest value was chosen for baseline technologies to yield a high-side net compliance costs for intermittently operating facilities. Similarly, for compliance technologies, EPA selected the highest value in the range of fixed component factors for each technology application, again, to provide a high-side estimate.

For each O&M cost equation, a single value (expressed either as a percentage or decimal value) representing the fixed component of O&M costs, is applied to each baseline and compliance technology O&M cost estimate for each facility. The variable O&M component is the difference between total O&M costs and the fixed O&M cost component. The fixed and variable cost components were then separately combined to derive the overall net fixed and overall net variable O&M costs for each facility/intake.

6.2 ESTIMATING THE FIXED/VARIABLE O&M COST MIX

Depending on the technology, the O&M cost estimates may generally include components for labor, power, and materials. The cost breakdown assumes facility downtime will be relatively short (hours to weeks). Thus, EPA assumes any periodic maintenance tasks, e.g., changing screens, changing nets, or inspection/cleaning by divers) are performed regardless of plant operation, and therefore are considered fixed costs. Fixed costs associated with episodic cost components are allocated according to whether they would still occur even if the downtime coincided with the activity. For example, annual labor estimates for passive screens includes increased labor for several weeks during high debris episodes. This increased labor is considered a 100% variable component because it would not be performed if the system were not operating during this period. A discussion of the assumptions and rationale for each general component is described below.

Power Requirements

In most cases, power costs are largely a variable cost. If there is a fixed power cost component, it will generally consists of low frequency, intermittent operations necessary to maintain equipment in working condition. For example, a 1% fixed factor for this component would equal roughly 1.0 hours of operation every four days for systems that normally operated continuously. Such a duration and frequency is considered as reasonable for most applications. For systems already operating intermittently, a factor that results in the equivalent of one hour of operation or one backwash every four days was used.

Labor Requirements

Labor costs generally have one or more of the following components:

- Routine monitoring and maintenance
- Episodes requiring higher monitoring and maintenance (high debris episodes)
- Equipment deployment and removal
- Periodic inspection/cleaning by divers.

Routine Monitoring and Maintenance
This component includes monitoring/adjustment of the equipment operation, maintaining equipment (repairs & preventive O&M), and cleaning. Of these the monitoring/adjustment and cleaning components will drop significantly when the intakes are not operating. A range of 30% to 50% will be considered for the fixed component.

Episodes requiring higher monitoring and maintenance
This component is generally associated with equipment that is operating and will be assumed to be 100% variable.

Equipment deployment and removal
This activity is generally seasonal in nature and assumed performed regardless of operation (i.e., 100% fixed).

Periodic Inspection/Cleaning by Divers
This periodic maintenance task is assumed to be performed regardless of plant operation, and therefore is considered as 100% fixed costs.

Equipment Replacement

The component includes two factors: parts replacement due to wear and tear (and varies with operation) and parts replacement due to corrosion (and occurs regardless of operation). A range of 50% to 70% of these costs will be considered the fixed component.

Technology-Specific Input Factors

Traveling Screens
To determine the range of calculated total O&M fixed factors, fixed O&M cost factors (Table 6-1) were applied to individual O&M cost components for the various screen width values that were used to generate the O&M cost curves. As described earlier, the lowest value of this range was selected for the baseline O&M fixed cost factor and the highest of this range was selected as the compliance O&M fixed cost factor.

Table 6-1
O&M Cost Component Fixed Factor

	Routine Labor	Parts Replacement	Equipment Power	Equipment Deployment
All Traveling Screens Without Fish Handling	0.5	0.7	0.05	1.0
All Traveling Screens With Fish Handling	0.3	0.5	0.01	1.0

Passive Screens
The fixed O&M component was based on the following:

- Seasonal high debris period monitoring labor set equal to 0 hours
- Routine labor set at 50% of full time operation
- Back washes are performed once every four days
- Dive team costs for new screens at existing offshore for high debris were set at 50% of full time operation
- Dive team costs for new screens at existing offshore were set equal to 0 assuming no net additional diver costs over what was necessary for existing submerged intake without screens.
- The same assumptions are applied to both fine mesh and very fine mesh screens.

Velocity Caps
Because the O&M cost for velocity caps was based on annual inspection and cleaning by divers, the entire velocity cap O&M cost is assumed to be fixed (100%).

Fish Barrier Nets
Fish barrier net O&M costs are based on deployment and removal of the nets plus periodic replacement of net materials. As described above, EPA assumes seasonal deployment and removal is a 100% fixed O&M cost. EPA has assumed that the need for net maintenance and replacement is a due to its presence in the waterbody and should not vary with the intake operation. Therefore, entire fish barrier net O&M cost is assumed to be fixed (100%).

Aquatic Filter barriers
The O&M costs for aquatic filter barriers (AFB) includes both periodic maintenance and repair of the filter fabric and equipment plus energy used in the operation of the airburst system. As with barrier nets the need for net repairs and replacement should not vary with the intake operation. There may be a reduction in the deposition of sediment during the periods when the intake is not operating and as a result there may be a reduction in the required frequency of airburst operation. However, the presence of tidal and other waterbody currents may continue to deposit sediment on the filter fabric requiring periodic operation. Thus, the degree of reduction in the airburst frequency will be dependent on site conditions. Additionally, the O&M costs provided by the vendor did not break out the O&M costs by component. Therefore, EPA concluded that an assumption that AFB O&M costs is 100% fixed is reasonable and represents a conservative estimate in that it will slightly overestimate O&M costs during periods when the intake is not operating.

Recirculating Wet Cooling Towers
Because the cooling tower O&M costs were derived using cost factors that estimate total O&M costs that are based on capital costs, a detailed analysis is not possible. However, using the pumping and fan energy requirements described in the Proposed Rule Development Document, EPA was able to estimate that the O&M energy component was under 50% of the total O&M cost. This energy requirement reduction, coupled with reductions in labor and parts replacement requirements, should result in a fixed cost factor of approximately 50%.

6.3 O&M FIXED COST FACTORS

Table 6-2 and 6-3 present the fixed O&M cost factors for baseline technologies and compliance technologies, respectively, derived using the above assumptions.

Table 6-2
Baseline Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.28
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.30
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.32
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.33
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.31
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.34
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.36
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.38
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Freshwater	0.45
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Freshwater	0.47
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Freshwater	0.48
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Freshwater	0.49
Traveling Screen Without Fish Handling	10 Ft Screen Wells	Saltwater	0.49
Traveling Screen Without Fish Handling	25 Ft Screen Wells	Saltwater	0.51
Traveling Screen Without Fish Handling	50 Ft Screen Wells	Saltwater	0.53
Traveling Screen Without Fish Handling	75 Ft Screen Wells	Saltwater	0.53

Table 6-3
Compliance Technology Fixed O&M Cost Factors

Technology Description	Application	Water Type	Fixed Factor
Aquatic Filter Barrier	All	All	1.0
Add Fish Barrier Net Using Anchors and Bouys	All	Freshwater	1.0
Add Fish Barrier Net Using Pilings for Support	10 Ft Net Depth	Saltwater	1.0
Add Fish Barrier Net Using Pilings for Support	20 Ft Net Depth	Saltwater	1.0
Add Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.21
Add Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	High Debris	All	0.19
Add Very Fine Mesh Passive T-screens to Existing Offshore Intake	Low Debris	All	0.27
Relocate Intake Offshore with Fine Mesh Passive T-screens	High Debris	All	0.46
Relocate Intake Offshore with Fine Mesh Passive T-screens	Low Debris	All	0.56
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	High Debris	All	0.38
Relocate Intake Offshore with Very Fine Mesh Passive T-screens	Low Debris	All	0.49
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Freshwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Freshwater	0.35
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Freshwater	0.37
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Freshwater	0.39
Traveling Screen With Fish Handling and Fine Mesh	10 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling and Fine Mesh	25 Ft Screen Wells	Saltwater	0.38
Traveling Screen With Fish Handling and Fine Mesh	50 Ft Screen Wells	Saltwater	0.40
Traveling Screen With Fish Handling and Fine Mesh	75 Ft Screen Wells	Saltwater	0.41
Traveling Screen With Fish Handling	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen With Fish Handling	25 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	50 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	75 Ft Screen Wells	Freshwater	0.42
Traveling Screen With Fish Handling	10 Ft Screen Wells	Saltwater	0.42
Traveling Screen With Fish Handling	25 Ft Screen Wells	Saltwater	0.43
Traveling Screen With Fish Handling	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen With Fish Handling	75 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	10 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	25 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	50 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	75 Ft Screen Wells	Freshwater	0.40
Traveling Screen Dual-Flow	10 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	25 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	50 Ft Screen Wells	Saltwater	0.44
Traveling Screen Dual-Flow	75 Ft Screen Wells	Saltwater	0.44
Velocity Cap	All	All	1.0
Cooling Towers	All	All	0.5

Chapter 2: Costing Methodology for Model Facilities

INTRODUCTION

This chapter presents the methodology used by the Agency to develop cost estimates for model facilities. For the final rule, the Agency used the cost modules, presented in Chapter 1, to develop cost estimates for 543 model facilities. These model facility costs and other costs of complying with the various requirements of the final rule were then used in the economic analysis to develop unit costs. Unit costs were then assigned to the 554 in-scope facilities, based on the facilities' modeled compliance responses, and aggregated to the national level. See the Economic and Benefits Analysis for the Final Section 316(b) Phase II Existing Facilities Rule for additional information national costs.

The term model facility is used frequently throughout this chapter. The Agency notes that model facilities are not actual existing facilities. Model facilities are statistical representations of existing facilities (or fractions of existing facilities). Therefore, the cost estimates developed for the rule should not be considered to reflect those exactly of a particular existing facility. However, in the Agency's view, the national estimates of benefits, compliance costs, and economic impacts are representative of those expected from the industry as a whole.

1.0 TECHNOLOGY COST MODULES APPLIED TO MODEL FACILITIES

EPA developed the following costing modules for assessing model-facility compliance costs for today's final rule:

1. Fish handling and return system (impingement mortality controls only (I only))
2. Fine mesh traveling screens with fish handling and return (impingement mortality & entrainment controls (I&E))
3. New larger intake structure with fine mesh, handling and return (I&E)
4. Passive fine mesh screens with 1.75 mm mesh size at shoreline (I&E)
5. Fish barrier net (I only)
6. Gunderboom (I&E)
7. Relocate intake to submerged offshore with passive fine mesh screen with 1.75 mm mesh size (I&E)
8. Velocity cap at inlet of offshore submerged (I only)
9. Passive fine mesh screen with 1.75 mm mesh size at inlet of offshore submerged (I&E)
10. Add/modify shoreline tech for submerged offshore (I only or I&E)
11. Add double-entry, single-exit with fine mesh and fish handling and return (I&E)
12. Add passive fine mesh screens with 0.76 mm mesh size at shoreline (I&E)
13. Relocate intake to submerged offshore with passive fine mesh screen with 0.75 mm mesh size (I&E)
14. Passive fine mesh screen at inlet of offshore submerged with 0.75 mm mesh size (I&E)

The derivation and background for each of these technology cost modules is presented in Chapter 1 of this document.

For the final rule, each model facility had three potential compliance actions: (1) no controls for impingement mortality or entrainment, (2) impingement morality controls only, or (3) impingement mortality controls plus entrainment controls. A facility qualifies for compliance action (1) if it has recirculating cooling systems in place or meets the impingement and/or entrainment reduction requirements with controls in-place. Figures 1 and 2 at the end of this section provide a decision tree for assigning compliance actions (2) and (3) to the in-scope Phase II model facilities.

Of the modules listed above, numbers 1, 5, and 8 are dedicated to impingement mortality controls alone. The Agency generally applied the remainder of the technology modules for cases where the model facility received entrainment and impingement requirements.

In the cases that a facility had a functional impingement control system at baseline and was deemed to require upgrades to entrainment controls, the Agency generally assigned costs to the model facility to upgrade the existing impingement mortality controls in addition to the entrainment upgrade. The Agency learned through its research that in the majority of cases when upgrading a technology for entrainment controls, the effort and cost of replacing the attached impingement controls generally compared with the effort and cost to retain and reuse the existing impingement controls (for more details, see the traveling screen technology module documentation in Chapter 1). The Agency assigned entrainment only (with no additional impingement upgrade costs) requirements to a few unique situations for the main option in the final rule. This included the case of a low-velocity, double-entry, single-exit screening system operating in-place at baseline. The Agency assigned only the costs associated with adding fine-mesh overlays for this system because the model facility had additional, redundant impingement technologies in-place. In addition, those facilities with barrier net systems in-place that required entrainment upgrades received only the entrainment system costs, as the existing barrier net would be functional for impingement controls regardless of changes to an intake structure.

The Agency based its approach of assigning costing modules to model facilities on a combination of facility and intake-specific questionnaire data in addition to publicly available satellite photos and maps, where appropriate. Because not all facilities received the same questionnaire, the Agency attempted to utilize data responses to questions that were asked in both the short-technical and detailed questionnaires whenever possible. In the end, the primary difference in data analysis between short-technical (STQ) and detailed questionnaire (DQ) respondents was the level to which the Agency developed costs. The STQ respondents did not provide significant intake-level data, outside of intake identification information and velocity. For instance, for the STQ, the Agency did not obtain intake-specific information on the exact technology in-place for each intake. The Agency instead obtained technology in-place information at the facility-level for STQs. Necessarily, the Agency utilized this facility-level information for the STQ respondents and treated the facility as though it were a single intake with the characteristics reported for the facility. For the DQ respondents, the Agency obtained sufficient intake-level information to develop individual costing decisions for each intake.

The Agency utilized questionnaire data as the primary tool in the assessment of the types of intake technologies and upgrades applied at each model-facility. For those facilities utilizing recirculating cooling systems in-place, the Agency assigned no compliance actions as they meet the requirements at baseline. For those with once-through, combination, other, or unknown cooling system types, the Agency treated the facility as though all intakes were of once-through configuration. The Agency chose this method so as to best estimate the compliance costs, as the Agency's methodology utilizes flow as the independent variable. For example, one intake of three at a facility is recirculating and the others of once-through configuration, then the flow rate of the recirculating intake assigned costs would not be too great in comparison to the once-through flows. See DCN 6-3585 for a discussion of the small effect on costs from this assumption about combination cooling system types The Agency then determined those intakes (facilities) that met compliance requirements with technologies in-place. These facilities received no capital or annual operating and maintenance compliance upgrade costs (although they may receive administrative or monitoring costs). The Agency categorized facilities according to waterbody type from which they withdraw cooling water. The Agency then sorted the intakes (facilities) within each waterbody type based on their configuration as reported in the questionnaires. (Note, as discussed above, the Agency examined short-technical questionnaire facilities on the facility-level and detailed questionnaire respondents by the intake level.)

Generally, the categories of intakes within one waterbody type are as follows: canal/channel, bay/embayment/cove, shoreline, and offshore. Once the intake (facility) is classified to this level the Agency examines the type of technology in-place and compares that against the compliance requirements of the particular intake (facility). For the case of entrainment requirements, the intake technologies (outside of recirculating cooling) that qualify to meet the requirements at baseline are fine mesh screen systems, and combinations of far-offshore inlets with passive intakes or fish handling/return systems. A small subset of intakes has entrainment qualifying technologies in-place at baseline (for the purposes of this costing effort). The Agency estimates that intakes at 24 facilities would pre-qualify for the entrainment requirements and avoid costs of such upgrades. Therefore, in the case of entrainment requirements, most facilities with the requirement would receive technology upgrades. The methodology for choosing these entrainment technology upgrades is explained further on in this discussion. For the case of impingement requirements, there are a variety of intake technologies that qualify (for the purposes of this costing effort) to meet the requirements at baseline. The intake types meeting impingement requirements at baseline include the following: barrier net, passive intakes (of a variety of types), and fish handling and return systems. A significant number of intakes (facilities) have impingement technology in-place that meets the qualifications for this costing effort. The Agency estimates that intakes at 87 facilities would pre-qualify for the impingement requirements and avoid costs of such upgrades. Therefore, some intakes (facilities) require no technology upgrades when only impingement requirements apply.

For facilities that do not pre-qualify for impingement and/or entrainment technology in-place (for the purposes of this costing effort), the Agency focuses next on questionnaire data relating to the intake type – canal/channel, bay/ embayment/cove, shoreline, and offshore. Within each intake type, the Agency further classifies according to certain specific characteristics. For the case of bays, embayments, and coves, the Agency determined if the intake is flush, protruding, or recessed from shoreline. For the case of canals and channels, the Agency similarly focuses on whether the intake is flush, protruding, or recessed from a shoreline. In addition, the Agency calculates an approximate approach velocity using reported information on the canal flow rate and cross-sectional area, where applicable (specific to detailed questionnaire respondents only). The approximated approach velocity aided the Agency in verifying the reported mean intake velocity. For the case of shoreline intakes, the Agency necessarily assessed whether the intake is flush, protruding, or recessed. For the case of offshore intakes, the Agency attempted to examine whether or not the intake has an onshore terminus (or well) and assesses the characteristics of the onshore system. The Agency found that very few facilities with offshore intakes reported consistent and clear information about onshore wells. Therefore, the Agency chose to develop costs for onshore intakes without using technology module 10.

The information the Agency gathers up to this point is sufficient to narrow down the likely technology applications for each intake (facility). However, in order to determine the best technology application, the Agency also utilizes publicly available satellite images and maps where appropriate. The use of the satellite images and maps aided the Agency in determining the potential for the construction of expanded intakes in-front of existing intakes, the possibility of installing a barrier net system, and the potential for an intake modification to protrude into the waterbody (such as a near-shore t-screen) due to the degree of navigational traffic in the near vicinity of the intake and whether a protrusion might be tolerated. The satellite images also helped identify obvious signs of strong currents, the relative distance of a potentially relocated intake inlet, the possibility for fish return installations of moderate length, etcetera. The Agency was able to collect satellite images for most intakes (facilities) for which it required the resource. However, in some cases (especially those in the rural, mid-western US), only maps were available. Hence, for the case of a significant number facilities located near small freshwater rivers/streams and lakes/reservoirs, the Agency utilized only the questionnaire data and the overhead maps available.

The Agency prepared the following crosswalk and breakdown of the application of the technology modules. The following sections provide the factors that the Agency used in determining the proper technology application and explain any exceptions to these cases.

Module 1 - Add Fish Handling and Return System: This technology applies for the case of impingement only upgrades. The Agency applied this technology generally to facilities that when requiring the impingement only upgrade had an existing traveling screen system. The Agency applied this technology generally when the intake velocity of the intake (facility) was roughly 1 ft/sec or below. The rationale behind applying this technology in this case is that because the intake velocity is relatively low and the existing traveling screen system is functional, the fish handling and return system could be added to the operating system and would perform under these conditions. Vendors noted that approximately 75% of the existing screen components would require replacement when adding fish handling and return. It would be more prudent to replace the entire screen unit. (See the traveling screen cost module in Chapter 1 of this document.)

Module 2 - Add Fine Mesh Travelling Screens with or without Fish Handling and Return: This technology generally applies for the case of impingement and entrainment upgrades. The Agency applied this technology to intakes (facilities) with an existing traveling screen system in-place. The Agency applied this technology when the intake velocity was roughly 1 ft/sec or below. The rationale behind the application is similar to that of Module 1, in that the low existing velocity allowed for replacement of the existing screen overlays without expanding the size of the intake appreciably to lower the velocity. As a general approach, the Agency applied this technology to a variety of waterbody types and intake locations (such as in canals, in coves, and along shorelines). In addition to adding fine-mesh screens that this technology also may replace the fish handling and return system of the intake. When the replacement of fish handling scenario is applied it requires replacement of all screen units with units that include fish handling and return features plus additional spray water pumps and a fish return flume. For those facilities with existing functional fish handling and return systems, the Agency may have applied fine mesh screen overlay panels only. See the documentation for this particular module in Chapter 1 of this document for more information.

Module 3 - Add New Larger Intake Structure with Fine Mesh, Handling and Return: This technology generally applies for the case of impingement and entrainment upgrades. However, in a few select cases, the Agency applied it for the case of impingement only, more on that below. The Agency applied this technology to intakes with a variety of onshore configurations. The Agency applied this technology when the intake velocity was appreciably above 1 ft/sec. The rationale behind the application is that demonstrated cases of operable fine-mesh screening systems for large plants have used design velocities of approximately 1 ft/sec. Because of the velocity implications, the Agency necessarily required certain intakes (facilities) to enlarge their intakes. Therefore, these intakes would be constructed anew in front of an existing structure and tied in towards the end of the construction project. As a general approach, the Agency applied this technology to a variety of waterbody types and intake locations (such as in canals, in coves, and along shorelines). Note that the Agency verified (through observation of satellite images and overhead maps) that sufficient open water area existed in front of the existing intake, and that the new protruding intake would not hinder boat traffic. In a select few cases, the intake velocity of a facility complying with the impingement only requirements was extremely high (ie, above 3 ft/s). In these cases, the Agency may have applied this module to allow for proper operation of the impingement technologies.

Modules 4 and 12 - Add Passive Fine Mesh Screens at Shoreline: This technology applies mostly for the case of entrainment and impingement upgrades. Module 12 applied to ocean and estuarine environments and module 4/12 to all others. The Agency applied this technology generally in a very similar fashion to Module 3 above. The primary difference for their applications is that Module 4/12 is slightly more flexible in its location than Module 3 and that Module 4/12 has the ability to be retrofitted to unusual intake structures, such as protruding intakes, submerged shoreline intakes, etc. In addition, the passive wedgewire t-screen system is very well suited for application where currents are present, as the system is designed to utilize currents for controlling impingement. The Agency applied this technology generally when the intake velocity of the intake (facility) was above roughly 1 ft/sec. However, that is not exclusively the case, as there were exceptions where even for low velocity, unusual passive screen systems, the Agency upgraded these intakes with Module 4/12. This module, similarly to Module 3 above, would apply for a select few cases that had extremely high intake velocities, even though they were required to comply with impingement only.

Module 5 - Add Fish Barrier Net: The Agency applied the barrier net module to control impingement, both in the case of impingement only upgrades and in a few cases for the combined impingement/entrainment upgrades. As a general rule, the Agency applied the barrier net only to cases where it could acertain that a favorable geographical condition existed, such as the case of a wide mouth canal without boat traffic and low current potential, the similar conditions in a wide mouth cove/bay, and the similar conditions for a lake/reservoir shore. In a select number of situations, the Agency applied both the fish barrier net system and an entrainment controlling system. Generally, this was for the case that a fish handling and return system could not reasonably be configured to deliver impinged fish safely away from the intake. Therefore, the barrier net served the purpose of preventing the cyclical impingement/reimpingement condition in several cases. The Agency did not examine intake velocities when applying barrier nets. Instead, the Agency focused on the configuration of the intake and its adjoining shorelines and sized the net according to an empirical, through-net velocity.

Module 6 - Marine Life Exclusion System (gunderboom): The Agency applied the gunderboom system to several intakes for the final rule analysis. The Agency examined the set of intakes according to similar criteria as for barrier nets (module 5 above), with respect to entrainment and impingement upgrade requirements. If an intake had an extremely high intake velocity (above 3 ft/sec), an below average intake flow, a suitable environment for a gunderboom system, similar to that for the barrier net technology described above, and no other entrainment options appeared reasonable, the Agency considered applying the gunderboom. This was a very small set of intakes, several of which the Agency did not have sufficient information to determine the potential wave/current activity, nor navigation traffic. Hence, the Agency applied the gunderboom in only a small set of cases for entrainment and impingement upgrades. It is likely that the Agency has underestimated the degree to which the gunderboom system could be applied in the final analysis, due to data uncertainty and its concern for applying the best technology for known site conditions. This had the effect of potentially biasing costs upward for entrainment controls in select cases, as the gunderboom system is less expensive than some other entrainment control technologies.

Modules 7 and 13 - Relocate Intake to Submerged Offshore with Passive Screen: The Agency applied these costing modules to address impingement and entrainment requirements. The Agency applied these module, generally, to any waterbody for which there was a clear advantage to its implementation. The module 13 was used for estuarine and ocean waters, and module 7 for all others. What the Agency defined as an advantage for this module generally related to the fact that an onshore intake or short canal intake provided no clear avenue for applying one of the velocity reducing modules, such as numbers 3 and 4. As a rule the Agency applied the relocation of an intake to submerged offshore only for cases where the existing intake velocity was significantly above 1 ft/s. At the NODA, the Agency relied on this module to represent situations where there was not one module that stood out as the clear choice solution, but in response to comments did not use that approach for the final rule. Instead, the Agency applied the module in a portion of the cases where no clear entrainment module choice stood out, balancing the number and distribution of applications so as not to bias costs upward above the median cost for entrainment controls in the final analysis. Contrary to intuition, the Agency learned in its research of offshore submerged intakes that a good number are used in river environments. Hence, the Agency utilized this module in several cases for large rivers. The relocation distance utilized for each case was that derived from the median of those within the intake's waterbody class.

Module 8 - Add Velocity Cap at Offshore Inlet: The Agency applied a velocity cap at the inlet of a submerged offshore pipe in several cases to address impingement only requirements. The prerequisite for this module was that the intake/facility had to have a submerged offshore intake with no reported impingement controls. This combination was not too common, as a significant portion of submerged offshore intakes had either passive offshore intake inlets or fish handling systems onshore. However, for the small number of cases where facilities did not have impingement controls (or at least did not report them in the questionnaire), the Agency applied this module to meet the impingement only requirements. As a general rule, the Agency has reservations about the ability of a velocity cap system to meet the numerical requirements of the impingement standards. However, it should be noted that in the case of offshore intakes that the "location" of an intake can be considered for the compliance action. Therefore, an offshore intake with a velocity cap is a combination that the Agency feels reasonably represents the costs of complying with the impingement requirements.

Modules 9 and 14 - Add Passive Fine Mesh Screen at Inlet of Offshore Submerged: The Agency applied a passive, fine-mesh, wedgewire, t-screen system at the inlet of a submerged offshore pipe to address impingement and entrainment requirements. Module 14 applied to ocean and estuarine environments and module 9 to all others. The prerequisite for this module was that the intake/facility had to have a submerged offshore intake with no reported entrainment controls. In some cases, the intake (facility) may have reported impingement controls, but the Agency generally ignored these controls and presumed that the installation of the passive fine mesh at the offshore inlet would suffice to control both entrainment and impingement effectively. This module obviously is one of the simplest in application, as it is clear for all intakes (facilities) through the questionnaire whether or not their intake is submerged offshore. The primary nuance for this situation exists where the intake (facility) may have reported both offshore inlet controls and onshore screening controls. See module 10 for more discussion of onshore screening technologies for submerged offshore intakes. For the purposes of the discussion of this module, it should be noted that the Agency treated the existence of an offshore inlet as the primary location for the application of a compliance technology over an onshore modification where both pre-existed.

Module 10 - Add/Modify Shoreline Tech for Submerged Offshore: The Agency did not apply this module for any of the intakes/facilities for the final rule. Even though this technology would be a reasonable method for an intake (facility) to comply with the rule, the Agency chose not to use it. The basic reason that the Agency did not use the technology was due to an incomplete and unclear data set on the existence and type of onshore wells for offshore intakes. In addition, in most cases where entrainment controls would be required this method did not allow the reconfigured intake to be enlarged in order to lower the intake velocity. In addition, the passive screen intake at the inlet of the offshore pipe was slightly more expensive. From the perspective of a range of facilities, the passive screen is likely more applicable for a wider range of applications.

Module 11 - Add Double-Entry, Single-Exit with Fine Mesh, Handling and Return: This would be a useful application for facilities attempting to comply with the impingement and entrainment requirements in the narrow terminus of a canal or cove. Additionally, in cases where the intake is recessed from shore, this technology can be applied to shoreline applications. The Agency generally applied this technology to canal facilities and when the intake velocity was roughly 1 ft/sec. The Agency mistakenly assumed for the NODA analysis that this module would lower the through-screen velocity for an intake without enlarging the intake structure. This is not the case, the Agency learned upon further research. However, the Agency did confirm that this module will offer considerable advantage in some high debris situations over a conventional flat-panel traveling screen, as the configuration allows for reduced debris carry through. Hence, the Agency chose to apply this type of technology as the standard for the screening portion of module 3, new expanded intake. This module may require clear space in front of the structure, which the Agency considered in its application.

2.0 EXAMPLES OF THE APPLICATION OF TECHNOLOGY COST MODULES TO MODEL FACILITIES

Because the determination of the best technology application depends on a variety of factors and there is a large population of intakes to which these multiple factors apply, the Agency views a series of examples as the best means for demonstrating the logical progression that it applied to the decisions. Based on the classification system described above, the Agency presents examples of each major intake type – canal/channel, bay/ embayment/cove, shoreline, and offshore– to aid the understanding of the Agency's costing assignment process.

Example 1: Canal or Channel Intake

In this example, an intake withdraws cooling water through a canal branching off a tidal river. The intake is a shoreline intake, flush with the shore and built at the terminus of the canal. Based on its characteristics, the facility is subject to impingement and entrainment requirements. The detailed questionnaire reports that the existing intake is a coarse-mesh traveling screen with a fish diversion system in-place. The Agency determined that the reported fish diversion technology in-place was a fish-bypass technology. The reported mean intake velocity is 1.0 ft/s, and the Agency calculated the approximate canal approach velocity as 1.1 ft/s based on the canal cross-sectional area and canal flow rate reported in the questionnaire. Therefore, the Agency concludes that the reported intake velocity is accurate. The canal length is reported at 100 ft. Both the overhead map and satellite photo demonstrate that the intake is close to this estimated length. In addition, the Agency observes that the intake location at the terminus of the canal is less than 100 feet from the bank of the tidal river. The Agency determines that the mouth of the canal is not significantly wider than the canal itself and that the apparent route of boat navigation is to utilize a portion of the canal for barge docking and traffic.

Based on the above factors, the Agency determines that the best technology for this model intake application is to add fine mesh traveling screen with fish handling and return system. The Agency studied existing cases of retrofit fine-mesh screen applications and found the 1 ft/s threshold a reliable design criterion for large intake systems where surface area can be constricted. Therefore, in this case, the existing screen system is sufficiently large to accommodate fine-mesh. The fish handling and return system in this case addresses the impingement control requirements. Because the canal is not long and the return branch would be of reasonable length, the Agency considered the fish handling and return system to be appropriate. The existing fish by-pass system is not considered to be adequate (in and of itself) for meeting the impingement requirements of the national rule. In addition, the navigational use of the canal and the canal's limited throat width necessarily prevents the use of a barrier net system.

In this case, the Agency determines that the debris loading potential near the intake is high. This is due to the clear evidence of boat/barge traffic and the known nature of the particular tidal river from which this facility withdraws water.

Example 2: Bay/Embayment/Cove

In this example, an intake withdraws cooling water from a Great Lake. The intake is a shoreline intake, flush with shore and built at the terminus of the cove. Based on its characteristics, the facility is subject to impingement and entrainment requirements. The detailed questionnaire reports that the existing intake is a coarse-mesh traveling screen with no impingement reducing technologies in-place. The reported mean intake velocity is 2.0 ft/s. Both the overhead map and satellite photo demonstrate that the cove recedes approximately 500 ft from the main water body. The Agency determines that the mouth of the cove is approximately 250 feet in width. Based on the overhead map and satellite image, there is no evidence of boat traffic in the cove. The onshore access routes of the plant apparently meet the fuel delivery needs of the plant.

Based on the above factors, the Agency determined that the best technology for this model intake application is construction of a new, larger intake directly in front of the existing structure. The reason that the Agency utilized a new, larger intake system in this case is that the velocity of the intake is significantly above 1 ft/s and the there is ample room directly in front of the existing intake to allow for the larger intake. The larger intake system provides increased surface area (compared to the existing single-entry, single-exit system), thereby reducing the intake velocity to a level that would facilitate use of the fine-mesh system. Alternatively, the Agency could have applied the gunderboom technology, but the flow of the intakes implied that the size of the system would be far larger than other planned and demonstrated cases of the technology.

A fish handling and return system in this case would be difficult to implement due to the orientation of the deep cove. Therefore, the Agency determined that a barrier net system would address the impingement requirements imposed on the intake. The Agency would be concerned about the creation of a cyclical impingement condition, which would exacerbate the strain on the organisms. A 500-foot return system could be built, but the alternative system of a barrier net is favorable for this particular situation, in the Agency's view. The lack of navigational use of the cove and the cove's wide throat provides a good environment for barrier net deployment.

In this case, the Agency determines that the debris loading potential near the intake is low. This is due to the lack of boat/barge traffic evidence and the known nature of the particular Great Lake from which this facility withdraws water.

Example 3: Shoreline

In this example, an intake withdraws cooling water from a freshwater river. The facility withdraws more than 5 percent of the mean annual flow of this river, even though this is a large river. Hence, it is subject to impingement and entrainment requirements. The intake is a shoreline intake, protruding from shore. The Agency determined that the intake extends 10 feet into the waterbody by examining the satellite imagery and overhead maps, using the reported latitude and longitude of the intake. The Agency also observes that the apparent river width at the intake location is well over 200 feet. The intake is located on a straight section of river, and an approximately 25 foot protruding diversion wall protects the intake from river debris and traffic. The detailed questionnaire reports that the existing intake is a coarse-mesh traveling screen with a fish handling and return system. The reported mean intake velocity is 3.0 ft/s. Based on the satellite images, there is evidence of coal barge traffic near the intake, but significantly far away to allow for the protruding intake.

Based on the above factors, the Agency determines that the best technology for this model intake application is construction of a fine-mesh, cylindrical, wedge wire t-screen system. This passive intake would be constructed to branch from the original protruding intake. In the Agency's view, the wedge wire t-screen system will address the impingement and entrainment requirements imposed on the intake. The reason that the Agency utilized a new intake system in this case is that the velocity of the intake is significantly above 1 ft/s and there is already precedence to allow for a protruding intake. With the construction of a properly sized replacement intake, the velocity can be lowered for entrainment and impingement controls, and the current of the river can be utilized to aid the operation of the intake. Another alternative would be to use a new, larger intake protruding into the waterbody as in the cove example above. Both of the larger intake system provides increased surface area (compared to the existing single-entry, single-exit system), thereby reducing the intake velocity to a level that would facilitate use of the fine-mesh system. However, the wedgewire screen system would provide additional advantages in the form of inherent impingement controls. A fish handling and return system with a traditional traveling system could be an option. Alternatively, the Agency could have applied a relocated intake to the center of the river and applied fine-mesh passive screens. For other cases where the Agency encountered similar conditions, the Agency did vary the application of modules so as to achieve a set of costs about the median cost technology.

In this case, the Agency determines that the debris loading potential near the intake is high. This is due to the clear evidence of boat/barge traffic and the known nature of the particular river from which this facility withdraws water.

Example 4: Offshore

In this example, an intake withdraws cooling water from a submerged offshore intake in an Ocean. At the offshore inlet of the intake is a passive intake built approximately 500 feet from shore. The facility is a short-technical questionnaire facility, and the Agency has no information as to whether or not the intake delivers water to an onshore well. Based on observations of the satellite imagery, the Agency was also unable to identify an onshore well. Based on its characteristics, the facility requires neither an entrainment nor impingement technology upgrade. The existing intake – a passive screen system – is insufficient to meet the entrainment requirements in and of itself. However, in combination with the offshore intake location, the intake meets both requirements.

3.0 REGIONAL COST FACTORS

As described in the sections above, the Agency developed technology-specific cost estimates for model facilities using the cost modules presented in Chapter 1. However, capital construction costs can vary significantly for different locations within the United States. Therefore, to account for these regional variations, EPA adjusted the capital cost estimates for the existing model plants using zip-code based cost factors. The applicable cost factors were multiplied by the facility model cost estimates to obtain the facility location-specific capital costs used in the impact analysis. The Agency derived the site-specific capital cost factors from the "location cost factor database" in RS Means Cost Works 2001. The Agency used the weighted-average factor category for total costs (including material and installation). The RS Means database provides cost factors (by 3-digit Zip code) for numerous locations.

4.0 REPOWERING FACILITIES AND MODEL FACILITY COSTS

Under this final rule certain forms of repowering could be undertaken by an existing power generating facility that uses a cooling water intake structure and it would remain subject to regulation as a Phase II existing facility. For example, the following scenarios would be existing facilities under the rule:

- An existing power generating facility undergoes a modification of its process short of total replacement of the process and concurrently increases the design capacity of its existing cooling water intake structures;

- An existing power generating facility builds a new process for purposes of the same industrial operation and concurrently increases the design capacity of its existing cooling water intake structures;

- An existing power generating facility completely rebuilds its process but uses the existing cooling water intake structure with no increase in design capacity.

Thus, in most situations, repowering an existing power generating facility would be addressed under this final rule.

As discussed in the preamble, the section 316(b) Survey acquired technological and economic information from facilities for the years 1998 and 1999. With this information, the Agency established a subset of facilities potentially subject to this rule. Since 1999, some existing facilities have proposed and/or enacted changes to their facilities in the form of repowering that could potentially affect the applicability of the final rule or a facility's compliance costs. The Agency therefore conducted research into repowering facilities for the section 316(b) existing facility rule and any information available on proposed changes to their cooling water intake structures. The Agency used two separate databases to assemble available information for the repowering facilities: RDI's NEWGen Database, November 2001 version and the Section 316(b) Survey.

In January 2000, EPA conducted a survey of the technological and economic characteristics of 961 steam-electric generating plants. Only the detailed questionnaire, filled out by 283 utility plants and 50 nonutility plants, contains information on planned changes to the facilities' cooling systems (Part 2, Section E). Of the respondents to the detailed questionnaire, only six facilities (three utility plants and three nonutility plants) indicated that their future plans would lead to changes in the operation of their cooling water intake structures.

The NEWGen database is a compilation of detailed information on new electric generating capacity proposed over the next several years. The database differentiates between proposed capacity at new (greenfield) facilities and additions/modifications to existing facilities. To identify repowering facilities of interest, the Agency screened the 1,530 facilities in the NEWGen database with respect to the following criteria: facility status, country, and steam electric additions. The Agency then identified 124 NEWGen facilities as potential repowering facilities.

Because the NEWGen database provides more information on repowering than the section 316(b) survey, the Agency used it as the starting point for the analysis of repowering facilities. Of the 124 NEWGen facilities identified as repowering facilities, 85 responded to the section 316(b) survey. Of these 85 facilities, 65 are in-scope and 20 are out of scope of this rule. For each of the 65 in scope facilities, the NEWGen database provided an estimation of the type and extent of the capacity additions or changes planned for the facility. The Agency found that 36 of the 65 facilities would be combined-cycle facilities after the repowering changes. Of these, 34 facilities are projected to decrease their cooling water intake after repowering (through the conversion from a simple steam cycle to a combined-cycle plant). The other 31 facilities within the scope of the rule would increase their cooling water intake. The Agency examined the characteristics of these facilities projected to undergo repowering and determined the waterbody type from which they withdraw cooling water. The results of this analysis are presented in Table 2-2.

Of the 65 in scope facilities identified as repowering facilities in the NEWGen database, 24 received the detailed questionnaire, which requested information about planned cooling water intake structures and changes to capacity. Nineteen of these 24 facilities are utilities and the remaining five are nonutilities. The Agency analyzed the section 316(b) detailed questionnaire data for these 24 facilities to identify facilities that indicated planned modifications to their cooling systems (in the NEWGen database) which will change the capacity of intake water collected for the plant and the estimated cost to comply with today's rule. Four such facilities were identified, two utilities and two nonutilities. Both utilities responded that the planned modifications will decrease their cooling water intake capacity and that they do not have any planned cooling water intake structures that will directly withdraw cooling water from surface water. The two nonutilities, on the other hand, indicated that the planned modifications will increase their cooling water intake capacity and that they do have planned cooling water intake structures that will directly withdraw cooling water from surface water.

Table 2-2: In-Scope Existing Facilities Projected to Enact Repowering Changes

Waterbody Type	Repowering Facilities Projected to Increase Cooling Water Withdrawals	Repowering Facilities Projected to Decrease or Maintain Cooling Water Withdrawals
Ocean	N/A	N/A
Estuary/Tidal River	3	17
Freshwater River/Stream	14	10
Freshwater Lake/Reservoir	10	1
Great Lakes	0	1

Using the NEWGen and section 316(b) detailed questionnaire information on repowering facilities, the Agency examined the extent to which planned and/or enacted repowering changes would effect cooling water withdrawals and, therefore, the potential costs of compliance with this final rule. Because the Agency developed a cost estimating methodology that primarily utilizes design intake flow as the independent variable, the Agency examined the extent to which compliance costs would change if the repowering data summarized above were incorporated into the cost analysis of this rule. The Agency determined that projected compliance costs for facilities withdrawing from estuaries could be lower after incorporating the repowering changes. The primary reason for this is the fact that the majority of estuary repowering facilities would change from a steam cycle to a combined-cycle, thereby maintaining or decreasing their cooling water withdrawals (note that a combined-cycle facility generally will withdraw one-third of the cooling water of a comparably sized full-steam facility). Therefore, the portion of compliance costs for regulatory options that included flow reduction requirements or technologies could significantly decrease if the Agency incorporated repowering changes into the analysis. As shown in Table 2-2 the majority of facilities projected to increase cooling water withdrawals due to the repowering changes use freshwater sources. In turn, the compliance costs for these facilities would increase if the Agency incorporated repowering for this final rule.

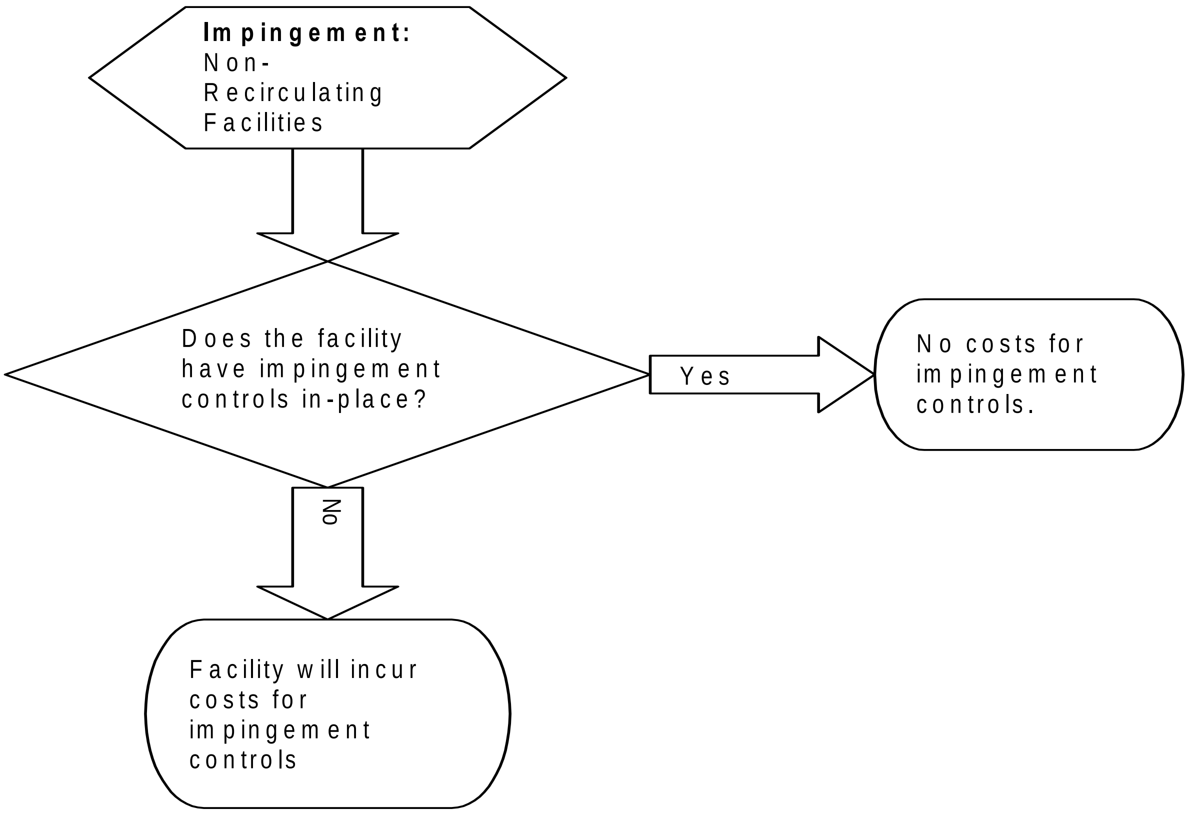


Figure 1. Impingement Controls Flowchart for Model Facility Compliance Costs

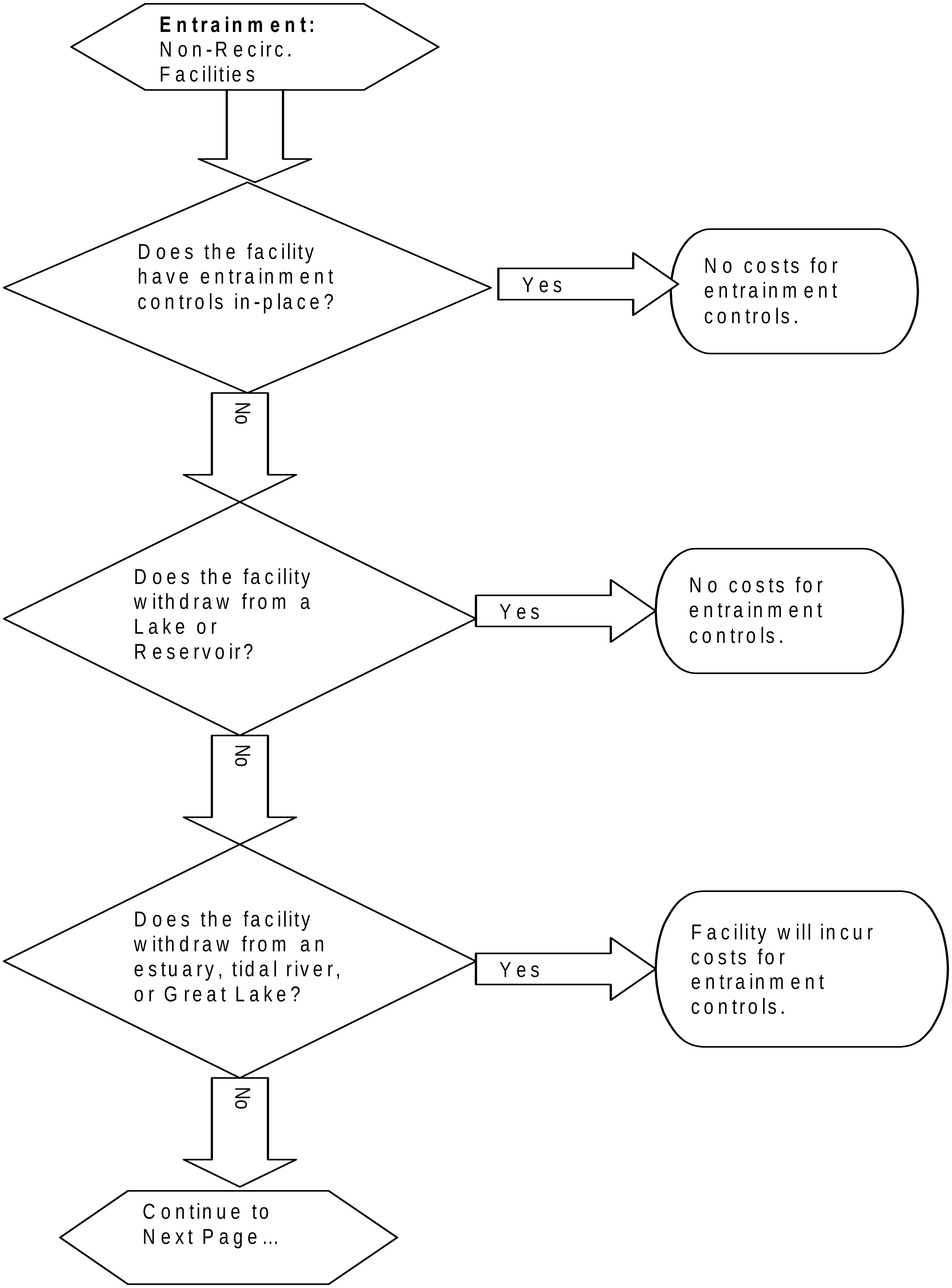


Figure 2. Entrainment Controls Flowchart for Model Facility Compliance Costs

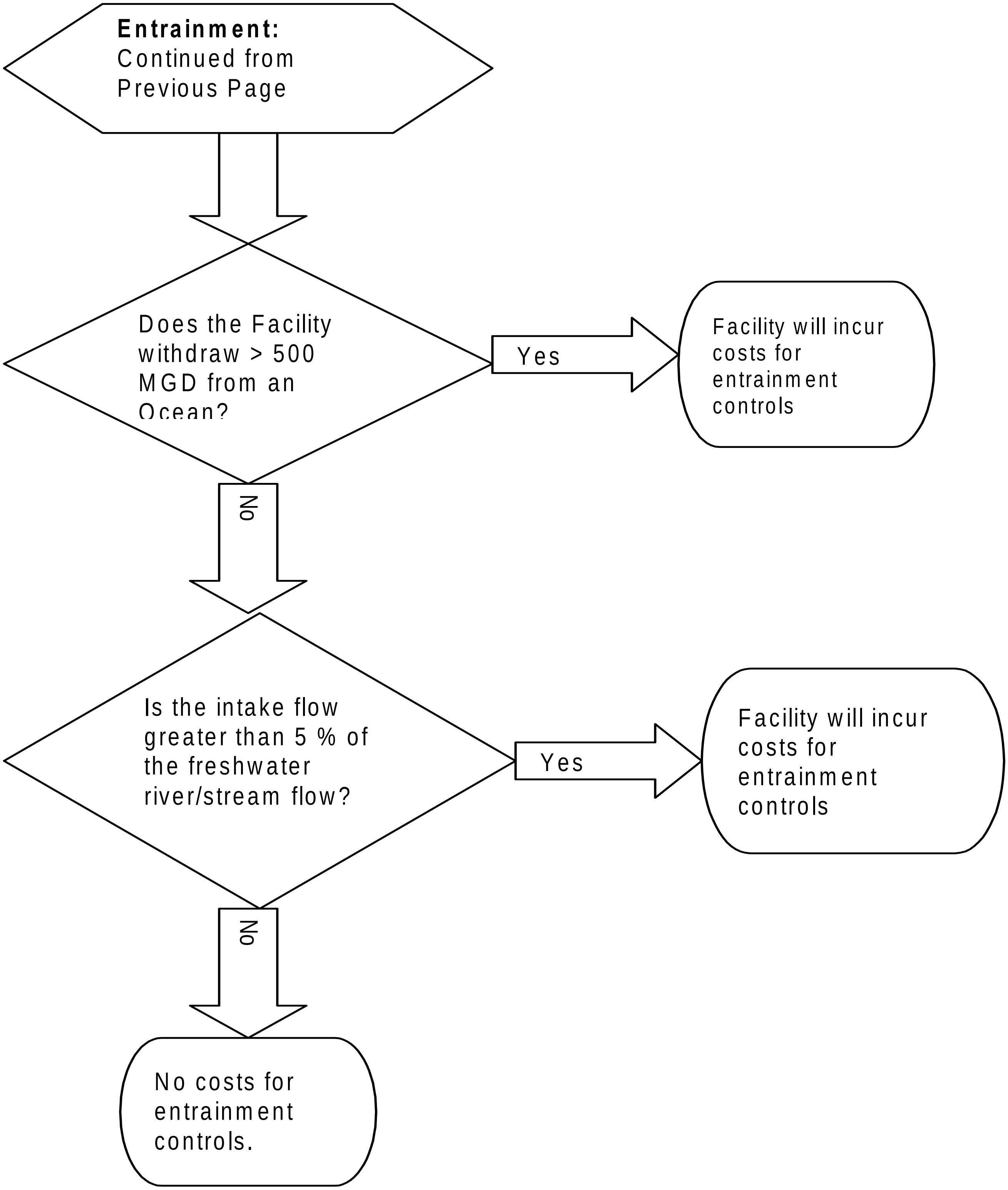


Figure 2 (cont.). Entrainment Controls Flowchart for Model Facility Compliance Costs

Chapter 3: Cost to Cost Test

INTRODUCTION
This chapter presents the cost-cost test for alternative site-specific requirements. The first two sections present the requirements of the cost-cost test and the data needs to carry out the test. Section 3 presents the step-by-step instructionf for carrying out the cost-cost test and the tabular data to be used with the cost-cost test. Section 4 presents the background information that supports the cost correction equations.

1.0 SITE SPECIFIC REQUIREMENTS - THE COST TO COST TEST

The final rule in § 125.94(a) (2) through (4) allows for a comparison between the projected costs of compliance of a facility (based on data specific to the facility) to the costs considered by the Agency for a facility like yours. A facility requesting a cost cost determination must submit a Comprehensive Cost Evaluation Study and a Site Specific Technology Plan, the requirements of each can be found at §125.94(b)(6)(i) and 125.94(b)(6)(iii), respectively. The Comprehensive Cost Evaluation Study must include engineering cost estimates in sufficient detail to document the costs of implementing design and construction technologies, operational measures, and/or restoration measures at the facility that would be needed to meet the applicable performance standards of the final rule; a demonstration that the documented costs significantly exceed the costs considered by EPA for a facility like yours in establishing the applicable performance standards; and engineering cost estimates in sufficient detail to document the costs of implementing alternative design and construction technologies, operational measures, and/or restoration measures in the facility's Site-Specific Technology Plan. If the facility's costs are significantly greater than the costs considered by the Agency for a facility like yours, then the Director may make a site-specific determination of the best technology available for minimizing adverse environmental impact.

2.0 DETERMINING COSTS

To make the demonstration that compliance costs are significantly greater than those considered by EPA, the facility must first determine its actual compliance costs. To do this, the facility first should determine the costs for any new design and construction technologies, operational measures, and/or restoration measures that would be needed to comply with the requirements of § 125.94 (a)(2) through (4), which may include the following cost categories: the installed capital cost of the technologies or measures, the net operation and maintenance (O&M) costs for the technologies or measures (that is, the O&M costs for the final suite of technologies and measures once all new technologies and measures have been installed less the O&M costs of any existing technologies and measures), the net revenue losses (lost revenues minus saved variable costs) associated with net construction downtime (actual construction downtime minus that portion which would have been needed anyway for repair, overhaul or maintenance) and any pilot study costs associated with on-site verification and/or optimization of the technologies or measures.

Costs should be annualized using a 7 percent discount rate, with an amortization period of 10 years for capital costs and 30 years for pilot study costs and construction downtime net revenue losses. Annualized costs should be converted to 2002 dollars ($2002), using the engineering news record construction cost index (see Engineering News-Record. New York: McGraw Hill. Annual average value is 6538 for year 2002). Costs for permitting and post-construction monitoring should not be included in this estimate, as these are not included in the EPA-estimated costs against which they will be compared, as described below. Because existing facilities already incur monitoring and permitting costs, and these are largely independent of the specific performance standards adopted and technologies selected to meet them, it is both simpler and more appropriate to conduct the cost comparison required in this provision using direct compliance costs (capital, net O&M, net construction downtime, and pilot study) only. Adding permitting and monitoring costs to both sides of the comparison would complicate the methodology without substantially changing the results.

To calculate the costs that the Administrator considered for a like facility in establishing the applicable performance standards, the facility must follow the steps laid out below, based on the information in Table 3-2 provided in Section 3.0 of this chapter. Note that those facilities that claimed the flow data that they submitted to EPA, and which EPA used to calculate compliance costs, as confidential business information (CBI), are not listed in the table provided in Table 3-2, unless the total calculated compliance costs were zero. If these facilities wish to request a site-specific determination of best technology available based on significantly greater compliance costs, they will need to waive their claim of confidentiality prior to submitting the Comprehensive Cost Evaluation Study so that EPA can make the necessary flow data available to the facility, Director, and public.

Cost Categories Considered By The Agency

The installed **capital cost** of the technology (suite) represents the material, equipment, and labor costs of the technology and retrofit, the civil and site work costs, instrumentation and controls, electrical (installed), construction management, engineering and architectural fees, contingency, overhead and profit, non-316(b) related permits, metalwork, performance bond, and insurance. Once determined by the facility, the capital costs for comparison to the Agency's estimates must be amortized with a 7 percent discount factor and a 10 year amortization period. The dollar years of the capital costs must be expressed in 2002 average dollars. The Agency used the Engineering News-Record Construction Cost Index (McGraw-Hill, New York, NY) for estimating dollar year values. The capital costs are presented in pre-tax form for the cost to cost comparison.

The **net operation and maintenance costs** of the technology or technology suite is the projected operation and maintenance costs of the upgraded intake technology, post-construction and start-up, less the operation and maintenance costs of the cooling water intake structures(s) in-place at the facility prior to enacting the technology upgrade. The Agency considered the periodic replacement of parts, the periodic and intermittent maintenance of the technology (such as debris clearing, parts changeout, etc.), the periodic and intermittent inspection of the technology, the energy usage of screen motors and spray wash and fish return pumps, and management/technician labor. Additional factors may apply for special intakes located far offshore, such as diver inspections, or for net systems or wedgewire screens, such as energy and maintenance costs associated with self-cleaning airburst systems. The Agency notes that for the technologies considered for meeting the requirements of the final rule that cooling water intake flows did not change from baseline to the technology upgrade. As a result the operation and maintenance of the main cooling water intake pumps would typically not be considered a component of a net operation and maintenance cost for the purposes of the cost to cost test. Some facilities may choose to comply with the requirements of the rule by adopting strategic flow reduction activities. As such, reduced O&M costs associated with reduced intake flows for strategic plant operation should not be factored into the compliance comparison of costs, as the Agency did not account for these savings in its cost estimates. Similarly, if dredging of canals or screen areas was a typical portion of the maintenance activities of the site at baseline, then the net operation and maintenance costs for the purposes of the cost to cost test may not include these costs. The Agency represented O&M costs on an annual basis. The O&M costs are presented in pre-tax form for the cost to cost comparison.

The Agency determined the cost of the technology connection outage **downtime** as the revenue loss during the downtime less the variable expenses that would normally be incurred during that period. The duration of the connection outage should be the total construction outage less any concurrent outages due to planned maintenance. The Agency notes that with the flexible compliance scheduling allowed with the final rule that facilities will have opportunities to plan construction schedules to take advantage of concurrent downtime periods (such as period inspections and maintenance outages). The following formulas were used to calculate the net loss due to downtime:

$$\textit{Cost of Connection Outage} = \textit{Revenue Loss} - \textit{Variable Production Costs}$$

where

$$\textit{Variable Production Cost} = \textit{Fuel Cost} + \textit{Variable Operating} \wedge \textit{Maintenance Cost}.$$

The Agency amortized net construction downtime costs using a discount rate of 7 percent and an amortization period of 30 years. The downtime costs are presented in pre-tax form for the cost to cost comparison.

The technology **pilot study** costs associated with site verification of the technology estimated by the Agency included the total capital and total operation and maintenance costs associated with a technology pilot study. Because pilot studies, by their nature, are short term activities, the Agency represented the total cost of the study as a one-time capital cost, even though the actual study may be extend out over a half-year to two-years; the total cost of the study was represented as a single one-time cost. Therefore, facilities enacting pilot studies should represent the total costs of the pilot study in a similar manner. Similar to a construction project lasting several months to years, some minor correction for dollar years may be necessary. The Agency amortized total capital costs using a discount rate of 7 percent and an amortization period of 30 years. The pilot study costs are presented in pre-tax form for the cost to cost comparison.

Site-specific Technology Plan

The Site-Specific Technology Plan is developed based on the results of the Comprehensive Cost Evaluation Study and must contain the following information:

- A narrative description of the design and operation of all existing and proposed design and construction technologies, operational measures, and/or restoration measures that you have selected;
- An engineering estimate of the efficacy of the proposed and/or implemented design and construction technologies or operational measures, and/or restoration measures. This estimate must include a site-specific evaluation of the suitability of the technologies or operational measures for reducing impingement mortality and/or entrainment (as applicable) of all life stages of fish and shellfish based on representative studies (e.g., studies that have been conducted at cooling water intake structures located in the same waterbody type with similar biological characteristics) and, if applicable, site-specific technology prototype or pilot studies. If restoration measures will be used, you must provide a Restoration Plan (see § 125.95 (b)(5));
- A demonstration that the proposed and/or implemented design and construction technologies, operational measures, and/or restoration measures achieve an efficacy that is as close as practicable to the applicable performance standards of § 125.94(b) without resulting in costs significantly greater than either the costs considered by the Administrator for a facility like yours in establishing the applicable performance standards, or as appropriate, the benefits of complying with the applicable performance standards at your facility; and,
- Design and engineering calculations, drawings, and estimates prepared by a qualified professional to support the elements of the Plan.

3.0 COST TO COST TEST INSTRUCTIONS

The data in Table 3-2 is keyed to survey ID number. Table 3-3 presents Facilities should be able to determine their ID number from the survey they submitted to EPA during the rule development process.

Step 1: Determine which technology EPA modeled as the most appropriate compliance technology for your facility. To do this, use the code in column 12 of Table 3-2 to look up the modeled technology in Table 3-1 below.

Table 3-1: Technology Codes and Descriptions

Technology Code	Technology Description
1	Addition of fish handling and return system to an existing traveling screen system
2	Addition of fine-mesh screens to an existing traveling screen system
3	Addition of a new, larger intake with fine-mesh and fish handling and return system in front of an existing intake system
4	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 1.75 mm
5	Addition of a fish net barrier system
6	Addition of an aquatic filter barrier system
7	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 1.75 mm
8	Addition of a velocity cap inlet to an existing offshore intake
9	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 1.75 mm
11	Addition of dual-entry, single-exit traveling screens (with fine- mesh) to a shoreline intake system
12	Addition of passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 0.76 mm
13	Addition of passive fine-mesh screen to an existing offshore intake with mesh width of 0.76 mm
14	Relocation of an existing intake to a submerged offshore location with passive fine-mesh screen inlet with mesh width of 0.76 mm

Step 2: Using EPA's costing equations, calculate the annualized capital and net operation and maintenance costs for a facility with your design flow using this technology. To do this, you should use the following formula, which is derived from the results of EPA's costing equations (see Section 4.0 of this chapter for more discussion) for a facility like yours using the selected technology:

$$y_f = y_{epa} + m*(x_f - x_{epa}), \quad (1)$$

where y_f = annualized capital and net O&M costs using actual facility design intake flow,
x_f = actual facility design intake flow (in gallons per minute),
x_{epa}= EPA assumed facility design intake flow (in gallons per minute) (column 3),
y_{epa} = Annualized capital and net O&M costs using EPA design intake flow (column 7), and
m = design flow adjustment slope (column 13).

EPA has provided some additional information in Table 3-2, beyond that which is needed to perform the calculations, to facilitate comparison of the results obtained using formula 1 to the detailed costing equations presented in Chapter 1 of this document, for those who wish to do so. EPA does not expect facilities or permit writers to do this, and has in fact provided the simplified formula to preclude the need for doing so, but is providing the additional information to increase transparency. Thus, for informational purposes, the total capital cost (not annualized), baseline O&M cost, and post construction O&M cost from which the annualized capital and net O&M costs using EPA design intake flow (y_{epa} in column 7) are derived are listed separately in columns 4 through 6. To calculate y_{epa}, EPA annualized the total capital cost using a 7 percent discount rate and 10 year amortization period, and added the result to the difference between the post construction O&M costs and the baseline O&M costs.

Note that some entries in Table 3-2 have "n/a" indicated for the EPA assumed design intake flow in column 2. These are facilities for which EPA projected that they would already meet otherwise applicable performance standards based on existing technologies and measures. EPA projected zero compliance costs for these facilities, irrespective of design intake flow, so no flow adjustment is needed. These facilities should use $0 as their value for the costs considered by EPA for a like facility in establishing the applicable performance standards. EPA recognizes that these facilities will still incur permitting and monitoring costs, but these are not included in the cost comparison for the reasons stated above.

Step 3: Determine the annualized net revenue loss associated with net construction downtime that EPA modeled for the facility to install the technology and the annualized pilot study costs that EPA modeled for the facility to test and optimize the technology. The sum of these two figures is listed in column 10. For informational purposes, the total (not annualized) net revenue losses from construction downtime, and total (not annualized) pilot study costs are listed separately in columns 8 and 9. These two figures were annualized using a 7% discount rate and 30 year amortization period and the results added together to get the annualized facility downtime and pilot study costs in column 10.

Step 4: Add the annualized capital and O&M costs using actual facility design intake flow (y_f from step 2), and the annualized facility downtime and pilot study costs (column 10 from step 3) to get the preliminary costs considered by EPA for a facility like yours.

Step 5: Determine which performance standards in 125.94(b)(1) and (2) (i.e., impingement mortality only, or impingement mortality and entrainment) are applicable to your facility, and compare these to the performance standards on which EPA's cost estimates are based, listed in column 11. If the applicable performance standards and those on which EPA's cost estimates are based are the same, then the preliminary costs considered by EPA for a facility like yours are the final costs considered by EPA for a facility like yours. If only the impingement mortality performance standards are applicable to your facility, but EPA based its cost estimates on impingement mortality and entrainment performance standards, then you should divide the preliminary costs by a factor of 2.148 to get the final costs. If impingement mortality and entrainment performance standards are applicable to your facility, but EPA based its cost estimates on impingement mortality performance standards only, then you should multiply the preliminary costs by 2.148 to get the final costs. See section 4.0 of this chapter for more discussion of the performance standard correction factor.

Survey IDs

The survey ID for a facility was that assigned to the recipients of either the short-technical questionnaire (STQ) or the detailed questionnaire (DQ). The Agency assigned STQ recipients questionnaire IDs in the form of "AUT0001", where the "AUT" prefix was constant and the four number suffix varies for each facility. The Agency assigned DQ recipient questionnaire IDs dependent on the type of recipient. Utilities received IDs in the form of "DUT1000", where the "DUT" prefix was constant and the four number suffix varied in the "1000" range for each recipient. Non-utilities received IDs in the form of "DNU2000", where the "DNU" prefix was constant and the four number suffix varied in the "2000" range for each recipient. Municipality operated facilities received IDs in the form of "DMU3000", where the "DMU" prefix was constant and the four number suffix varied in the "3000" range for each recipient.

Table 3-2 presents costs for individual cooling water intake structures only for the case of DQ recipients. For STQ recipients, the Agency necessarily estimated costs on the facility-level by assuming that the entire set of intakes at the facility would have the intake characteristics reported at the facility level. STQ recipients would make the potential corrections to EPA's estimated costs at the facility-level only (as outlined in Steps 2, 3, and 4 below).

In completing the questionnaire, the DQ respondents assigned each cooling water intake structure at their plant a designating number or name (through part 2, question 1a). The Agency has included these reported intake descriptors in Table 3-2 to allow the DQ recipients to identify individual intake structures. Even though the cost to cost test is evaluated on the facility-level, DQ recipients would make potential corrections to EPA's estimated capital and O&M costs as outlined in Step 2 for each cooling water intake structure and then aggregate at the facility-level.

If a facility within the scope of the rule completed and returned a questionnaire but is not included in Table 3-1, then the facility may have claimed cooling water intake flow information pertaining to their facility to be confidential business information (CBI). If these facilities wish to request a site-specific determination of best technology available based on significantly greater compliance costs, they will need to waive their claim of confidentiality prior to submitting the Comprehensive Cost Evaluation Study so that EPA can make the necessary flow data available to the facility, Director, and public.

Because the Agency has based its list of facilities projected to be within the scope of the rule on information collected through a survey that is subject to some degree of uncertainty, there could be a small set of facilities that are subject to this rule that may not be included in Table 3-2. Table 3-2 is the Agency's best estimate of the facilities that it projects to fall within the scope of the final rule (less those claiming flow information as CBI). However, Table 3-2 is not a definitive list of the in-scope population of facilities for the final rule. Therefore, a complying facility may discover when attempting to conduct a cost to cost test that the Agency did not include costs for the particular facility in Table 3-2. This is not to say that the Agency has not considered costs for the facility, as the Agency scaled its national costs to represent weighted a population of facilities not receiving the survey. In the case of a facility not included in Table 3-2, the method for determining the representative costs that EPA considered for a similar facility should be conducted by assessing the projected annual capital cost + net annual O&M cost of the intake technology determined by a facility like that facility. Figures 3-1 through 3-13 provide estimated equations for calculating annual capital cost + net annual O&M cost for each technology module considered by the Agency. In addition, the facility should find in Table 3-2 facilities with the same cost-correction equation slope (m) and could utilize the median annualized facility-level downtime and pilot study costs for that technology in the comparison.

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0001		401,881	$ 322,884	$ 699,866	$ 795,393	$ 141,498
AUT0002		549,533	$ 5,750,259	$ 68,489	$ 104,063	$ 854,282
AUT0004		239,107	$ 528,427	$ 30,725	$ 104,458	$ 148,969
AUT0011		453,758	$ 967,675	$ 55,545	$ 193,660	$ 275,890
AUT0012		2,018,917	$ 48,835,329	$ 360,813	$ 989,876	$ 7,582,115
AUT0014		572,383	$ 2,732,729	$ 91,057	$ 110,893	$ 408,915
AUT0015		1,296,872	$ 510,784	$ -	$ 134,070	$ 206,794
AUT0016		301,127	$ 41,613	$ -	$ 28,195	$ 34,120
AUT0019		848,784	$ 11,094,343	$ 271,045	$ 994,876	$ 2,303,416
AUT0020		207,514	$ 1,517,779	$ 34,859	$ 42,089	$ 223,327
AUT0021		267,138	$ 1,187,727	$ 65,395	$ 263,140	$ 366,851
AUT0024		639,702	$ 72,402	$ -	$ 47,164	$ 57,472
AUT0027		404,214	$ 2,362,864	$ 147,563	$ 532,881	$ 721,737
AUT0044		457,869	$ 183,653	$ -	$ 57,997	$ 84,145
AUT0049		820,866	$ 6,080,054	$ 196,361	$ 797,241	$ 1,466,543
AUT0051		348,052	$ 11,832,011	$ 17,181	$ 50,842	$ 1,718,273
AUT0053		147,762	$ 454,296	$ 27,346	$ 108,078	$ 145,413
AUT0057		56,391	$ 271,166	$ 19,811	$ 65,525	$ 84,322
AUT0058		624,376	$ 8,582,766	$ 68,231	$ 225,908	$ 1,379,670
AUT0064		553,145	$ 3,039,302	$ 195,656	$ 695,636	$ 932,709
AUT0066		65,571	$ 2,006,184	$ 80,531	$ 63,685	$ 268,790
AUT0078		288,792	$ 5,683,876	$ 267,577	$ 1,083,987	$ 1,625,667
AUT0084		2,100,000	$ 2,976,122	$ 3,003,550	$ 3,318,577	$ 738,760
AUT0085		975,261	$ 23,279,870	$ 341,127	$ 452,608	$ 3,426,011
AUT0092		2,786,349	$ 929,777	$ -	$ 269,122	$ 401,501
AUT0095		67,369	$ 55,826	$ 120,772	$ 140,422	$ 27,598
AUT0106		325,449	$ 1,104,684	$ 55,757	$ 223,858	$ 325,383
AUT0110		551,114	$ 6,445,617	$ 70,141	$ 104,066	$ 951,636
AUT0120		207,333	$ 2,085,862	$ 55,736	$ 225,656	$ 466,900
AUT0123		62,226	$ 106,975	$ 7,021	$ 20,122	$ 28,333
AUT0127		104,672	$ 573,136	$ 34,651	$ 118,506	$ 165,457
AUT0130		929,723	$ 8,127,384	$ 402,025	$ 1,628,672	$ 2,383,804
AUT0131		492,987	$ 3,299,931	$ 195,321	$ 694,407	$ 968,921
AUT0134		99,252	$ 3,334,593	$ 8,170	$ 35,218	$ 501,819
AUT0137		401,222	$ 1,916,441	$ 117,385	$ 475,099	$ 630,572
AUT0139		369,074	$ 117,095	$ -	$ 49,945	$ 66,617
AUT0142		407,669	$ 9,461,494	$ 66,798	$ 78,036	$ 1,358,342
AUT0143		289,294	$ 971,645	$ 50,004	$ 200,412	$ 288,748
AUT0146		213,207	$ 1,618,126	$ 88,506	$ 313,588	$ 455,467
AUT0148		1,036,476	$ 12,443,192	$ -	$ 288,984	$ 2,060,615
AUT0149		848,079	$ 109,389	$ -	$ 58,838	$ 74,413
AUT0151		482,911	$ 1,465,485	$ 95,774	$ 340,264	$ 453,142
AUT0161		555,680	$ 1,600,167	$ 101,254	$ 360,434	$ 487,008
AUT0168		329,758	$ 5,156,763	$ 39,196	$ 51,388	$ 746,399
AUT0171		1,189,016	$ 14,989,478	$ 120,512	$ 398,517	$ 2,412,170
AUT0174		1,341,997	$ 934,469	$ 1,387,449	$ 1,537,156	$ 282,755

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0175		258,008	$ 2,505,868	$ 134,658	$ 484,461	$ 706,582
AUT0176		1,652,395	$ 6,892,691	$ 425,370	$ 1,533,553	$ 2,089,548
AUT0183		118,504	$ 196,689	$ 7,303	$ 21,121	$ 41,823
AUT0185		810,911	$ 97,503	$ -	$ 56,756	$ 70,638
AUT0187		1,242,691	$ 257,332	$ -	$ 107,659	$ 144,297
AUT0190		511,950	$ 27,779,896	$ 616,589	$ 191,870	$ 3,530,513
AUT0191		692,335	$ 19,255,865	$ 184,161	$ 66,491	$ 2,623,932
AUT0192		359,686	$ 959,625	$ 71,963	$ 253,183	$ 317,849
AUT0193		1,006,084	$ 19,112,665	$ 90,728	$ 323,635	$ 2,954,121
AUT0196		230,120	$ 374,975	$ -	$ 10,672	$ 64,060
AUT0197		407,061	$ 4,773,876	$ 248,548	$ 891,410	$ 1,322,554
AUT0202		2,080,399	$ 106,025,028	$ 477,625	$ 769,048	$ 15,387,001
AUT0203		1,083,174	$ 4,847,332	$ 232,706	$ 851,244	$ 1,308,689
AUT0205		313,218	$ 720,557	$ 37,147	$ 127,449	$ 192,893
AUT0208		220,683	$ 3,140,556	$ 27,181	$ 51,205	$ 471,169
AUT0222		156,464	$ 299,274	$ -	$ 9,554	$ 52,164
AUT0227		82,468	$ 523,999	$ 30,107	$ 102,249	$ 146,748
AUT0228		147,594	$ 837,743	$ 41,023	$ 163,811	$ 242,064
AUT0229		483,349	$ 1,784,794	$ 87,496	$ 391,634	$ 558,253
AUT0238		376,148	$ 757,400	$ 51,856	$ 180,342	$ 236,323
AUT0242		1,113,045	$ 8,239,161	$ 291,327	$ 1,039,947	$ 1,921,691
AUT0244		49,980	$ 426,844	$ 22,868	$ 76,413	$ 114,318
AUT0245		491,302	$ 1,459,999	$ 50,879	$ 61,192	$ 218,185
AUT0254		145,838	$ 353,928	$ 22,339	$ 74,527	$ 102,580
AUT0255		194,919	$ 258,805	$ -	$ 10,232	$ 47,080
AUT0261		201,229	$ 943,433	$ 57,335	$ 230,290	$ 307,278
AUT0264		840,000	$ 21,384,690	$ 1,502,211	$ 185,672	$ 1,728,160
AUT0266		653,994	$ 139,380	$ 307,951	$ 351,075	$ 62,969
AUT0268		712,677	$ 2,998,753	$ 114,173	$ 417,470	$ 730,253
AUT0273		173,689	$ 994,534	$ 52,039	$ 208,703	$ 298,263
AUT0277		88,831	$ 1,192,106	$ 45,779	$ 51,021	$ 174,971
AUT0278		1,642,492	$ 6,410,550	$ 771,895	$ 257,586	$ 398,409
AUT0284		728,495	$ 3,743,165	$ 208,370	$ 742,487	$ 1,067,059
AUT0292		556,596	$ 2,227,636	$ 99,379	$ 350,087	$ 567,874
AUT0295		359,098	$ 3,584,905	$ 53,365	$ 114,232	$ 571,276
AUT0297		184,293	$ 1,172,223	$ 63,592	$ 255,790	$ 359,096
AUT0298		897,819	$ 100,769	$ -	$ 61,625	$ 75,972
AUT0299		864,873	$ 9,012,107	$ 150,709	$ 127,282	$ 1,259,694
AUT0302		71,413	$ 91,562	$ 6,933	$ 19,813	$ 25,916
AUT0305		762,197	$ 42,822,242	$ 146,012	$ 281,593	$ 6,232,505
AUT0308		394,361	$ 3,381,768	$ 151,364	$ 77,961	$ 408,085
AUT0309		789,860	$ 81,433	$ -	$ 55,577	$ 67,171
AUT0314		1,039,315	$ 2,438,597	$ 134,759	$ 484,839	$ 697,281
AUT0319		468,117	$ 1,326,662	$ 88,025	$ 355,386	$ 456,248
AUT0321		669,493	$ 2,092,630	$ 88,910	$ 107,698	$ 316,732
AUT0331		178,562	$ 24,860	$ -	$ 21,328	$ 24,867

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0333		336,448	$ 786,807	$ 46,794	$ 162,104	$ 227,333
AUT0337		1,110,944	$ 131,046	$ -	$ 73,566	$ 92,224
AUT0341		405,256	$ 2,429,275	$ 115,249	$ 412,169	$ 642,794
AUT0345		610,223	$ 5,103,322	$ 267,506	$ 952,013	$ 1,411,106
AUT0349		2,429,925	$ 8,146,829	$ 424,696	$ 1,514,477	$ 2,249,706
AUT0351		301,024	$ 6,389,631	$ 42,269	$ 99,196	$ 966,667
AUT0358		210,439	$ 2,170,195	$ 117,833	$ 421,759	$ 612,913
AUT0361		433,165	$ 7,652,621	$ 59,105	$ 140,320	$ 1,170,775
AUT0362		312,830	$ 1,566,464	$ 51,821	$ 185,883	$ 357,091
AUT0364		505,137	$ 5,447,440	$ 170,196	$ 611,090	$ 1,216,487
AUT0365		140,093	$ 445,526	$ 29,331	$ 116,166	$ 150,268
AUT0368		83,406	$ 2,715,938	$ 146,752	$ 529,832	$ 769,768
AUT0370		322,374	$ 1,816,861	$ 79,915	$ 289,868	$ 468,633
AUT0379		351,933	$ 41,890	$ -	$ 31,041	$ 37,006
AUT0381		50,143	$ 960,912	$ 9,964	$ 22,083	$ 148,931
AUT0384		146,511	$ 66,229	$ 91,020	$ 104,211	$ 22,620
AUT0385		130,966	$ 1,823,217	$ 20,420	$ 25,983	$ 265,149
AUT0387		576,057	$ 5,283,933	$ 122,322	$ 496,655	$ 1,126,646
AUT0398		537,402	$ 6,842,592	$ 63,631	$ 75,697	$ 986,297
AUT0399		140,486	$ 232,496	$ -	$ 9,212	$ 42,314
AUT0401		613,529	$ 578,957	$ -	$ 72,110	$ 154,541
AUT0404		291,400	$ 4,124,975	$ 44,642	$ 51,995	$ 594,657
AUT0408		73,728	$ 900,969	$ 13,020	$ 49,057	$ 164,315
AUT0416		143,562	$ 41,835	$ 96,659	$ 112,954	$ 22,251
AUT0423		564,501	$ 29,714,518	$ 122,524	$ 248,148	$ 4,356,303
AUT0427		148,668	$ 291,697	$ -	$ 9,392	$ 50,923
AUT0431		143,775	$ 356,208	$ 20,913	$ 69,450	$ 99,253
AUT0434		400,472	$ 763,363	$ 40,353	$ 138,952	$ 207,284
AUT0435		183,306	$ 483,907	$ 27,166	$ 107,346	$ 149,077
AUT0441		108,296	$ 276,983	$ 17,492	$ 57,275	$ 79,220
AUT0446		278,043	$ 3,528,075	$ 28,547	$ 111,202	$ 584,973
AUT0449		487,640	$ 1,738,410	$ 110,263	$ 393,700	$ 530,948
AUT0472		239,620	$ 218,958	$ 453,683	$ 511,926	$ 89,417
AUT0476		233,631	$ 489,074	$ 27,565	$ 93,169	$ 135,237
AUT0483		1,146,722	$ 2,715,801	$ 112,654	$ 136,742	$ 410,757
AUT0489		211,629	$ 1,477,232	$ 84,570	$ 299,177	$ 424,931
AUT0490		405,350	$ 3,527,610	$ 73,321	$ 78,027	$ 506,958
AUT0493		257,137	$ 1,429,134	$ 51,159	$ 206,956	$ 359,274
AUT0496		603,432	$ 1,649,804	$ 57,304	$ 206,130	$ 383,721
AUT0499		45,374	$ 171,551	$ 9,346	$ 48,606	$ 63,685
AUT0501		346,213	$ 115,781	$ 205,027	$ 230,840	$ 42,297
AUT0513		1,296,772	$ 27,395,451	$ 170,929	$ 603,316	$ 4,332,883
AUT0517		98,553	$ 1,040,022	$ 20,976	$ 72,416	$ 199,516
AUT0518		193,413	$ 435,346	$ 28,467	$ 96,388	$ 129,905
AUT0522		237,692	$ 856,098	$ 40,165	$ 162,010	$ 243,734
AUT0523		608,373	$ 7,741,521	$ -	$ 189,045	$ 1,291,263

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0529		422,181	$ 3,402,665	$ 144,308	$ 530,442	$ 870,598
AUT0534		70,565	$ 230,241	$ 17,175	$ 56,150	$ 71,756
AUT0535		196,084	$ 3,706,283	$ 25,082	$ 66,100	$ 568,710
AUT0539		1,056,137	$ 13,978,398	$ 183,682	$ 342,369	$ 2,148,896
AUT0541		117,759	$ 3,346,437	$ 108,327	$ 37,393	$ 405,523
AUT0547		780,279	$ 9,747,498	$ 118,281	$ 129,393	$ 1,398,937
AUT0551		295,707	$ 823,114	$ 30,125	$ 35,820	$ 122,888
AUT0552		1,226,625	$ 133,029	$ -	$ 80,047	$ 98,987
AUT0553		71,128	$ 230,549	$ 10,379	$ 32,023	$ 54,468
AUT0554		429,991	$ 8,840,925	$ 249,963	$ 170,468	$ 1,179,253
AUT0557		37,500	$ 20,033	$ -	$ 19,881	$ 22,734
AUT0564		1,129,749	$ 14,903,816	$ 170,408	$ 396,749	$ 2,348,309
AUT0567		441,177	$ 5,817,871	$ 67,488	$ 77,963	$ 838,809
AUT0568		584,525	$ 2,308,321	$ 342,703	$ 382,141	$ 368,091
AUT0570		951,201	$ 4,021,857	$ 164,817	$ 591,048	$ 998,853
AUT0577		741,931	$ 10,647,710	$ 113,337	$ 129,884	$ 1,532,542
AUT0583		222,087	$ 2,210,305	$ 36,279	$ 51,245	$ 329,663
AUT0585		128,015	$ 1,561,382	$ 49,933	$ 54,853	$ 227,225
AUT0588		396,576	$ 1,788,685	$ 191,759	$ 66,639	$ 129,548
AUT0590		147,803	$ 315,803	$ 22,592	$ 75,430	$ 97,801
AUT0599		198,681	$ 3,040,887	$ 21,121	$ 104,455	$ 516,288
AUT0600		711,801	$ 1,717,012	$ 80,592	$ 284,636	$ 448,508
AUT0601		1,151,214	$ 541,482	$ 677,194	$ 742,753	$ 142,654
AUT0603		1,228,633	$ 684,562	$ 720,077	$ 802,140	$ 179,529
AUT0607		635,364	$ 9,044,216	$ 111,819	$ 226,342	$ 1,402,216
AUT0611		547,114	$ 3,195,898	$ 88,288	$ 320,973	$ 687,709
AUT0612		186,464	$ 6,614,075	$ -	$ 85,670	$ 1,027,365
AUT0613		493,923	$ 4,341,494	$ 155,354	$ 572,021	$ 1,034,798
AUT0617		2,292,812	$ 37,040,390	$ 1,403,836	$ 741,877	$ 4,611,760
AUT0619		159,600	$ 62,547	$ 98,454	$ 112,506	$ 22,957
AUT0620		551,528	$ 2,198,869	$ 264,319	$ 90,714	$ 139,464
AUT0621		391,137	$ 2,018,600	$ 70,658	$ 245,595	$ 462,340
AUT0623		73,622	$ 267,379	$ 13,006	$ 49,653	$ 74,715
AUT0625		562,255	$ 2,841,330	$ 104,168	$ 380,113	$ 680,487
AUT0630		569,211	$ 16,086,712	$ 94,881	$ 227,787	$ 2,423,292
AUT0631		480,721	$ 11,721,529	$ 77,934	$ 190,232	$ 1,781,179
AUT0635		72,550	$ 1,057,088	$ 50,149	$ 201,000	$ 301,357
AUT0638		201,395	$ 2,336,881	$ 50,154	$ 202,851	$ 485,416
AUT0639		479,860	$ 2,960,066	$ 143,531	$ 527,524	$ 805,439
DMU3244	1	22,222	$ 138,465	$ -	$ 27,927	$ 47,641
DMU3244	2	56,250	$ 163,334	$ -	$ 33,357	$ 56,612
DMU3310		41,319	$ 25,594	$ 8,793	$ 27,169	$ 22,020
DNU2003		156,944	$ 68,455	$ -	$ 30,711	$ 40,458
DNU2010		67,000	$ 1,010,938	$ 11,787	$ 23,430	$ 155,578
DNU2011		181,250	$ 2,707,585	$ 21,222	$ 102,473	$ 466,750
DNU2013		65,000	$ 588,369	$ -	$ 24,812	$ 108,583
DNU2014		42,798	$ 531,997	$ 64,365	$ 22,327	$ 33,707

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
DNU2017		38,194	$ 984,494	$ -	$ 13,803	$ 153,973
DNU2018		44,260	$ 446,336	$ 11,513	$ 13,633	$ 65,668
DNU2021		55,750	$ 292,158	$ 18,165	$ 59,671	$ 83,103
DNU2025		120,689	$ 7,720,257	$ -	$ 825,174	$ 1,924,365
DNU2032	Units 1 & 2	156,250	$ -	$ -	$ -	$ -
DNU2032	Unit 3	124,306	$ -	$ -	$ -	$ -
DNU2032	Unit 4	136,806	$ 143,049	$ -	$ 54,324	$ 74,691
DNU2038		41,667	$ 465,858	$ 50,489	$ 58,892	$ 74,730
DUT0062	1	72,917	$ 1,069,902	$ 8,527	$ 48,944	$ 192,747
DUT0062	2	156,250	$ 1,922,088	$ 14,312	$ 56,483	$ 315,834
DUT0576	5&6	50,000	$ 1,434,192	$ 51,770	$ 185,694	$ 338,121
DUT0576	7	43,056	$ 866,245	$ 29,000	$ 101,863	$ 196,197
DUT0576	CT	2,083	$ 202,358	$ -	$ 25,785	$ 54,596
DUT1002	Screenhouse 1	685,833	$ 166,652	$ 322,571	$ 367,337	$ 68,493
DUT1002	Screenhouse 2	685,833	$ 166,652	$ 322,571	$ 367,337	$ 68,493
DUT1003		38,500	$ 703,237	$ 15,912	$ 20,989	$ 105,202
DUT1006	Unit 1/2	173,611	$ 1,286,341	$ 54,154	$ 153,027	$ 282,018
DUT1006	Unit 3/4	20,833	$ 281,263	$ 12,914	$ 39,309	$ 66,440
DUT1007		242,778	$ 680,059	$ 32,861	$ 39,165	$ 103,129
DUT1008		60,000	$ 1,016,367	$ 26,935	$ 107,846	$ 225,619
DUT1011		283,611	$ 1,350,484	$ 76,112	$ 267,481	$ 383,648
DUT1012		173,611	$ 522,205	$ 29,576	$ 100,351	$ 145,125
DUT1014		87,000	$ 920,321	$ 40,859	$ 163,140	$ 253,315
DUT1022		2,200,000	$ 8,268,801	$ 291,801	$ 1,051,593	$ 1,937,083
DUT1023	CWS #535	478,444	$ 28,961,166	$ 360,609	$ 274,535	$ 4,037,344
DUT1023	DWS #536	520,000	$ 39,708,776	$ 97,288	$ 361,137	$ 5,917,486
DUT1029	CRS	638,000	$ 14,391,478	$ 63,709	$ 254,538	$ 2,239,852
DUT1029	CR Nuc	680,000	$ 6,740,847	$ 162,470	$ 659,152	$ 1,456,426
DUT1029	CRN	68,000	$ 649,893	$ 13,914	$ 16,340	$ 94,956
DUT1029	HCT	735,000	$ 4,654,560	$ 159,675	$ 194,358	$ 697,388
DUT1031	1	59,000	$ 808,777	$ 17,797	$ 22,826	$ 120,181
DUT1031	2	140,000	$ 1,524,044	$ 24,132	$ 26,017	$ 218,874
DUT1033		240,000	$ 1,076,251	$ 43,293	$ 55,502	$ 165,443
DUT1034		1,231,944	$ 4,990,608	$ 202,923	$ 820,337	$ 1,327,964
DUT1036		444,000	$ 753,297	$ 41,568	$ 141,630	$ 207,314
DUT1038		65,972	$ 213,848	$ 12,804	$ 38,918	$ 56,561
DUT1041		188,958	$ 433,167	$ 27,973	$ 94,625	$ 128,325
DUT1043		280,556	$ 36,345	$ -	$ 27,042	$ 32,217
DUT1044		756,944	$ 76,726	$ -	$ 53,732	$ 64,656
DUT1047		614,306	$ 16,998,704	$ 151,032	$ 103,667	$ 2,372,868
DUT1048	HI-1	256,944	$ 1,766,372	$ 113,534	$ 405,813	$ 543,770
DUT1048	HI-2	170,139	$ 473,836	$ 33,127	$ 113,050	$ 147,387
DUT1050		2,104,167	$ 407,068	$ -	$ 171,852	$ 229,809
DUT1051		374,000	$ 1,027,013	$ 55,468	$ 193,382	$ 284,137
DUT1057		340,000	$ 2,844,898	$ 35,159	$ 51,102	$ 420,993
DUT1062		670,139	$ 67,658	$ -	$ 48,869	$ 58,502

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
DUT1066		1,712,000	$ 32,777,974	$ 260,695	$ 678,771	$ 5,084,922
DUT1067	1	63,611	$ -	$ -	$ -	$ -
DUT1067	2	31,667	$ -	$ -	$ -	$ -
DUT1067	3	69,653	$ 23,159	$ -	$ 20,564	$ 23,862
DUT1068		91,528	$ 360,536	$ 56,351	$ 20,060	$ 15,042
DUT1072		366,597	$ 691,381	$ 40,319	$ 137,184	$ 195,303
DUT1084		264,583	$ 835,764	$ 54,494	$ 189,863	$ 254,363
DUT1085		297,000	$ 2,410,696	$ 159,608	$ 619,834	$ 803,455
DUT1086	Unit 1	57,292	$ 667,197	$ 29,048	$ 122,691	$ 188,637
DUT1086	Unit 2	57,292	$ 667,197	$ 29,048	$ 122,691	$ 188,637
DUT1088	#4	49,280	$ 865,324	$ 11,129	$ 22,007	$ 134,081
DUT1088	#5	99,458	$ 1,438,399	$ 12,058	$ 25,232	$ 217,970
DUT1093		307,760	$ 9,456,466	$ -	$ 33,762	$ 1,380,150
DUT1097		106,007	$ 2,349,646	$ -	$ 242,606	$ 577,143
DUT1098		71,528	$ 507,025	$ 29,461	$ 99,942	$ 142,669
DUT1100	Units 1 & 2	188,000	$ -	$ -	$ -	$ -
DUT1100	Units 3 & 4	188,000	$ 136,878	$ -	$ 50,573	$ 70,062
DUT1103	Unit 1 Screenhouse	118,000	$ -	$ -	$ -	$ -
DUT1103	Unit 2 Screenhouse	250,000	$ 47,060	$ -	$ 31,941	$ 38,642
DUT1103	Hvdc Lake Intake	1,200	$ 34,615	$ -	$ 4,734	$ 9,662
DUT1103	Hvdc Separator Dike	1,200	$ 34,615	$ -	$ 4,734	$ 9,662
DUT1103	River Intake	7,800	$ 75,587	$ 5,734	$ 15,570	$ 20,597
DUT1109		58,333	$ 873,553	$ 32,385	$ 130,170	$ 222,159
DUT1111	Unit 1&2	199,716	$ 764,700	$ 99,547	$ 37,851	$ 47,181
DUT1111	Unit 3	189,842	$ 717,221	$ 93,277	$ 35,552	$ 44,391
DUT1112		193,750	$ 501,403	$ 28,510	$ 96,543	$ 139,421
DUT1113	System 27	1,125,000	$ 6,518,329	$ 281,013	$ 1,001,831	$ 1,648,882
DUT1113	System 67	44,028	$ 181,599	$ -	$ 8,508	$ 34,364
DUT1116		355,556	$ 2,886,459	$ 69,804	$ 84,921	$ 426,084
DUT1118		667,361	$ 140,959	$ -	$ 64,789	$ 84,858
DUT1122		120,000	$ 23,134	$ -	$ 18,047	$ 21,341
DUT1123	6	111,806	$ 4,071,741	$ 15,536	$ 39,240	$ 603,428
DUT1123	7	256,250	$ 5,809,773	$ -	$ 431,082	$ 1,258,263
DUT1123	8	220,139	$ 5,590,610	$ 27,185	$ 73,721	$ 842,513
DUT1132		1,896,000	$ 3,995,072	$ 197,552	$ 927,311	$ 1,298,568
DUT1133		213,889	$ 1,180,537	$ 44,631	$ 57,260	$ 180,711
DUT1138		77,083	$ 264,532	$ 12,475	$ 37,753	$ 62,942
DUT1140	Mc2-4	131,250	$ 334,100	$ 20,512	$ 66,264	$ 93,320
DUT1140	Mc5&6	383,958	$ 1,450,787	$ 82,444	$ 290,867	$ 414,982
DUT1145		178,472	$ 2,702,979	$ 38,035	$ 57,101	$ 403,909
DUT1146		181,944	$ 325,271	$ 276,184	$ 309,256	$ 79,383
DUT1152		399,306	$ 10,606,982	$ 355,225	$ 1,321,682	$ 2,476,653
DUT1156		496,000	$ 16,234,946	$ 67,033	$ 77,047	$ 2,321,504
DUT1157	6	110,000	$ 1,262,753	$ 47,827	$ 25,593	$ 157,553
DUT1157	7	5,833	$ 305,286	$ 13,438	$ 17,201	$ 47,229
DUT1165	1	480,000	$ 9,356,403	$ 220,447	$ 189,951	$ 1,301,645

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

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Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
DUT1165	2	489,233	$ -	$ -	$ -	$ -
DUT1169		620,000	$ 14,855,719	$ 47,990	$ 185,073	$ 2,252,203
DUT1173		37,986	$ 312,285	$ 18,521	$ 72,119	$ 98,061
DUT1179		390,278	$ 1,204,485	$ 74,177	$ 261,241	$ 358,556
DUT1185		225,000	$ 3,496,693	$ 21,560	$ 51,324	$ 527,614
DUT1186	Unit 4	62,000	$ 577,654	$ 26,371	$ 88,907	$ 144,780
DUT1186	Unit 5	62,000	$ 577,654	$ 26,371	$ 88,907	$ 144,780
DUT1187	Mt 2&3	147,014	$ -	$ -	$ -	$ -
DUT1187	Mt 6-8	500,000	$ 78,370	$ -	$ 47,573	$ 58,732
DUT1189	Unit 6 & 8	72,222	$ -	$ -	$ -	$ -
DUT1189	Unit 7	80,000	$ 22,427	$ -	$ 19,852	$ 23,045
DUT1198		279,511	$ 5,198,159	$ 27,451	$ 92,443	$ 805,093
DUT1202	Power Plant	36,000	$ 1,154,817	$ -	$ 13,668	$ 178,088
DUT1202	Filtration Plant	30,000	$ 987,137	$ -	$ 13,284	$ 153,830
DUT1206	1	85,972	$ 53,440	$ 56,705	$ 65,852	$ 16,756
DUT1206	2	85,000	$ 59,054	$ 56,155	$ 65,236	$ 17,489
DUT1206	3	120,972	$ 87,045	$ 76,530	$ 88,027	$ 23,890
DUT1209	Plant a	640,000	$ 2,227,053	$ 89,172	$ 116,036	$ 343,947
DUT1209	Plant B	515,972	$ 10,503,729	$ 51,204	$ 184,394	$ 1,628,685
DUT1211		1,666,667	$ 32,926,766	$ 3,240,832	$ 1,072,136	$ 2,519,335
DUT1212		687,500	$ 2,000,922	$ 85,020	$ 302,122	$ 501,987
DUT1214		51,944	$ 754,488	$ 34,900	$ 22,241	$ 94,763
DUT1217	Unit 1	-	$ -	$ -	$ -	$ -
DUT1217	Unit 6-8	104,861	$ 848,612	$ -	$ 16,547	$ 137,371
DUT1217	Unit 4	-	$ -	$ -	$ -	$ -
DUT1219		550,000	$ 2,862,608	$ 108,307	$ 438,079	$ 737,343
DUT1223	1	142,000	$ 1,422,632	$ 8,898	$ 55,779	$ 249,432
DUT1223	2	224,800	$ 2,121,274	$ 22,284	$ 56,502	$ 336,239
DUT1227	1 & 2	130,000	$ 373,205	$ 21,493	$ 71,516	$ 103,159
DUT1227	3	185,000	$ 512,326	$ 29,084	$ 98,594	$ 142,454
DUT1229		73,000	$ 30,638	$ 82,612	$ 96,918	$ 18,668
DUT1238	A	676,000	$ 386,447	$ 531,800	$ 688,788	$ 212,010
DUT1238	B	334,000	$ 344,428	$ 525,715	$ 662,610	$ 185,934
DUT1248		452,083	$ 49,114	$ -	$ 36,652	$ 43,645
DUT1249		43,900	$ 10,765	$ -	$ 13,783	$ 15,316
DUT1250		360,000	$ 12,788,752	$ 160,063	$ 151,944	$ 1,812,711
DUT1252		112,000	$ 157,353	$ 10,988	$ 32,494	$ 43,910
DUT1258	Screen House No.1	287,083	$ 6,665,603	$ 171,249	$ 116,490	$ 894,273
DUT1258	Screen House No.2	422,708	$ 9,009,434	$ 248,577	$ 168,448	$ 1,202,611
DUT1258	Screen House No.3	243,056	$ 4,842,849	$ 108,025	$ 73,278	$ 654,766
DUT1259		71,181	$ 2,706,303	$ 20,742	$ 26,203	$ 390,778
DUT1261	U12	79,000	$ 49,889	$ 119,643	$ 139,137	$ 26,598
DUT1261	U34	139,750	$ 1,735,631	$ 101,580	$ 26,018	$ 171,552
DUT1265		70,000	$ 495,281	$ 35,987	$ 143,288	$ 177,818
DUT1268		2,400,000	$ 20,911,797	$ 1,793,928	$ 623,613	$ 1,807,054
DUT1269		456,000	$ 3,012,280	$ 107,765	$ 130,761	$ 451,877

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

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Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
DUT1270		89,583	$ 18,084	$ -	$ 16,343	$ 18,918
DUT1271		186,000	$ 14,970,016	$ 30,165	$ 49,913	$ 2,151,142
DUT1272	Mo1 & 2	713,889	$ 1,238,695	$ 76,910	$ 270,425	$ 369,877
DUT1272	Mo3	528,472	$ 849,029	$ 53,826	$ 185,965	$ 253,021
DUT1273		444,444	$ 2,752,775	$ 164,719	$ 582,187	$ 809,401
DUT1274		330,556	$ 1,564,234	$ 62,476	$ 225,250	$ 385,486
DUT1275		1,992,500	$ 6,739,793	$ -	$ 355,766	$ 1,315,361
DUT1276		62,500	$ 412,277	$ 23,754	$ 26,574	$ 61,518
DUT1278		559,722	$ 4,962,033	$ 193,479	$ 688,069	$ 1,201,071
Facilities Receiving No EPA Technology Upgrade Costs						
AUT0010		n/a	$ -	$ -	$ -	$ -
AUT0013		n/a	$ -	$ -	$ -	$ -
AUT0018		n/a	$ -	$ -	$ -	$ -
AUT0022		n/a	$ -	$ -	$ -	$ -
AUT0033		n/a	$ -	$ -	$ -	$ -
AUT0036		n/a	$ -	$ -	$ -	$ -
AUT0041		n/a	$ -	$ -	$ -	$ -
AUT0047		n/a	$ -	$ -	$ -	$ -
AUT0050		n/a	$ -	$ -	$ -	$ -
AUT0054		n/a	$ -	$ -	$ -	$ -
AUT0067		n/a	$ -	$ -	$ -	$ -
AUT0068		n/a	$ -	$ -	$ -	$ -
AUT0071		n/a	$ -	$ -	$ -	$ -
AUT0072		n/a	$ -	$ -	$ -	$ -
AUT0073		n/a	$ -	$ -	$ -	$ -
AUT0077		n/a	$ -	$ -	$ -	$ -
AUT0079		n/a	$ -	$ -	$ -	$ -
AUT0080		n/a	$ -	$ -	$ -	$ -
AUT0083		n/a	$ -	$ -	$ -	$ -
AUT0087		n/a	$ -	$ -	$ -	$ -
AUT0091		n/a	$ -	$ -	$ -	$ -
AUT0093		n/a	$ -	$ -	$ -	$ -
AUT0097		n/a	$ -	$ -	$ -	$ -
AUT0101		n/a	$ -	$ -	$ -	$ -
AUT0104		n/a	$ -	$ -	$ -	$ -
AUT0111		n/a	$ -	$ -	$ -	$ -
AUT0114		n/a	$ -	$ -	$ -	$ -
AUT0125		n/a	$ -	$ -	$ -	$ -
AUT0126		n/a	$ -	$ -	$ -	$ -
AUT0129		n/a	$ -	$ -	$ -	$ -
AUT0152		n/a	$ -	$ -	$ -	$ -
AUT0156		n/a	$ -	$ -	$ -	$ -
AUT0157		n/a	$ -	$ -	$ -	$ -
AUT0160		n/a	$ -	$ -	$ -	$ -

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column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0163		n/a	$ -	$ -	$ -	$ -
AUT0170		n/a	$ -	$ -	$ -	$ -
AUT0173		n/a	$ -	$ -	$ -	$ -
AUT0178		n/a	$ -	$ -	$ -	$ -
AUT0181		n/a	$ -	$ -	$ -	$ -
AUT0182		n/a	$ -	$ -	$ -	$ -
AUT0199		n/a	$ -	$ -	$ -	$ -
AUT0201		n/a	$ -	$ -	$ -	$ -
AUT0215		n/a	$ -	$ -	$ -	$ -
AUT0216		n/a	$ -	$ -	$ -	$ -
AUT0221		n/a	$ -	$ -	$ -	$ -
AUT0226		n/a	$ -	$ -	$ -	$ -
AUT0230		n/a	$ -	$ -	$ -	$ -
AUT0232		n/a	$ -	$ -	$ -	$ -
AUT0235		n/a	$ -	$ -	$ -	$ -
AUT0240		n/a	$ -	$ -	$ -	$ -
AUT0241		n/a	$ -	$ -	$ -	$ -
AUT0246		n/a	$ -	$ -	$ -	$ -
AUT0248		n/a	$ -	$ -	$ -	$ -
AUT0257		n/a	$ -	$ -	$ -	$ -
AUT0260		n/a	$ -	$ -	$ -	$ -
AUT0270		n/a	$ -	$ -	$ -	$ -
AUT0275		n/a	$ -	$ -	$ -	$ -
AUT0276		n/a	$ -	$ -	$ -	$ -
AUT0285		n/a	$ -	$ -	$ -	$ -
AUT0286		n/a	$ -	$ -	$ -	$ -
AUT0287		n/a	$ -	$ -	$ -	$ -
AUT0296		n/a	$ -	$ -	$ -	$ -
AUT0300		n/a	$ -	$ -	$ -	$ -
AUT0304		n/a	$ -	$ -	$ -	$ -
AUT0307		n/a	$ -	$ -	$ -	$ -
AUT0310		n/a	$ -	$ -	$ -	$ -
AUT0315		n/a	$ -	$ -	$ -	$ -
AUT0343		n/a	$ -	$ -	$ -	$ -
AUT0344		n/a	$ -	$ -	$ -	$ -
AUT0350		n/a	$ -	$ -	$ -	$ -
AUT0355		n/a	$ -	$ -	$ -	$ -
AUT0356		n/a	$ -	$ -	$ -	$ -
AUT0359		n/a	$ -	$ -	$ -	$ -
AUT0363		n/a	$ -	$ -	$ -	$ -
AUT0373		n/a	$ -	$ -	$ -	$ -
AUT0380		n/a	$ -	$ -	$ -	$ -
AUT0388		n/a	$ -	$ -	$ -	$ -

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0390		n/a	$ -	$ -	$ -	$ -
AUT0394		n/a	$ -	$ -	$ -	$ -
AUT0396		n/a	$ -	$ -	$ -	$ -
AUT0397		n/a	$ -	$ -	$ -	$ -
AUT0403		n/a	$ -	$ -	$ -	$ -
AUT0405		n/a	$ -	$ -	$ -	$ -
AUT0406		n/a	$ -	$ -	$ -	$ -
AUT0411		n/a	$ -	$ -	$ -	$ -
AUT0415		n/a	$ -	$ -	$ -	$ -
AUT0419		n/a	$ -	$ -	$ -	$ -
AUT0424		n/a	$ -	$ -	$ -	$ -
AUT0433		n/a	$ -	$ -	$ -	$ -
AUT0440		n/a	$ -	$ -	$ -	$ -
AUT0443		n/a	$ -	$ -	$ -	$ -
AUT0444		n/a	$ -	$ -	$ -	$ -
AUT0453		n/a	$ -	$ -	$ -	$ -
AUT0455		n/a	$ -	$ -	$ -	$ -
AUT0459		n/a	$ -	$ -	$ -	$ -
AUT0462		n/a	$ -	$ -	$ -	$ -
AUT0463		n/a	$ -	$ -	$ -	$ -
AUT0467		n/a	$ -	$ -	$ -	$ -
AUT0473		n/a	$ -	$ -	$ -	$ -
AUT0477		n/a	$ -	$ -	$ -	$ -
AUT0478		n/a	$ -	$ -	$ -	$ -
AUT0481		n/a	$ -	$ -	$ -	$ -
AUT0482		n/a	$ -	$ -	$ -	$ -
AUT0492		n/a	$ -	$ -	$ -	$ -
AUT0500		n/a	$ -	$ -	$ -	$ -
AUT0507		n/a	$ -	$ -	$ -	$ -
AUT0512		n/a	$ -	$ -	$ -	$ -
AUT0515		n/a	$ -	$ -	$ -	$ -
AUT0521		n/a	$ -	$ -	$ -	$ -
AUT0531		n/a	$ -	$ -	$ -	$ -
AUT0536		n/a	$ -	$ -	$ -	$ -
AUT0537		n/a	$ -	$ -	$ -	$ -
AUT0538		n/a	$ -	$ -	$ -	$ -
AUT0540		n/a	$ -	$ -	$ -	$ -
AUT0544		n/a	$ -	$ -	$ -	$ -
AUT0546		n/a	$ -	$ -	$ -	$ -
AUT0555		n/a	$ -	$ -	$ -	$ -
AUT0559		n/a	$ -	$ -	$ -	$ -
AUT0561		n/a	$ -	$ -	$ -	$ -
AUT0571		n/a	$ -	$ -	$ -	$ -
AUT0573		n/a	$ -	$ -	$ -	$ -

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
AUT0575		n/a	$ -	$ -	$ -	$ -
AUT0580		n/a	$ -	$ -	$ -	$ -
AUT0582		n/a	$ -	$ -	$ -	$ -
AUT0595		n/a	$ -	$ -	$ -	$ -
AUT0602		n/a	$ -	$ -	$ -	$ -
AUT0604		n/a	$ -	$ -	$ -	$ -
AUT0606		n/a	$ -	$ -	$ -	$ -
AUT0608		n/a	$ -	$ -	$ -	$ -
AUT0618		n/a	$ -	$ -	$ -	$ -
AUT0636		n/a	$ -	$ -	$ -	$ -
AUT0637		n/a	$ -	$ -	$ -	$ -
AUT0755		n/a	$ -	$ -	$ -	$ -
DNU2002		n/a	$ -	$ -	$ -	$ -
DNU2005		n/a	$ -	$ -	$ -	$ -
DNU2006		n/a	$ -	$ -	$ -	$ -
DNU2015		n/a	$ -	$ -	$ -	$ -
DNU2031		n/a	$ -	$ -	$ -	$ -
DNU2047		n/a	$ -	$ -	$ -	$ -
DUT1010		n/a	$ -	$ -	$ -	$ -
DUT1013		n/a	$ -	$ -	$ -	$ -
DUT1021		n/a	$ -	$ -	$ -	$ -
DUT1026		n/a	$ -	$ -	$ -	$ -
DUT1027		n/a	$ -	$ -	$ -	$ -
DUT1032		n/a	$ -	$ -	$ -	$ -
DUT1039		n/a	$ -	$ -	$ -	$ -
DUT1046		n/a	$ -	$ -	$ -	$ -
DUT1049		n/a	$ -	$ -	$ -	$ -
DUT1053		n/a	$ -	$ -	$ -	$ -
DUT1056		n/a	$ -	$ -	$ -	$ -
DUT1070		n/a	$ -	$ -	$ -	$ -
DUT1071		n/a	$ -	$ -	$ -	$ -
DUT1078		n/a	$ -	$ -	$ -	$ -
DUT1081		n/a	$ -	$ -	$ -	$ -
DUT1087		n/a	$ -	$ -	$ -	$ -
DUT1092		n/a	$ -	$ -	$ -	$ -
DUT1104		n/a	$ -	$ -	$ -	$ -
DUT1105		n/a	$ -	$ -	$ -	$ -
DUT1106		n/a	$ -	$ -	$ -	$ -
DUT1117		n/a	$ -	$ -	$ -	$ -
DUT1120		n/a	$ -	$ -	$ -	$ -
DUT1129		n/a	$ -	$ -	$ -	$ -
DUT1130		n/a	$ -	$ -	$ -	$ -
DUT1142		n/a	$ -	$ -	$ -	$ -

Tabe 3-2: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 3	column 4	column 5	column 6	column 7
Facility ID	Intake ID	EPA Assumed Design Intake Flow, gpm (x_{epa})	Capital Cost	Baseline O&M Annual Cost	Post Construction O&M Annual Cost	Annualized Capital[3] + Net O&M Using EPA Design Intake Flow[2] (y_{epa})
DUT1143		n/a	$ -	$ -	$ -	$ -
DUT1148		n/a	$ -	$ -	$ -	$ -
DUT1149		n/a	$ -	$ -	$ -	$ -
DUT1153		n/a	$ -	$ -	$ -	$ -
DUT1154		n/a	$ -	$ -	$ -	$ -
DUT1155		n/a	$ -	$ -	$ -	$ -
DUT1161		n/a	$ -	$ -	$ -	$ -
DUT1167		n/a	$ -	$ -	$ -	$ -
DUT1170		n/a	$ -	$ -	$ -	$ -
DUT1172		n/a	$ -	$ -	$ -	$ -
DUT1174		n/a	$ -	$ -	$ -	$ -
DUT1175		n/a	$ -	$ -	$ -	$ -
DUT1176		n/a	$ -	$ -	$ -	$ -
DUT1177		n/a	$ -	$ -	$ -	$ -
DUT1183		n/a	$ -	$ -	$ -	$ -
DUT1188		n/a	$ -	$ -	$ -	$ -
DUT1191		n/a	$ -	$ -	$ -	$ -
DUT1192		n/a	$ -	$ -	$ -	$ -
DUT1194		n/a	$ -	$ -	$ -	$ -
DUT1199		n/a	$ -	$ -	$ -	$ -
DUT1201		n/a	$ -	$ -	$ -	$ -
DUT1213		n/a	$ -	$ -	$ -	$ -
DUT1220		n/a	$ -	$ -	$ -	$ -
DUT1222		n/a	$ -	$ -	$ -	$ -
DUT1224		n/a	$ -	$ -	$ -	$ -
DUT1225		n/a	$ -	$ -	$ -	$ -
DUT1228		n/a	$ -	$ -	$ -	$ -
DUT1233		n/a	$ -	$ -	$ -	$ -
DUT1234		n/a	$ -	$ -	$ -	$ -
DUT1235		n/a	$ -	$ -	$ -	$ -
DUT1239		n/a	$ -	$ -	$ -	$ -
DUT1243		n/a	$ -	$ -	$ -	$ -
DUT1254		n/a	$ -	$ -	$ -	$ -
DUT1257		n/a	$ -	$ -	$ -	$ -
DUT1262		n/a	$ -	$ -	$ -	$ -

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0001		$ -	$ -	$ -	I&E	2	0.8639
AUT0002		$ 6,650,155	$ 290,459	$ 559,082	I&E	12	3.6581
AUT0004		$ -	$ -	$ -	I	1	1.1604
AUT0011		$ -	$ -	$ -	I	1	1.1604
AUT0012		$ 110,716,357	$ 4,933,578	$ 9,315,779	I&E	12	3.6581
AUT0014		$ -	$ 276,073	$ 22,022	I&E	11	0.7352
AUT0015		$ -	$ -	$ -	I	5	0.1286
AUT0016		$ -	$ -	$ -	I	5	0.1286
AUT0019		$ -	$ -	$ -	I	1	1.1604
AUT0020		$ -	$ 153,333	$ 12,231	I&E	11	0.7352
AUT0021		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0024		$ -	$ -	$ -	I	5	0.1286
AUT0027		$ -	$ -	$ -	I	1	1.1604
AUT0044		$ -	$ -	$ -	I	5	0.1286
AUT0049		$ -	$ 204,745	$ 16,332	I&E	2	0.8639
AUT0051		$ -	$ -	$ -	I	4	2.5787
AUT0053		$ -	$ -	$ -	I&E	2	0.8639
AUT0057		$ -	$ -	$ -	I	1	1.1604
AUT0058		$ 7,092,806	$ 867,072	$ 640,749	I&E	12	3.6581
AUT0064		$ -	$ -	$ -	I	1	1.1604
AUT0066		$ 23,985,660	$ 150,000	$ 1,944,883	I&E	4	2.5787
AUT0078		$ -	$ 574,212	$ 45,804	I&E	2	0.8639
AUT0084		$ -	$ 150,331	$ 11,992	I&E	2	0.8639
AUT0085		$ 52,842,026	$ 2,351,844	$ 4,445,953	I&E	4	2.5787
AUT0092		$ -	$ -	$ -	I	5	0.1286
AUT0095		$ -	$ -	$ -	I&E	2	0.8639
AUT0106		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0110		$ 5,297,741	$ 651,167	$ 478,869	I&E	12	3.6581
AUT0120		$ -	$ 210,724	$ 16,809	I&E	2	0.8639
AUT0123		$ -	$ -	$ -	I	1	1.1604
AUT0127		$ -	$ -	$ -	I	1	1.1604
AUT0130		$ -	$ 821,067	$ 65,496	I&E	2	0.8639
AUT0131		$ -	$ -	$ -	I	1	1.1604
AUT0134		$ 238,035	$ -	$ 19,182	I	3	3.4562
AUT0137		$ -	$ 193,608	$ 15,444	I&E	2	0.8639
AUT0139		$ -	$ -	$ -	I	5	0.1286
AUT0142		$ 3,421,735	$ 955,845	$ 351,992	I&E	14	6.9559
AUT0143		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0146		$ -	$ -	$ -	I	1	1.1604
AUT0148		$ -	$ -	$ -	I&E	9	5.973
AUT0149		$ -	$ -	$ -	I	5	0.1286
AUT0151		$ -	$ -	$ -	I	1	1.1604
AUT0161		$ -	$ -	$ -	I	1	1.1604
AUT0168		$ 492,266	$ 260,480	$ 60,448	I&E	12	3.6581
AUT0171		$ 15,890,363	$ -	$ 1,280,547	I&E	7	2.504
AUT0174		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0175		$ -	$ -	$ -	I	1	1.1604
AUT0176		$ -	$ -	$ -	I	1	1.1604
AUT0183		$ -	$ -	$ -	I	1	1.1604
AUT0185		$ -	$ -	$ -	I	5	0.1286

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0187		$ -	$ -	$ -	I	5	0.1286
AUT0190		$ -	$ -	$ -	I&E	9	5.973
AUT0191		$ -	$ -	$ -	I&E	9	5.973
AUT0192		$ -	$ -	$ -	I	1	1.1604
AUT0193		$ 3,278,888	$ -	$ 264,234	I	3	3.4562
AUT0196		$ -	$ -	$ -	I	8	0.3315
AUT0197		$ -	$ -	$ -	I	1	1.1604
AUT0202		$ -	$ -	$ -	I&E	9	5.973
AUT0203		$ -	$ -	$ -	I	1	1.1604
AUT0205		$ -	$ -	$ -	I&E	1	1.1604
AUT0208		$ 3,544,915	$ -	$ 285,672	I&E	4	2.5787
AUT0222		$ -	$ -	$ -	I	8	0.3315
AUT0227		$ -	$ -	$ -	I	1	1.1604
AUT0228		$ -	$ -	$ -	I&E	2	0.8639
AUT0229		$ -	$ -	$ -	I&E	2	0.8639
AUT0238		$ -	$ -	$ -	I	1	1.1604
AUT0242		$ -	$ -	$ -	I	1	1.1604
AUT0244		$ -	$ -	$ -	I	1	1.1604
AUT0245		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
AUT0254		$ -	$ -	$ -	I	1	1.1604
AUT0255		$ -	$ -	$ -	I	8	0.3315
AUT0261		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0264		$ 43,525,468	$ 2,160,384	$ 3,679,892	I&E	12	3.6581
AUT0266		$ -	$ -	$ -	I&E	2	0.8639
AUT0268		$ -	$ -	$ -	I	1	1.1604
AUT0273		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0277		$ 186,802	$ -	$ 15,054	I&E	4	2.5787
AUT0278		$ -	$ 647,624	$ 51,660	I&E	11	0.7352
AUT0284		$ -	$ -	$ -	I	1	1.1604
AUT0292		$ -	$ -	$ -	I	1	1.1604
AUT0295		$ 5,005,800	$ -	$ 403,399	I&E	4	2.5787
AUT0297		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0298		$ -	$ -	$ -	I	5	0.1286
AUT0299		$ 15,622,548	$ 227,612	$ 1,277,121	I&E	12	3.6581
AUT0302		$ -	$ -	$ -	I	1	1.1604
AUT0305		$ 49,751,104	$ 4,326,108	$ 4,354,352	I&E	14	6.9559
AUT0308		$ 3,407,223	$ -	$ 274,576	I&E	7	2.504
AUT0309		$ -	$ -	$ -	I	5	0.1286
AUT0314		$ -	$ -	$ -	I	1	1.1604
AUT0319		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0321		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
AUT0331		$ -	$ -	$ -	I	5	0.1286
AUT0333		$ -	$ -	$ -	I	1	1.1604
AUT0337		$ -	$ -	$ -	I	5	0.1286
AUT0341		$ -	$ -	$ -	I	1	1.1604
AUT0345		$ -	$ -	$ -	I	1	1.1604
AUT0349		$ -	$ -	$ -	I	1	1.1604
AUT0351		$ 700,911	$ -	$ 56,484	I&E	3	3.4562
AUT0358		$ -	$ -	$ -	I	1	1.1604
AUT0361		$ 893,934	$ -	$ 72,039	I&E	3	3.4562

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0362		$ -	$ -	$ -	I	1	1.1604
AUT0364		$ -	$ -	$ -	I	1	1.1604
AUT0365		$ -	$ -	$ -	I&E	2	0.8639
AUT0368		$ -	$ -	$ -	I	1	1.1604
AUT0370		$ -	$ -	$ -	I	1	1.1604
AUT0379		$ -	$ -	$ -	I	5	0.1286
AUT0381		$ 506,182	$ -	$ 40,791	I&E	4	2.5787
AUT0384		$ -	$ -	$ -	I&E	2	0.8639
AUT0385		$ 1,445,463	$ -	$ 116,485	I&E	4	2.5787
AUT0387		$ -	$ 533,808	$ 42,581	I&E	2	0.8639
AUT0398		$ 6,440,309	$ -	$ 519,001	I&E	4	2.5787
AUT0399		$ -	$ -	$ -	I	8	0.3315
AUT0401		$ -	$ -	$ -	I	5	0.1286
AUT0404		$ 3,259,312	$ -	$ 262,656	I&E	4	2.5787
AUT0408		$ 803,968	$ -	$ 64,789	I&E	4	2.5787
AUT0416		$ -	$ -	$ -	I&E	2	0.8639
AUT0423		$ -	$ -	$ -	I&E	9	5.973
AUT0427		$ -	$ -	$ -	I	8	0.3315
AUT0431		$ -	$ -	$ -	I	1	1.1604
AUT0434		$ -	$ -	$ -	I	1	1.1604
AUT0435		$ -	$ -	$ -	I&E	2	0.8639
AUT0441		$ -	$ -	$ -	I	1	1.1604
AUT0446		$ 1,404,150	$ -	$ 113,155	I&E	4	2.5787
AUT0449		$ -	$ -	$ -	I	1	1.1604
AUT0472		$ -	$ -	$ -	I&E	2	0.8639
AUT0476		$ -	$ -	$ -	I	1	1.1604
AUT0483		$ -	$ 274,363	$ 21,886	I&E	11	0.7352
AUT0489		$ -	$ -	$ -	I	1	1.1604
AUT0490		$ 3,548,991	$ -	$ 286,000	I&E	4	2.5787
AUT0493		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0496		$ -	$ -	$ -	I	1	1.1604
AUT0499		$ -	$ -	$ -	I&E	2	0.8639
AUT0501		$ -	$ -	$ -	I&E	2	0.8639
AUT0513		$ 36,923,245	$ -	$ 2,975,512	I&E	4	2.5787
AUT0517		$ -	$ -	$ -	I	1	1.1604
AUT0518		$ -	$ -	$ -	I	1	1.1604
AUT0522		$ -	$ -	$ -	I&E	2	0.8639
AUT0523		$ -	$ -	$ -	I&E	9	5.973
AUT0529		$ -	$ -	$ -	I	1	1.1604
AUT0534		$ -	$ -	$ -	I	1	1.1604
AUT0535		$ 604,316	$ -	$ 48,700	I&E	3	3.4562
AUT0539		$ 2,343,730	$ 1,412,165	$ 301,520	I&E	12	3.6581
AUT0541		$ 27,152,758	$ 169,037	$ 2,201,627	I&E	12	3.6581
AUT0547		$ 17,882,815	$ -	$ 1,441,112	I&E	4	2.5787
AUT0551		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
AUT0552		$ -	$ -	$ -	I	5	0.1286
AUT0553		$ -	$ -	$ -	I	1	1.1604
AUT0554		$ 1,498,242	$ -	$ 120,738	I&E	3	3.4562
AUT0557		$ -	$ -	$ -	I	5	0.1286
AUT0564		$ 15,236,406	$ -	$ 1,227,847	I&E	7	2.504

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0567		$ 4,139,441	$ -	$ 333,583	I&E	4	2.5787
AUT0568		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0570		$ -	$ -	$ -	I	1	1.1604
AUT0577		$ -	$ -	$ -	I&E	7	2.504
AUT0583		$ 9,610,528	$ -	$ 774,478	I&E	4	2.5787
AUT0585		$ 1,102,473	$ -	$ 88,844	I&E	4	2.5787
AUT0588		$ -	$ 180,701	$ 14,414	I&E	11	0.7352
AUT0590		$ -	$ -	$ -	I	1	1.1604
AUT0599		$ -	$ 307,205	$ 24,505	I	4	2.5787
AUT0600		$ -	$ -	$ -	I	1	1.1604
AUT0601		$ -	$ -	$ -	I&E	2	0.8639
AUT0603		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0607		$ 3,693,163	$ 456,845	$ 334,061	I&E	12	3.6581
AUT0611		$ -	$ -	$ -	I	1	1.1604
AUT0612		$ -	$ -	$ -	I&E	13	7.0567
AUT0613		$ -	$ -	$ -	I	1	1.1604
AUT0617		$ 2,161,531	$ 1,247,332	$ 273,688	I&E	12	3.6581
AUT0619		$ -	$ -	$ -	I&E	2	0.8639
AUT0620		$ -	$ 222,140	$ 17,720	I&E	11	0.7352
AUT0621		$ -	$ -	$ -	I	1	1.1604
AUT0623		$ -	$ -	$ -	I	2	0.8639
AUT0625		$ -	$ -	$ -	I	1	1.1604
AUT0630		$ 974,792	$ -	$ 78,555	I&E	3	3.4562
AUT0631		$ 193,002	$ -	$ 15,553	I&E	3	3.4562
AUT0635		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
AUT0638		$ -	$ 236,083	$ 18,832	I&E	2	0.8639
AUT0639		$ -	$ -	$ -	I	1	1.1604
DMU3244	1	$ -	$ -	$ -	I	1	1.1604
DMU3244	2	$ -	$ -	$ -	I	1	1.1604
DMU3310		$ -	$ -	$ -	I	1	1.1604
DNU2003		$ -	$ -	$ -	I	5	0.1286
DNU2010		$ 543,834	$ -	$ 43,826	I	4	2.5787
DNU2011		$ 5,223,420	$ 273,533	$ 442,756	I&E	12	3.6581
DNU2013		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DNU2014		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DNU2017		$ -	$ -	$ -	I&E	13	7.0567
DNU2018		$ -	$ -	$ -	I&E	11	0.7352
DNU2021		$ -	$ -	$ -	I	1	1.1604
DNU2025		$ -	$ 779,937	$ 62,215	I&E	2	0.8639
DNU2032	Units 1 & 2	$ -	$ -	$ -	I	5	0.1286
DNU2032	Unit 3	$ -	$ -	$ -	I	5	0.1286
DNU2032	Unit 4	$ -	$ -	$ -	I	5	0.1286
DNU2038		$ -	$ -	$ -	I&E	2	0.8639
DUT0062	1	$ 5,279,493	$ -	$ 425,455	I&E	4	2.5787
DUT0062	2	$ 5,279,493	$ -	$ 425,455	I&E	4	2.5787
DUT0576	5&6	$ -	$ -	$ -	I	1	1.1604
DUT0576	7	$ -	$ -	$ -	I	1	1.1604
DUT0576	CT	$ -	$ -	$ -	I	1	1.1604
DUT1002	Screenhouse 1	$ -	$ -	$ -	I&E	2	0.8639
DUT1002	Screenhouse 2	$ -	$ -	$ -	I&E	2	0.8639

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
DUT1003		$ 236,360	$ -	$ 19,047	I	4	2.5787
DUT1006	Unit 1/2	$ -	$ -	$ -	I	1	1.1604
DUT1006	Unit 3/4	$ -	$ -	$ -	I	1	1.1604
DUT1007		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DUT1008		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
DUT1011		$ -	$ -	$ -	I	1	1.1604
DUT1012		$ -	$ -	$ -	I	1	1.1604
DUT1014		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
DUT1022		$ -	$ -	$ -	I	1	1.1604
DUT1023	CWS #535		$ -	$ -	I&E	3	3.4562
DUT1023	DWS #536	$ 4,830,432	$ -	$ 389,267	I&E	3	3.4562
DUT1029	CRS		$ -	$ -	I&E	3	3.4562
DUT1029	CR Nuc		$ -	$ -	I&E	2	0.8639
DUT1029	CRN		$ -	$ -	I&E	11	0.7352
DUT1029	HCT	$ 21,796,254	$ 667,692	$ 1,809,743	I&E	11	0.7352
DUT1031	1		$ -	$ -	I&E	4	2.5787
DUT1031	2	$ 5,399,114	$ -	$ 435,095	I&E	4	2.5787
DUT1033		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DUT1034		$ -	$ 504,175	$ 40,218	I&E	2	0.8639
DUT1036		$ -	$ -	$ -	I	1	1.1604
DUT1038		$ -	$ -	$ -	I	1	1.1604
DUT1041		$ -	$ -	$ -	I	1	1.1604
DUT1043		$ -	$ -	$ -	I	5	0.1286
DUT1044		$ -	$ -	$ -	I	5	0.1286
DUT1047		$ 4,783,541	$ -	$ 385,488	I&E	7	2.504
DUT1048	HI-1	$ -	$ -	$ -	I	1	1.1604
DUT1048	HI-2	$ -	$ -	$ -	I	1	1.1604
DUT1050		$ -	$ -	$ -	I	5	0.1286
DUT1051		$ -	$ -	$ -	I	1	1.1604
DUT1057		$ 7,997,712	$ -	$ 644,507	I&E	4	2.5787
DUT1062		$ -	$ -	$ -	I	5	0.1286
DUT1066		$ 845,987	$ -	$ 68,175	I&E	3	3.4562
DUT1067	1	$ -	$ -	$ -	I	5	0.1286
DUT1067	2	$ -	$ -	$ -	I	5	0.1286
DUT1067	3	$ -	$ -	$ -	I	5	0.1286
DUT1068		$ -	$ -	$ -	I&E	11	0.7352
DUT1072		$ -	$ -	$ -	I	1	1.1604
DUT1084		$ -	$ -	$ -	I	1	1.1604
DUT1085		$ -	$ 243,540	$ 19,427	I&E	2	0.8639
DUT1086	Unit 1	$ -	$ -	$ -	I&E	2	0.8639
DUT1086	Unit 2	$ -	$ 150,000	$ 11,965	I&E	2	0.8639
DUT1088	#4		$ -	$ -	I&E	7	2.504
DUT1088	#5	$ 1,601,167	$ -	$ 129,032	I&E	7	2.504
DUT1093		$ -	$ -	$ -	I&E	9	5.973
DUT1097		$ -	$ 237,372	$ 18,935	I&E	6	5.0065
DUT1098		$ -	$ -	$ -	I	1	1.1604
DUT1100	Units 1 & 2	$ -	$ -	$ -	I	5	0.1286
DUT1100	Units 3 & 4	$ -	$ -	$ -	I	5	0.1286
DUT1103	Unit 1 Screenhouse	$ -	$ -	$ -	I		

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
DUT1103	Unit 2 Screenhouse	$ -	$ -	$ -	I	5	0.1286
DUT1103	Hvdc Lake Intake	$ -	$ -	$ -	I	8	0.3315
DUT1103	Hvdc Separator Dike	$ -	$ -	$ -	I	8	0.3315
DUT1103	River Intake	$ -	$ -	$ -	I	1	1.1604
DUT1109		$ -	$ 150,000	$ 11,965	I	2	0.8639
DUT1111	Unit 1&2	$ -	$ -	$ -	I&E	11	0.7352
DUT1111	Unit 3	$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DUT1112		$ -	$ -	$ -	I	1	1.1604
DUT1113	System 27	$ -	$ -	$ -	I	1	1.1604
DUT1113	System 67	$ -	$ -	$ -	I	8	0.3315
DUT1116		$ -	$ 291,604	$ 23,261	I&E	11	0.7352
DUT1118		$ -	$ -	$ -	I	5	0.1286
DUT1122		$ -	$ -	$ -	I	5	0.1286
DUT1123	6		$ -	$ -	I&E	3	3.4562
DUT1123	7		$ -	$ -	I&E	6	5.0065
DUT1123	8	$ 1,136,010	$ -	$ 91,547	I&E	3	3.4562
DUT1132		$ -	$ 403,601	$ 32,195	I&E	2	0.8639
DUT1133		$ -	$ 150,000	$ 11,965	I&E	11	0.7352
DUT1138		$ -	$ -	$ -	I	1	1.1604
DUT1140	Mc2-4	$ -	$ -	$ -	I	1	1.1604
DUT1140	Mc5&6	$ -	$ -	$ -	I	1	1.1604
DUT1145		$ 1,565,614	$ 273,068	$ 147,950	I&E	12	3.6581
DUT1146		$ -	$ -	$ -	I&E	2	0.8639
DUT1152		$ -	$ -	$ -	I	1	1.1604
DUT1156		$ 9,287,608	$ -	$ 748,455	I&E	7	2.504
DUT1157	6	$ -	$ -	$ -	I&E	4	2.5787
DUT1157	7	$ -	$ -	$ -	I&E	4	2.5787
DUT1165	1		$ -	$ -	I&E	3	3.4562
DUT1165	2	$ 9,426,676	$ -	$ 759,662	I&E		
DUT1169		$ 1,896,934	$ -	$ 152,867	I&E	3	3.4562
DUT1173		$ -	$ -	$ -	I&E	2	0.8639
DUT1179		$ -	$ -	$ -	I	1	1.1604
DUT1185		$ 1,266,125	$ -	$ 102,032	I&E	7	2.504
DUT1186	Unit 4	$ -	$ -	$ -	I	1	1.1604
DUT1186	Unit 5	$ -	$ -	$ -	I	1	1.1604
DUT1187	Mt 2&3	$ -	$ -	$ -	I	5	0.1286
DUT1187	Mt 6-8	$ -	$ -	$ -	I	5	0.1286
DUT1189	Unit 6 & 8	$ -	$ -	$ -	I	5	0.1286
DUT1189	Unit 7	$ -	$ -	$ -	I	5	0.1286
DUT1198		$ 268,118	$ -	$ 21,607	I&E	3	3.4562
DUT1202	Power Plant	$ -	$ -	$ -	I&E	11	0.7352
DUT1202	Filtration Plant	$ -	$ -	$ -	I&E	9	5.973
DUT1206	1	$ -	$ -	$ -	I&E	2	0.8639
DUT1206	2	$ -	$ -	$ -	I&E	2	0.8639
DUT1206	3	$ -	$ -	$ -	I&E	2	0.8639
DUT1209	Plant a		$ -	$ -	I&E	11	0.7352
DUT1209	Plant B	$ 5,849,051	$ -	$ 471,354	I&E	3	3.4562
DUT1211		$ -	$ 3,326,419	$ 265,345	I&E	11	0.7352

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
DUT1212		$ -	$ -	$ -	I	1	1.1604
DUT1214		$ 7,829,721	$ -	$ 630,969	I	4	2.5787
DUT1217	Unit 1	$ -	$ -	$ -	I&E		
DUT1217	Unit 6-8	$ -	$ -	$ -	I&E	13	7.0567
DUT1217	Unit 4	$ -	$ -	$ -	I&E		
DUT1219		$ -	$ 289,194	$ 23,069	I&E	2	0.8639
DUT1223	1		$ -	$ -	I&E	12	3.6581
DUT1223	2	$ 376,088	$ 179,011	$ 44,587	I&E	12	3.6581
DUT1227	1 & 2	$ -	$ -	$ -	I	1	1.1604
DUT1227	3	$ -	$ -	$ -	I	1	1.1604
DUT1229		$ -	$ -	$ -	I&E	2	0.8639
DUT1238	A	$ -	$ -	$ -	I	2	0.8639
DUT1238	B	$ -	$ -	$ -	I	2	0.8639
DUT1248		$ -	$ -	$ -	I	5	0.1286
DUT1249		$ -	$ -	$ -	I	5	0.1286
DUT1250		$ 17,224,807	$ -	$ 1,388,085	I&E	7	2.504
DUT1252		$ -	$ -	$ -	I	1	1.1604
DUT1258	Screen House No.1		$ -	$ -	I&E	3	3.4562
DUT1258	Screen House No.2		$ -	$ -	I&E	3	3.4562
DUT1258	Screen House No.3	$ 4,429,893	$ -	$ 356,989	I&E	3	3.4562
DUT1259		$ 81,723	$ -	$ 6,586	I&E	3	3.4562
DUT1261	U12		$ -	$ -	I&E	2	0.8639
DUT1261	U34	$ 1,650,821	$ -	$ 133,034	I&E	4	2.5787
DUT1265		$ -	$ 150,000	$ 11,965	I&E	2	0.8639
DUT1268		$ -	$ 2,112,610	$ 168,521	I&E	11	0.7352
DUT1269		$ -	$ 304,315	$ 24,275	I&E	11	0.7352
DUT1270		$ -	$ -	$ -	I	5	0.1286
DUT1271		$ 4,337,253	$ 1,512,343	$ 470,162	I&E	7	2.504
DUT1272	Mo1 & 2	$ -	$ -	$ -	I	1	1.1604
DUT1272	Mo3	$ -	$ -	$ -	I	1	1.1604
DUT1273		$ -	$ -	$ -	I	1	1.1604
DUT1274		$ -	$ -	$ -	I	1	1.1604
DUT1275		$ -	$ 680,886	$ 54,314	I	2	0.8639
DUT1276		$ -	$ -	$ -	I&E	11	0.7352
DUT1278		$ -	$ -	$ -	I	1	1.1604
Facilities Receiving No EPA Technology Upgrade Costs							
AUT0010		$ -	$ -	$ -		n/a	n/a
AUT0013		$ -	$ -	$ -		n/a	n/a
AUT0018		$ -	$ -	$ -		n/a	n/a
AUT0022		$ -	$ -	$ -		n/a	n/a
AUT0033		$ -	$ -	$ -		n/a	n/a
AUT0036		$ -	$ -	$ -		n/a	n/a
AUT0041		$ -	$ -	$ -		n/a	n/a
AUT0047		$ -	$ -	$ -		n/a	n/a
AUT0050		$ -	$ -	$ -		n/a	n/a
AUT0054		$ -	$ -	$ -		n/a	n/a
AUT0067		$ -	$ -	$ -		n/a	n/a

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0068		$ -	$ -	$ -		n/a	n/a
AUT0071		$ -	$ -	$ -		n/a	n/a
AUT0072		$ -	$ -	$ -		n/a	n/a
AUT0073		$ -	$ -	$ -		n/a	n/a
AUT0077		$ -	$ -	$ -		n/a	n/a
AUT0079		$ -	$ -	$ -		n/a	n/a
AUT0080		$ -	$ -	$ -		n/a	n/a
AUT0083		$ -	$ -	$ -		n/a	n/a
AUT0087		$ -	$ -	$ -		n/a	n/a
AUT0091		$ -	$ -	$ -		n/a	n/a
AUT0093		$ -	$ -	$ -		n/a	n/a
AUT0097		$ -	$ -	$ -		n/a	n/a
AUT0101		$ -	$ -	$ -		n/a	n/a
AUT0104		$ -	$ -	$ -		n/a	n/a
AUT0111		$ -	$ -	$ -		n/a	n/a
AUT0114		$ -	$ -	$ -		n/a	n/a
AUT0125		$ -	$ -	$ -		n/a	n/a
AUT0126		$ -	$ -	$ -		n/a	n/a
AUT0129		$ -	$ -	$ -		n/a	n/a
AUT0152		$ -	$ -	$ -		n/a	n/a
AUT0156		$ -	$ -	$ -		n/a	n/a
AUT0157		$ -	$ -	$ -		n/a	n/a
AUT0160		$ -	$ -	$ -		n/a	n/a
AUT0163		$ -	$ -	$ -		n/a	n/a
AUT0170		$ -	$ -	$ -		n/a	n/a
AUT0173		$ -	$ -	$ -		n/a	n/a
AUT0178		$ -	$ -	$ -		n/a	n/a
AUT0181		$ -	$ -	$ -		n/a	n/a
AUT0182		$ -	$ -	$ -		n/a	n/a
AUT0199		$ -	$ -	$ -		n/a	n/a
AUT0201		$ -	$ -	$ -		n/a	n/a
AUT0215		$ -	$ -	$ -		n/a	n/a
AUT0216		$ -	$ -	$ -		n/a	n/a
AUT0221		$ -	$ -	$ -		n/a	n/a
AUT0226		$ -	$ -	$ -		n/a	n/a
AUT0230		$ -	$ -	$ -		n/a	n/a
AUT0232		$ -	$ -	$ -		n/a	n/a
AUT0235		$ -	$ -	$ -		n/a	n/a
AUT0240		$ -	$ -	$ -		n/a	n/a
AUT0241		$ -	$ -	$ -		n/a	n/a
AUT0246		$ -	$ -	$ -		n/a	n/a
AUT0248		$ -	$ -	$ -		n/a	n/a
AUT0257		$ -	$ -	$ -		n/a	n/a
AUT0260		$ -	$ -	$ -		n/a	n/a
AUT0270		$ -	$ -	$ -		n/a	n/a
AUT0275		$ -	$ -	$ -		n/a	n/a
AUT0276		$ -	$ -	$ -		n/a	n/a
AUT0285		$ -	$ -	$ -		n/a	n/a
AUT0286		$ -	$ -	$ -		n/a	n/a
AUT0287		$ -	$ -	$ -		n/a	n/a

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0296		$ -	$ -	$ -		n/a	n/a
AUT0300		$ -	$ -	$ -		n/a	n/a
AUT0304		$ -	$ -	$ -		n/a	n/a
AUT0307		$ -	$ -	$ -		n/a	n/a
AUT0310		$ -	$ -	$ -		n/a	n/a
AUT0315		$ -	$ -	$ -		n/a	n/a
AUT0343		$ -	$ -	$ -		n/a	n/a
AUT0344		$ -	$ -	$ -		n/a	n/a
AUT0350		$ -	$ -	$ -		n/a	n/a
AUT0355		$ -	$ -	$ -		n/a	n/a
AUT0356		$ -	$ -	$ -		n/a	n/a
AUT0359		$ -	$ -	$ -		n/a	n/a
AUT0363		$ -	$ -	$ -		n/a	n/a
AUT0373		$ -	$ -	$ -		n/a	n/a
AUT0380		$ -	$ -	$ -		n/a	n/a
AUT0388		$ -	$ -	$ -		n/a	n/a
AUT0390		$ -	$ -	$ -		n/a	n/a
AUT0394		$ -	$ -	$ -		n/a	n/a
AUT0396		$ -	$ -	$ -		n/a	n/a
AUT0397		$ -	$ -	$ -		n/a	n/a
AUT0403		$ -	$ -	$ -		n/a	n/a
AUT0405		$ -	$ -	$ -		n/a	n/a
AUT0406		$ -	$ -	$ -		n/a	n/a
AUT0411		$ -	$ -	$ -		n/a	n/a
AUT0415		$ -	$ -	$ -		n/a	n/a
AUT0419		$ -	$ -	$ -		n/a	n/a
AUT0424		$ -	$ -	$ -		n/a	n/a
AUT0433		$ -	$ -	$ -		n/a	n/a
AUT0440		$ -	$ -	$ -		n/a	n/a
AUT0443		$ -	$ -	$ -		n/a	n/a
AUT0444		$ -	$ -	$ -		n/a	n/a
AUT0453		$ -	$ -	$ -		n/a	n/a
AUT0455		$ -	$ -	$ -		n/a	n/a
AUT0459		$ -	$ -	$ -		n/a	n/a
AUT0462		$ -	$ -	$ -		n/a	n/a
AUT0463		$ -	$ -	$ -		n/a	n/a
AUT0467		$ -	$ -	$ -		n/a	n/a
AUT0473		$ -	$ -	$ -		n/a	n/a
AUT0477		$ -	$ -	$ -		n/a	n/a
AUT0478		$ -	$ -	$ -		n/a	n/a
AUT0481		$ -	$ -	$ -		n/a	n/a
AUT0482		$ -	$ -	$ -		n/a	n/a
AUT0492		$ -	$ -	$ -		n/a	n/a
AUT0500		$ -	$ -	$ -		n/a	n/a
AUT0507		$ -	$ -	$ -		n/a	n/a
AUT0512		$ -	$ -	$ -		n/a	n/a
AUT0515		$ -	$ -	$ -		n/a	n/a
AUT0521		$ -	$ -	$ -		n/a	n/a
AUT0531		$ -	$ -	$ -		n/a	n/a
AUT0536		$ -	$ -	$ -		n/a	n/a

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
AUT0537		$ -	$ -	$ -		n/a	n/a
AUT0538		$ -	$ -	$ -		n/a	n/a
AUT0540		$ -	$ -	$ -		n/a	n/a
AUT0544		$ -	$ -	$ -		n/a	n/a
AUT0546		$ -	$ -	$ -		n/a	n/a
AUT0555		$ -	$ -	$ -		n/a	n/a
AUT0559		$ -	$ -	$ -		n/a	n/a
AUT0561		$ -	$ -	$ -		n/a	n/a
AUT0571		$ -	$ -	$ -		n/a	n/a
AUT0573		$ -	$ -	$ -		n/a	n/a
AUT0575		$ -	$ -	$ -		n/a	n/a
AUT0580		$ -	$ -	$ -		n/a	n/a
AUT0582		$ -	$ -	$ -		n/a	n/a
AUT0595		$ -	$ -	$ -		n/a	n/a
AUT0602		$ -	$ -	$ -		n/a	n/a
AUT0604		$ -	$ -	$ -		n/a	n/a
AUT0606		$ -	$ -	$ -		n/a	n/a
AUT0608		$ -	$ -	$ -		n/a	n/a
AUT0618		$ -	$ -	$ -		n/a	n/a
AUT0636		$ -	$ -	$ -		n/a	n/a
AUT0637		$ -	$ -	$ -		n/a	n/a
AUT0755		$ -	$ -	$ -		n/a	n/a
DNU2002		$ -	$ -	$ -		n/a	n/a
DNU2005		$ -	$ -	$ -		n/a	n/a
DNU2006		$ -	$ -	$ -		n/a	n/a
DNU2015		$ -	$ -	$ -		n/a	n/a
DNU2031		$ -	$ -	$ -		n/a	n/a
DNU2047		$ -	$ -	$ -		n/a	n/a
DUT1010		$ -	$ -	$ -		n/a	n/a
DUT1013		$ -	$ -	$ -		n/a	n/a
DUT1021		$ -	$ -	$ -		n/a	n/a
DUT1026		$ -	$ -	$ -		n/a	n/a
DUT1027		$ -	$ -	$ -		n/a	n/a
DUT1032		$ -	$ -	$ -		n/a	n/a
DUT1039		$ -	$ -	$ -		n/a	n/a
DUT1046		$ -	$ -	$ -		n/a	n/a
DUT1049		$ -	$ -	$ -		n/a	n/a
DUT1053		$ -	$ -	$ -		n/a	n/a
DUT1056		$ -	$ -	$ -		n/a	n/a
DUT1070		$ -	$ -	$ -		n/a	n/a
DUT1071		$ -	$ -	$ -		n/a	n/a
DUT1078		$ -	$ -	$ -		n/a	n/a
DUT1081		$ -	$ -	$ -		n/a	n/a
DUT1087		$ -	$ -	$ -		n/a	n/a
DUT1092		$ -	$ -	$ -		n/a	n/a
DUT1104		$ -	$ -	$ -		n/a	n/a
DUT1105		$ -	$ -	$ -		n/a	n/a
DUT1106		$ -	$ -	$ -		n/a	n/a
DUT1117		$ -	$ -	$ -		n/a	n/a
DUT1120		$ -	$ -	$ -		n/a	n/a

Tabe 3-2, continued: Costs Considered by EPA in Establishing Performance Standards ($2002)

column 1	column 2	column 8	column 9	column 10	column 11	column 12	column 13
Facility ID	Intake ID	Net Revenue Losses from Net Construction Downtime	Pilot Study Costs	Annualized Downtime and Pilot Study Costs[2,4]	Performance Standards on which EPA Cost Estimates are Based	EPA Modeled Technology	Design Flow Adjustment Slope (m)[1]
DUT1129		$ -	$ -	$ -		n/a	n/a
DUT1130		$ -	$ -	$ -		n/a	n/a
DUT1142		$ -	$ -	$ -		n/a	n/a
DUT1143		$ -	$ -	$ -		n/a	n/a
DUT1148		$ -	$ -	$ -		n/a	n/a
DUT1149		$ -	$ -	$ -		n/a	n/a
DUT1153		$ -	$ -	$ -		n/a	n/a
DUT1154		$ -	$ -	$ -		n/a	n/a
DUT1155		$ -	$ -	$ -		n/a	n/a
DUT1161		$ -	$ -	$ -		n/a	n/a
DUT1167		$ -	$ -	$ -		n/a	n/a
DUT1170		$ -	$ -	$ -		n/a	n/a
DUT1172		$ -	$ -	$ -		n/a	n/a
DUT1174		$ -	$ -	$ -		n/a	n/a
DUT1175		$ -	$ -	$ -		n/a	n/a
DUT1176		$ -	$ -	$ -		n/a	n/a
DUT1177		$ -	$ -	$ -		n/a	n/a
DUT1183		$ -	$ -	$ -		n/a	n/a
DUT1188		$ -	$ -	$ -		n/a	n/a
DUT1191		$ -	$ -	$ -		n/a	n/a
DUT1192		$ -	$ -	$ -		n/a	n/a
DUT1194		$ -	$ -	$ -		n/a	n/a
DUT1199		$ -	$ -	$ -		n/a	n/a
DUT1201		$ -	$ -	$ -		n/a	n/a
DUT1213		$ -	$ -	$ -		n/a	n/a
DUT1220		$ -	$ -	$ -		n/a	n/a
DUT1222		$ -	$ -	$ -		n/a	n/a
DUT1224		$ -	$ -	$ -		n/a	n/a
DUT1225		$ -	$ -	$ -		n/a	n/a
DUT1228		$ -	$ -	$ -		n/a	n/a
DUT1233		$ -	$ -	$ -		n/a	n/a
DUT1234		$ -	$ -	$ -		n/a	n/a
DUT1235		$ -	$ -	$ -		n/a	n/a
DUT1239		$ -	$ -	$ -		n/a	n/a
DUT1243		$ -	$ -	$ -		n/a	n/a
DUT1254		$ -	$ -	$ -		n/a	n/a
DUT1257		$ -	$ -	$ -		n/a	n/a
DUT1262		$ -	$ -	$ -		n/a	n/a

[1]The design flow adjustment slope (m) represents the slope that corresponds to the particular facility using the technology in column 3.

[2]Discount rate = 7%

[3]Amortization period for capital costs = 10 years

[4]Amortization period for downtime and pilot study costs = 30 years

Note: Depending on the data provided, some facilities with multiple intakes were costed separately for each intake. In such cases, the facility should calculate the costs considered by EPA for each intake using the steps below and sum. Note that some costs (eg construction downtime) are assigned evenly to each intake for convenience.

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0001	Cane Run
AUT0002	Chesapeake
AUT0004	Hennepin
AUT0010	Bowen
AUT0011	Shawville
AUT0012	Diablo Canyon Nuclear
AUT0013	Montville
AUT0014	Williams
AUT0015	Northport
AUT0016	Cholla
AUT0018	R M Heskett Station
AUT0019	Charles Poletti
AUT0020	B L England
AUT0021	B C Cobb
AUT0022	St Johns River Power
AUT0024	Bull Run
AUT0027	Lake Hubbard
AUT0033	Muscatine
AUT0036	Edgewater
AUT0041	Edwin I Hatch
AUT0044	Hunters Point
AUT0047	Michoud
AUT0049	Chalk Point
AUT0050	Wyandotte
AUT0051	Suwannee River
AUT0053	Nelson Dewey
AUT0054	Flint Creek
AUT0057	Thomas Fitzhugh
AUT0058	Mercer
AUT0064	Decordova
AUT0066	Fermi Nuclear
AUT0067	Henry D King
AUT0068	Scattergood
AUT0071	Oswego
AUT0072	Sioux
AUT0073	Lake Catherine
AUT0078	Missouri City
AUT0079	Eagle Mountain
AUT0080	Lone Star
AUT0083	Schiller
AUT0084	Salem Nuclear
AUT0085	Point Beach Nuclear
AUT0092	Linden
AUT0093	Perry Nuclear
AUT0095	Tyrone
AUT0097	Little Gypsy
AUT0101	Lakeside
AUT0106	Cheswick
AUT0110	C P Crane
AUT0111	Cape Fear
AUT0114	Kewaunee Nuclear
AUT0120	Norwalk Harbor
AUT0123	Warren

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0125	Beaver Valley Nuclear
AUT0127	Lake Road
AUT0129	Susquehanna Nuclear
AUT0130	Elmer W Stout
AUT0131	Hammond
AUT0134	Mount Tom
AUT0137	Mitchell
AUT0139	Albany
AUT0142	Lauderdale
AUT0143	Wood River
AUT0146	Meredosia
AUT0148	Tanners Creek
AUT0149	Thomas Hill
AUT0151	Decker Creek
AUT0152	Duck Creek
AUT0156	Waterford 1 & 2
AUT0157	Pulliam
AUT0160	L V Sutton
AUT0161	Valley
AUT0163	Belle River
AUT0168	E F Barrett
AUT0170	O W Sommers
AUT0171	New Madrid
AUT0173	Fort Calhoun Nuclear
AUT0174	Herbert a Wagner
AUT0175	R E Burger
AUT0176	Martin Lake
AUT0178	Mt Storm
AUT0181	Prairie Creek
AUT0182	Arsenal Hill
AUT0183	Schuylkill
AUT0185	Gallatin
AUT0187	North Anna Nuclear
AUT0190	Ginna
AUT0191	J H Campbell
AUT0192	R W Miller
AUT0193	Joliet 29
AUT0196	Southside
AUT0197	Austin-dt
AUT0201	Cope
AUT0202	Donald C Cook Nuclear
AUT0203	Riverside
AUT0205	Joliet 9
AUT0208	New Castle
AUT0215	Coleto Creek
AUT0216	Fort St Vrain
AUT0221	Polk
AUT0222	Marion
AUT0226	Sooner
AUT0227	Silver Lake
AUT0228	High Bridge
AUT0229	Dan E Karn

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0230	Mcwilliams
AUT0232	V H Braunig
AUT0235	Sam Rayburn
AUT0238	North Lake
AUT0240	Lee
AUT0241	J B Sims
AUT0242	Quad Cities Nuclear
AUT0244	Elk River
AUT0245	Avon Lake
AUT0246	Canaday
AUT0248	Sam Bertron
AUT0254	Chamois
AUT0255	Cooper
AUT0257	Gerald Gentleman
AUT0260	Marshall
AUT0261	Dale
AUT0264	Indian Point 3 Nucler
AUT0266	North Omaha
AUT0268	Cutler
AUT0270	Possum Point
AUT0273	Stanton
AUT0275	Seabrook Nuclear
AUT0276	River Rouge
AUT0277	Dubuque
AUT0278	Morgantown
AUT0284	Handley
AUT0285	Conners Creek
AUT0286	Welsh
AUT0287	Horseshoe Lake
AUT0292	Harris Nuclear
AUT0295	Jack Mcdonough
AUT0296	W H Zimmer
AUT0297	Quindaro
AUT0298	Harllee Branch
AUT0299	Chesterfield
AUT0300	Eckert Station
AUT0302	US DOE SRS (D-area)
AUT0304	Lansing
AUT0305	Kahe
AUT0307	Rodemacher
AUT0308	W S Lee
AUT0309	Wilkes
AUT0310	A B Paterson
AUT0314	Philip Sporn
AUT0315	Sabine
AUT0319	Cliffside
AUT0321	J E Corette
AUT0331	Lake Creek
AUT0333	Hamilton
AUT0337	Johnsonville
AUT0341	Montrose
AUT0343	John E Amos
AUT0344	Weston

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0345	Summer Nuclear
AUT0349	Mcguire Nuclear
AUT0350	Clinton Nuclear
AUT0351	Portland
AUT0355	Limerick Nuclear
AUT0356	Byron Nuclear
AUT0358	H T Pritchard
AUT0359	Hookers Point
AUT0361	Hawthorn
AUT0362	Teche
AUT0363	Wansley
AUT0364	Dresden Nuclear
AUT0365	Arkwright
AUT0368	Kaw
AUT0370	Deepwater
AUT0373	Valmont
AUT0379	Lake Pauline
AUT0380	Will County
AUT0381	Healy
AUT0384	Somerset
AUT0385	Hutsonville
AUT0387	Haynes
AUT0388	Lewis Creek
AUT0390	Fort Churchill
AUT0394	Nebraska City
AUT0396	Bremo Power Station
AUT0397	George Neal North
AUT0398	Iatan
AUT0399	Boomer Lake
AUT0401	Fort Myers
AUT0403	Nine Mile Point Nuclear
AUT0404	Mitchell
AUT0405	Fisk
AUT0406	Merom
AUT0408	Cameo
AUT0411	Roseton
AUT0415	Rochester 7
AUT0416	Noblesville
AUT0419	Brunswick Nuclear
AUT0423	James a Fitzpatrick
AUT0424	Davis-besse
AUT0427	Blount Street
AUT0431	San Angelo
AUT0433	Mistersky
AUT0434	Paradise
AUT0435	Shiras
AUT0440	Eaton
AUT0441	Piqua
AUT0443	Milton L Kapp
AUT0444	Gibbons Creek
AUT0446	Richard H. Gorsuch
AUT0449	Big Brown

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0453	Four Corners
AUT0455	Seminole
AUT0459	Vogtle Nuclear
AUT0462	Warrick
AUT0463	Rex Brown
AUT0467	Vero Beach
AUT0472	Miami Fort
AUT0473	Palisades Nuclear
AUT0476	Trinidad
AUT0477	Fair Station
AUT0478	Dansby
AUT0481	Powerlane
AUT0482	Gen J M Gavin
AUT0483	Shawnee
AUT0489	Nearman Creek
AUT0490	Buck
AUT0492	Collins
AUT0493	E S Joslin
AUT0496	Indian River
AUT0499	Bay Front
AUT0500	Big Cajun 2
AUT0501	Jack Watson
AUT0507	Crawford
AUT0512	J K Spruce
AUT0513	Waterford #3 Nuclear
AUT0515	Rockport
AUT0517	Humboldt Bay
AUT0518	James River
AUT0521	Menasha
AUT0522	Jefferies
AUT0523	Walter C Beckjord
AUT0529	Gould Street
AUT0531	Braidwood Nuclear
AUT0534	Crisp
AUT0535	Urquhart
AUT0536	Rush Island
AUT0537	Dallman
AUT0538	Genoa
AUT0539	Edge Moor
AUT0540	J P Madgett
AUT0541	Indian Point Nuclear
AUT0544	Eddystone
AUT0546	Watts Bar Nuclear
AUT0547	Muskingum River
AUT0551	Allen S King
AUT0552	Kingston
AUT0553	Hunlock Pwr Station
AUT0554	Potomac River
AUT0555	Zuni
AUT0557	Sayreville
AUT0561	J T Deely
AUT0564	Kyger Creek
AUT0567	F B Culley

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
AUT0568	Northside
AUT0570	Peach Bottom Nuclear
AUT0571	Baxter Wilson
AUT0573	San Onofre Nuclear
AUT0575	Trenton Channel
AUT0577	Middletown
AUT0580	Sixth Street
AUT0582	E W Brown
AUT0583	Dave Johnston
AUT0585	Burlington
AUT0588	Monticello
AUT0590	C D Mcintosh Jr
AUT0599	Kearny
AUT0600	Kincaid
AUT0601	Bridgeport Harbor
AUT0602	Mason Steam
AUT0603	Astoria
AUT0604	C R Huntley
AUT0606	Hmp&l Station 2
AUT0607	Moss Landing
AUT0608	Pilgrim Nuclear
AUT0611	New Boston
AUT0612	Huntington Beach
AUT0613	Morro Bay
AUT0617	Ravenswood
AUT0618	New Haven Harbor
AUT0619	William F Wyman
AUT0620	Dunkirk
AUT0621	Contra Costa
AUT0623	Kendall Square
AUT0625	Encina
AUT0630	Lovett
AUT0631	Salem Harbor
AUT0635	Aes Hickling
AUT0637	Ormond Beach
AUT0638	Mandalay
AUT0639	Pittsburg
DMU3244	University of Notre Dame Power Plant
DMU3310	University of Iowa - Main Power Plant
DNU2002	Brooklyn Navy Yard Cogeneration Partners, L.P.
DNU2011	Long Beach Generation
DNU2013	Maine Energy Recovery Company
DNU2014	Baltimore Resco
DNU2015	Southern Energy-Canal
DNU2017	Westchester Resco Co.
DNU2018	Grays Ferry Cogeneration Partnership
DNU2021	Morgantown
DNU2025	Sparrows Point Div Bethlehem Steel Corp
DNU2031	Ch Resources - Beaver Falls
DNU2032	Duke Energy South Bay
DNU2038	Saugus Resco
DNU2047	El Segundo Power

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
DUT0062	Leland Olds Station
DUT0576	Sam O. Purdom Generating Station
DUT1002	Monroe
DUT1003	Peru
DUT1006	Martins Creek
DUT1007	Presque Isle
DUT1008	Far Rockaway
DUT1011	Stryker Creek
DUT1012	Grand Tower
DUT1014	Dolphus M Grainger
DUT1021	Alma
DUT1022	Comanche Peak Nuclea
DUT1023	Oyster Creek Nuclear
DUT1026	Delaware
DUT1029	Crystal River
DUT1031	Merrimack
DUT1033	J C Weadock
DUT1034	South Oak Creek
DUT1036	Allen
DUT1038	North Texas
DUT1041	Elmer Smith
DUT1043	Ray Olinger
DUT1044	Tradinghouse
DUT1046	Labadie
DUT1047	Elrama
DUT1048	Holly Street
DUT1049	Joppa Steam
DUT1050	Browns Ferry Nuclear
DUT1051	Havana
DUT1056	Webster
DUT1057	Wateree
DUT1062	Fayette Power Prj
DUT1066	F J Gannon
DUT1067	Paint Creek
DUT1068	Harbor
DUT1070	Millstone
DUT1072	Graham
DUT1084	Fort Phantom
DUT1085	Petersburg
DUT1086	Valley
DUT1088	Seward
DUT1093	Bailly
DUT1097	Rock River
DUT1098	Blackhawk
DUT1100	Sewaren
DUT1103	Milton R Young
DUT1109	Riverside
DUT1111	E D Edwards
DUT1112	Lieberman
DUT1113	Sequoyah Nuclear
DUT1116	Waiau
DUT1117	Columbia
DUT1118	Cooper

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
DUT1122	Edgewater
DUT1123	Waukegan
DUT1132	Cumberland
DUT1133	J R Whiting
DUT1138	Harbor
DUT1140	Morgan Creek
DUT1142	Victoria
DUT1143	East River
DUT1145	Honolulu
DUT1146	Devon
DUT1148	Council Bluffs
DUT1152	Coffeen
DUT1153	Mill Creek
DUT1154	Mcclellan
DUT1155	P H Robinson
DUT1156	John Sevier
DUT1157	Sterlington
DUT1161	Robert E Ritchie
DUT1165	Big Bend
DUT1167	Ninemile Point
DUT1169	Hudson
DUT1170	Carl Bailey
DUT1172	Barney M Davis
DUT1173	Logansport
DUT1174	Arkansas Nuclear One
DUT1175	Fox Lake
DUT1179	Pirkey
DUT1185	Cromby
DUT1186	Glenwood
DUT1187	Mountain Creek
DUT1189	Larsen Memorial
DUT1191	Monroe
DUT1192	Meramec
DUT1194	Gerald Andrus
DUT1198	O H Hutchings
DUT1202	Manitowoc
DUT1206	Indian River
DUT1209	Widows Creek
DUT1211	Surry Nuclear
DUT1212	J M Stuart
DUT1213	Riverside
DUT1214	Charles R Lowman
DUT1217	Deepwater
DUT1219	Port Washington
DUT1223	Nueces Bay
DUT1225	Burlington
DUT1227	Sibley
DUT1228	Willow Glen
DUT1229	Riverton
DUT1235	Riverside
DUT1238	Cedar Bayou
DUT1248	Knox Lee

Table 3-3: Facility ID and Facility Name for All Facilities Not Claiming Survey Information CBI

Facility ID	Facility Name
DUT1249	Oak Creek
DUT1250	Vermont Yankee Nuclear
DUT1252	Muskogee
DUT1258	St Clair
DUT1259	James De Young
DUT1261	Green River
DUT1265	River Crest
DUT1268	Calvert Cliffs Nuclear
DUT1269	Dean H Mitchell
DUT1270	Pueblo
DUT1271	Michigan City
DUT1272	Monticello
DUT1273	Sim Gideon
DUT1274	P L Bartow
DUT1275	Anclote
DUT1276	Animas
DUT1278	Newton

4.0 COST CORRECTION

Derivation of the cost correction equation and technology module slopes.

Rather than providing the detailed costing equations that EPA used to calculate annualized capital and net O&M costs for facilities to use each of the modeled technologies, EPA has provided the simplified formula (equation 1), which collapses the results of those equations for the particular facility and technology into a single result (y_{epa}) and then allows the facility to adjust this result to reflect its actual design intake flow, using a technology specific slope for a facility like yours that is derived from the costing equations. This allows facilities to perform the flow adjustment in a straightforward and transparent manner. The Agency analyzed each of the cooling water intake structures (facilities) predicted to implement each technology module with respect to its annual capital plus net O&M costs, normalized by design intake flow. The Agency then performed a best-fit for each technology, as presented in figures 3-1 through 3-13.

Derivation of the correction factor for impingement mortality and/or entrainment requirements.

In calculating compliance costs, EPA projected what performance standards would be applicable to the facility based on available data. However, because of both variability and uncertainty in the underlying parameters that determine which performance standards apply (e.g., capacity utilization rate, mean annual flow), it is possible that in some cases the performance standards that EPA projected are not correct. The adjustment factor of 2.148 was determined by taking the ratio of median compliance costs for facilities to meet impingement mortality and entrainment performance standards over median compliance costs for facilities to meet impingement mortality performance standards only. While using this adjustment factor will not necessarily yield the exact compliance costs that EPA would have calculated had it had current information, EPA believes the results are reasonable for determining whether a facility's actual compliance costs are "significantly greater than" the costs considered by EPA for a like facility in establishing the applicable performance standards. EPA believes it is preferable to provide a simple and transparent methodology for making this adjustment that yields reasonably accurate results, rather than a much more complex methodology that would be difficult to use and understand (for the facility, permit writer, and public), even if the more complex methodology would yield slightly more accurate results. DCN 6-3588 in the confidential business information docket provides the calculations upon which the correction factor is based.

Fig. 3-1. Module 1, Add fish handling and return system to traveling screens

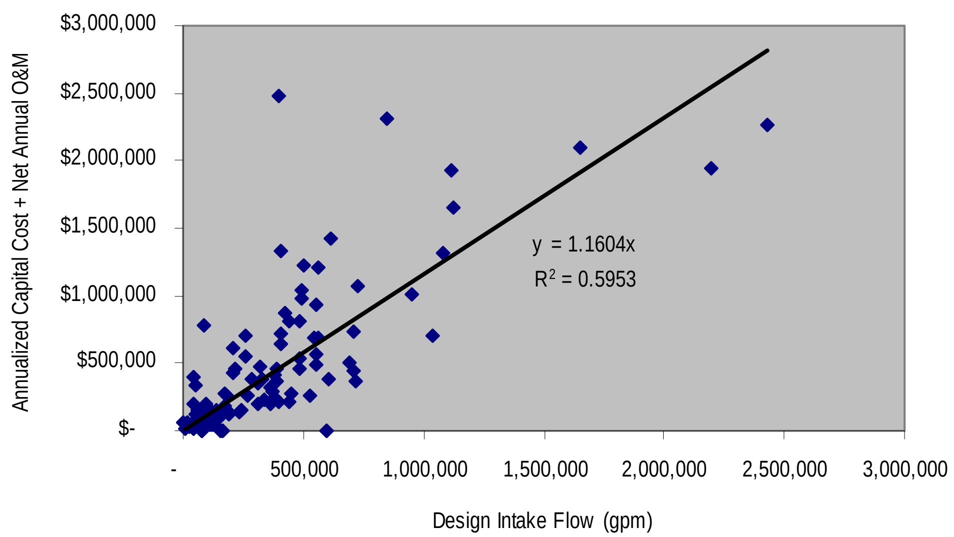


Fig. 3-2. Module 2, Add fine-mesh screens to traveling screens

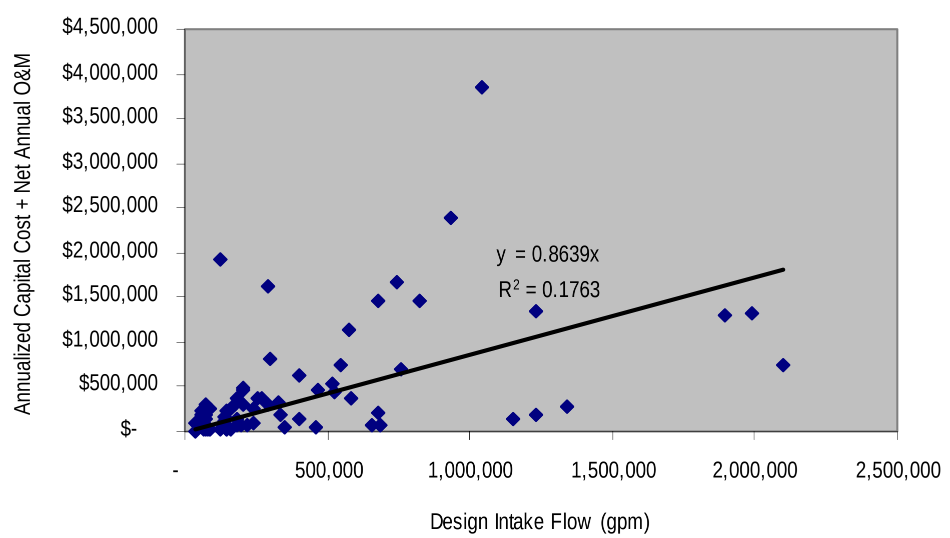


Fig. 3-3. Module 3, Add new, larger intake in front of existing intake

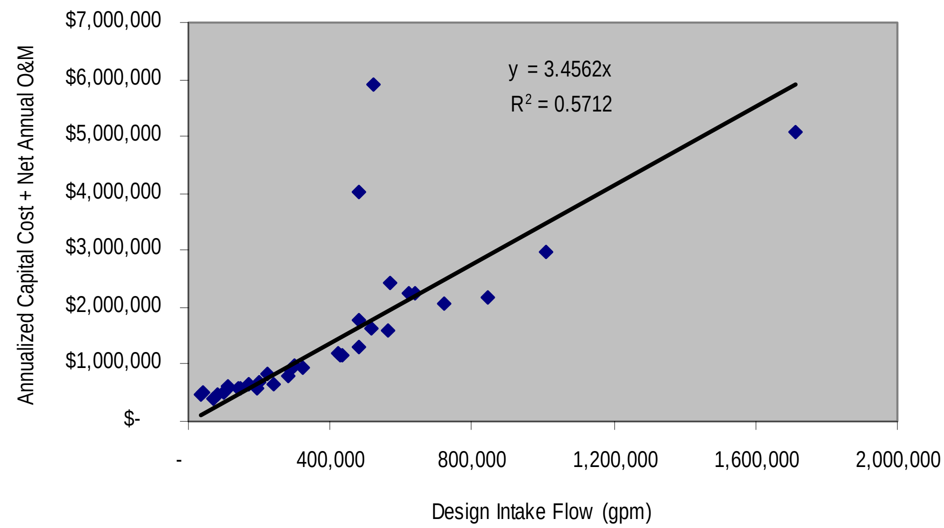


Fig. 3-4. Module 4, Add passive fine-mesh screen near shoreline w/ 1.75 mm mesh

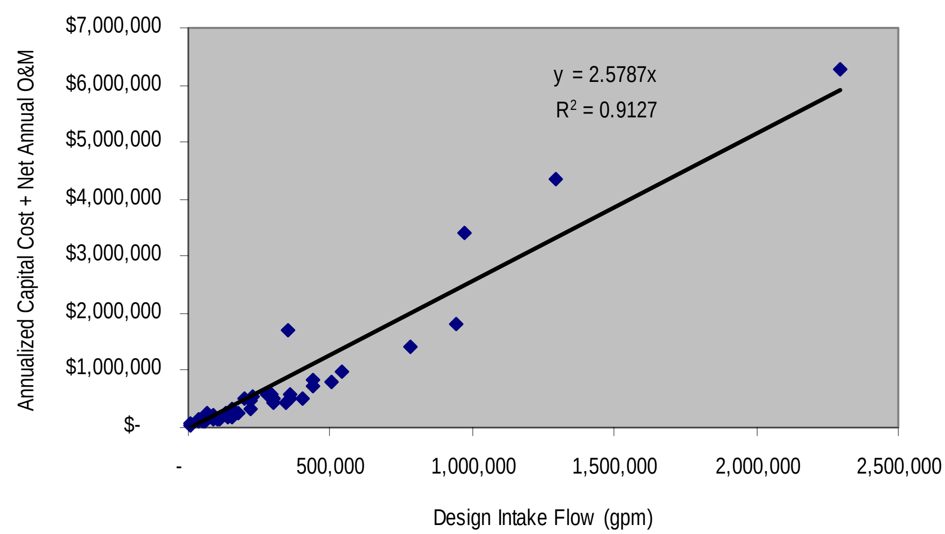


Fig. 3-5. Module 5, Add fish net barrier system

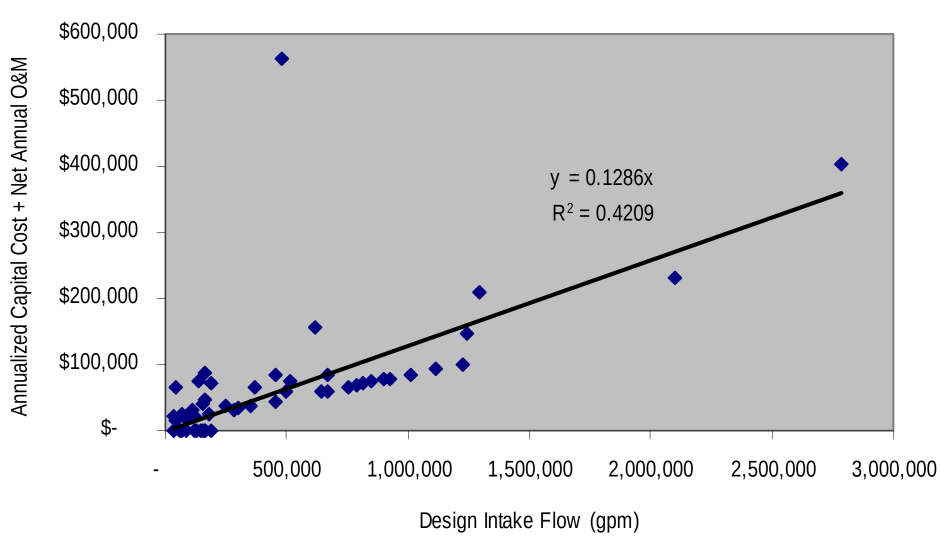


Fig. 3-6. Module 6, Add Aquatic filter barrier system

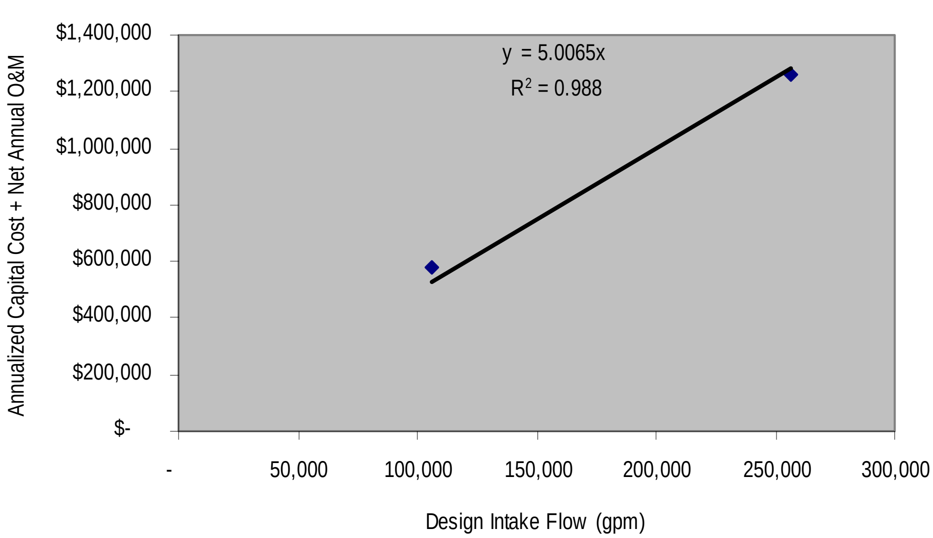


Fig. 3-7. Module 7, Relocate to submerged offshore w/ passive fine-mesh screen inlet & 1.75 mm mesh

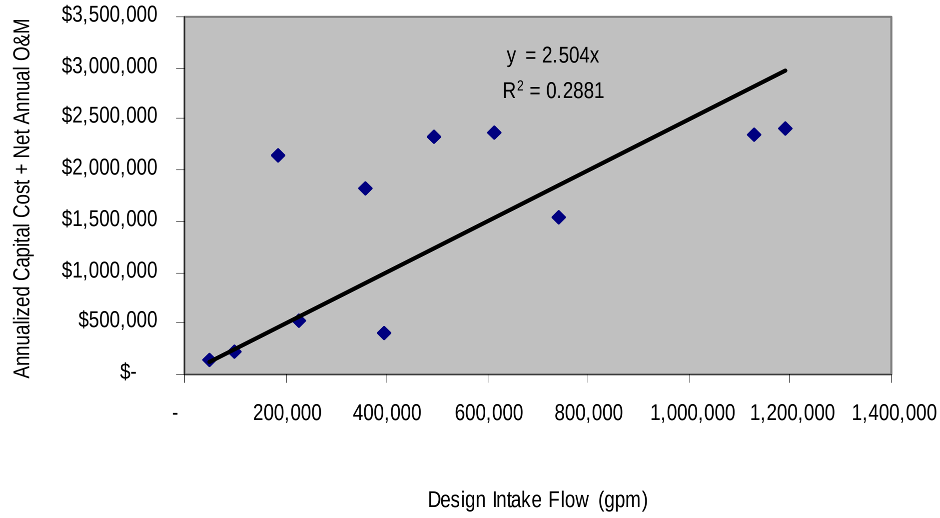
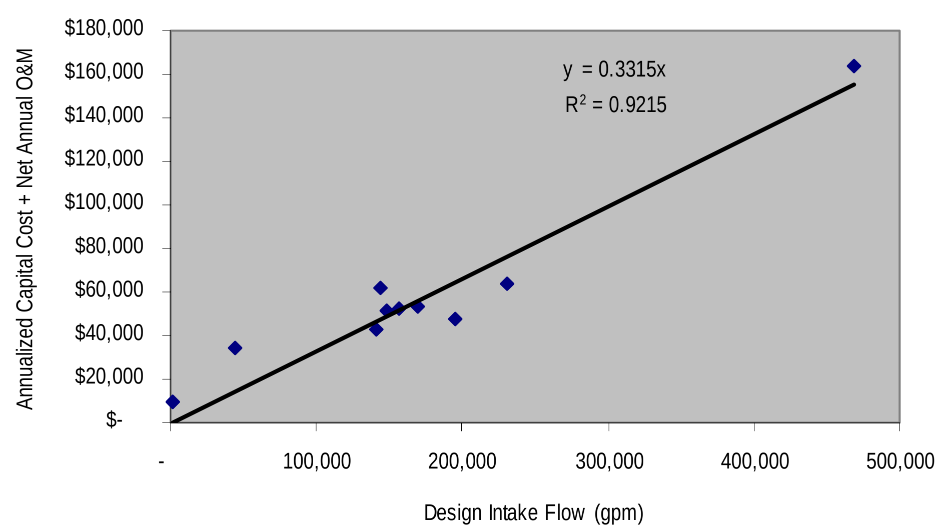


Fig. 3-8. Module 8, Add velocity cap inlet to offshore intake



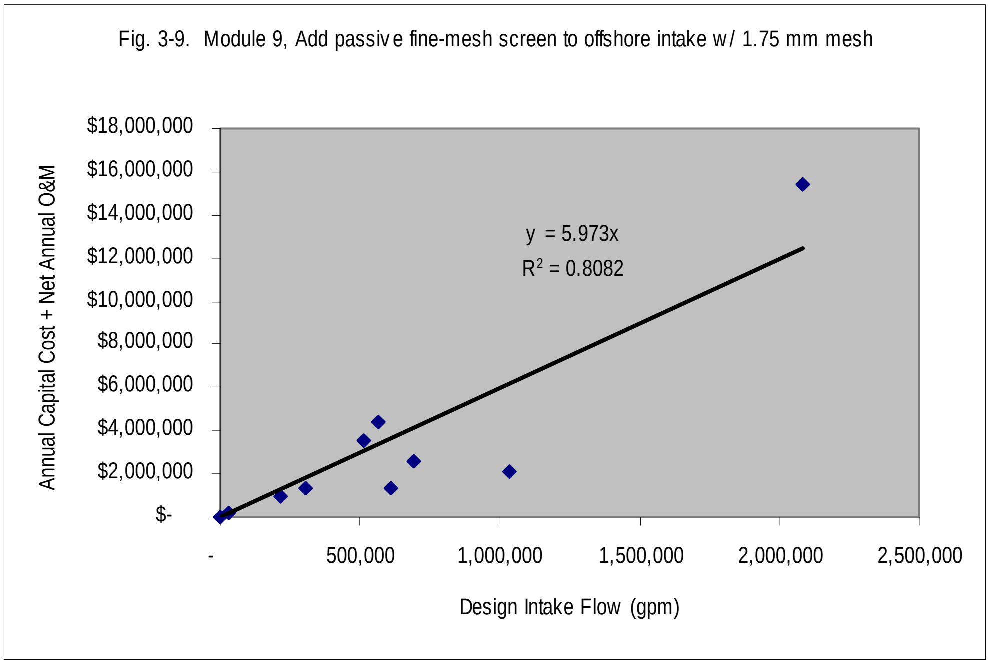


Fig. 3-9. Module 9, Add passive fine-mesh screen to offshore intake w/ 1.75 mm mesh
Annual Capital Cost + Net Annual O&M
$18,000,000
$16,000,000
$14,000,000
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$-
y = 5.973x
R^2 = 0.8082
-
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Design Intake Flow (gpm)

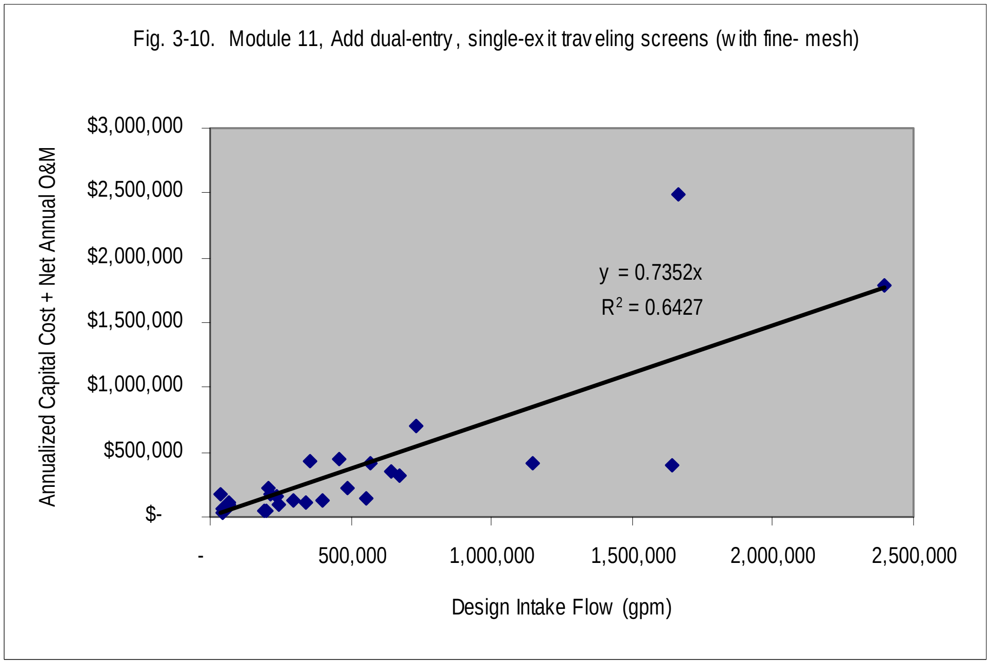


Fig. 3-10. Module 11, Add dual-entry, single-exit traveling screens (with fine- mesh)
Annualized Capital Cost + Net Annual O&M
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$-
y = 0.7352x
R^2 = 0.6427
-
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Design Intake Flow (gpm)

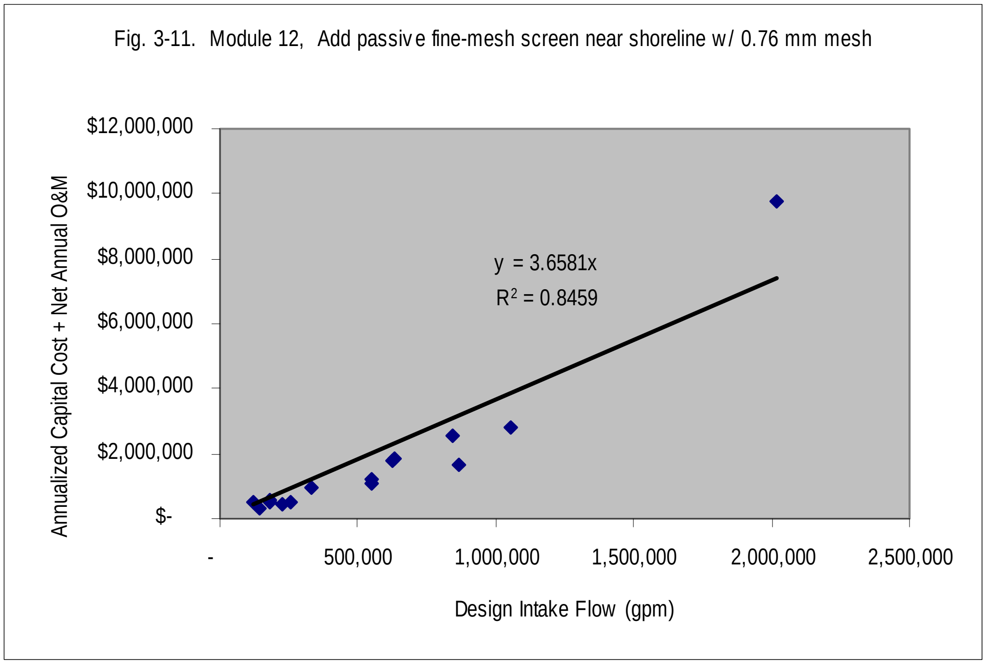


Fig. 3-11. Module 12, Add passive fine-mesh screen near shoreline w/ 0.76 mm mesh
y = 3.6581x
R2 = 0.8459
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$-
-
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Design Intake Flow (gpm)
Annualized Capital Cost + Net Annual O&M

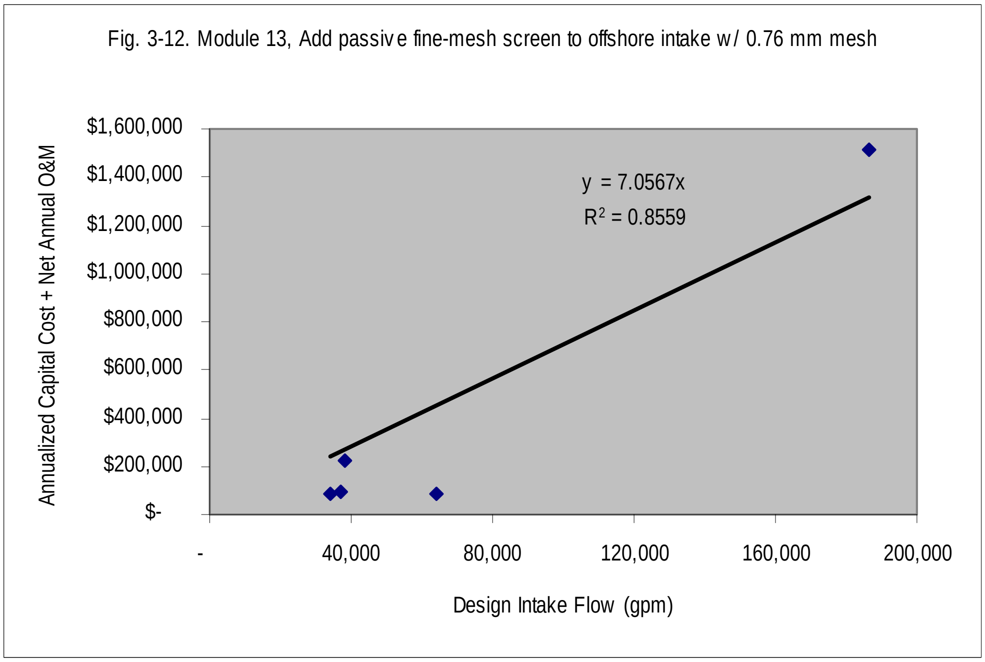
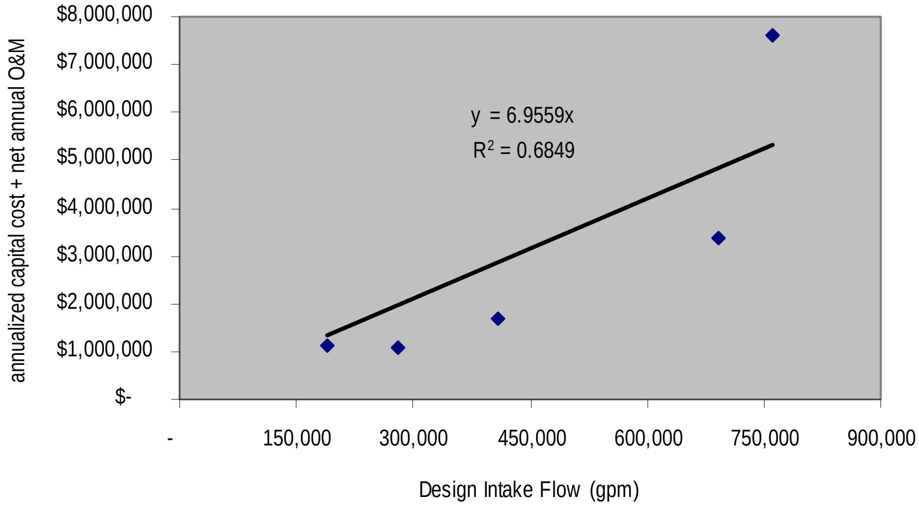


Fig. 3-12. Module 13, Add passive fine-mesh screen to offshore intake w/ 0.76 mm mesh
y = 7.0567x
R2 = 0.8559
$1,600,000
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$-
-
40,000
80,000
120,000
160,000
200,000
Design Intake Flow (gpm)
Annualized Capital Cost + Net Annual O&M

Fig. 3-13. Module 14, Relocate to submerged offshore w/ passive fine-mesh screen inlet & 0.76 mm mesh



Chapter 4: Efficacy of Cooling Water Intake Structure Technologies

INTRODUCTION

This chapter presents the data compiled by the Agency on the performance of the range of technologies currently used to minimize impingement and entrainment (I&E) at power plants nationwide.

1.0 DATA COLLECTION OVERVIEW

To support the section 316(b) rule for existing facilities, the Agency compiled data on the performance of the range of technologies currently used to minimize impingement and entrainment (I&E) at power plants nationwide. The goal of this data collection and analysis effort was to determine whether specific technologies could be shown to provide a consistent level of proven performance. The information compiled was used to compare specific regulatory options and their associated costs and benefits, as well as provide stakeholders with a comprehensive summary of previous studies designed to assess the efficacy of the various technologies. It provided the supporting information for the rule and alternative regulatory options considered during the development process and final action by the Administrator.

Throughout this chapter, *baseline technology performance* refers to the performance of conventional, wide-mesh traveling screens that are not intended to prevent impingement and/or entrainment. The term *alternative technologies* generally refer to those technologies, other than closed-cycle recirculating cooling systems, that can be used to minimize impingement and/or entrainment. Overall, the Agency has found that performance and applicability vary to some degree based on site-specific and seasonal conditions. The Agency has also determined, however, that alternative technologies can be used effectively on a widespread basis if properly designed, operated, and maintained.

1.1 SCOPE OF DATA COLLECTION EFFORTS

The Agency has compiled readily available information on the nationwide performance of I&E-reduction technologies. This information has been obtained through the following:

- Literature searches and associated collection of relevant documents on facility-specific performance.
- Contacts with governmental (e.g., TVA) and non-governmental entities (e.g., EPRI) that have undertaken national or regional data collection efforts/performance studies.
- Meetings with and visits to the offices of EPA regional and state agency staff as well as site visits to operating power plants.

It is important to recognize that the Agency did not use a systematic approach to data collection; that is, the Agency did not obtain all the facility performance data available nor did it obtain the same amount and detail of information for every facility. The Agency is not aware of such an evaluation ever being performed nationally. The most recent national data compilation was conducted by EPRI in 2000; see *Fish Protection at Cooling Water Intakes, Status Report*. The findings of that report are cited extensively in the following subsections. EPRI's analysis, however, was primarily a literature collection and review effort and was not intended to be an exhaustive compilation and analysis of all available data. Through this evaluation, EPA worked to build on the EPRI review by reviewing primary study documents cited by EPRI as well as through the collection and reviewing of additional data.

1.2 TECHNOLOGY DATABASE

In an effort to document and further assess the performance of various technologies and operational measures designed to minimize the impacts of cooling water withdrawals, EPA compiled a database of documents to allow analyses of the efficacy of a specific technology or suite of technologies. The data collected and entered into this database came from materials ranging from brief journal articles to the more intensive analyses found in historical section 316(b) demonstration reports and technology evaluations. In preparing this database, EPA assembled as much documentation as possible within the available timeframe to support future Agency decisions. It should be noted that the data may be of varying quality. EPA did not validate all database entries. However, EPA did evaluate the general quality and thoroughness of the study. Information entered into the database includes some notation of the limitations the individual studies might have for use in further analyses (e.g., no biological data or conclusions).

EPA's intent in assembling this information was fourfold. First, the Agency sought to develop a categorized database containing a comprehensive collection of available literature regarding technology performance. The database is intended to allow, to the extent possible, a rigorous compilation of data supporting the determination that the proposed performance standards are considered best technology available. Second, EPA used the data to demonstrate that the technologies chosen as compliance technologies for costing purposes are reasonable and can meet the performance standards. Third, the availability of a user-friendly database will allow EPA, state permit writers, and the public to more easily evaluate potential compliance options and facility compliance with performance standards. Fourth, EPA attempted to evaluate the technology efficacy data against objective criteria to assess the general quality and thoroughness of each study. This evaluation might assist in further analysis of conclusions made using the data.

Basic information from each document was recorded in the database (e.g., type of technology evaluated, facility at which it was tested). In addition to basic document information, the database contains two types of information: (1) general facility information and (2) detailed study information.

For those documents that refer to a specific facility (or facilities), basic technical information was included to enable EPA to classify facilities according to general categories. EPA collected locational data (e.g., waterbody type, name, state), as well as basic cooling water intake structure configuration information. Each technology evaluated in the study is also recorded, along with specific details regarding its design and operation. Major categories of technologies include modified traveling screens, wedgewire screens, fine-mesh screens, velocity caps, barrier nets, and behavioral barriers. (Data identifying the technologies present at a facility, as well as the configuration of the intake structure, refer to the configuration when the study was conducted and do not necessarily reflect the present facility configuration.)

Information on the type of study, along with any study results, is recorded in the second part of the database. EPA identifies whether the study evaluates the technology with respect to impingement mortality reduction (or avoidance), entrainment survival, or entrainment exclusion (or avoidance). Some studies address more than one area of concern, and that is noted. EPA records basic biological data used to evaluate the technology, if such data are provided. These data include target or commercially/recreationally valuable species, species type, life history stage, size, sample size, and raw numbers of impinged and/or entrained organisms. Finally, EPA records any overall conclusions reached by the study, usually presented as a percentage reduction or increase, depending on the area of focus. Including this information for each document allows EPA and others to readily locate and compare documents addressing similar technologies. Each document is reviewed according to five areas of data quality where possible: (1) applicability and utility, (2) soundness, (3) clarity and completeness, (4) uncertainty and variability, and (5) evaluation and review. Because the compiled literature comes from many different sources and was developed under widely varying standards, EPA reviewed all documents in the database against all five criteria.

To date, EPA has collected 153 documents for inclusion in the database. The Agency did not exclude from the database any document that addressed technology performance in relation to impingement and entrainment, regardless of the overall quality of the data.

1.3 DATA LIMITATIONS

Because EPA did not undertake a systematic data collection effort with consistent data collection procedures, there is significant variability in the information available from different data sources. This variability leads to the following data limitations:

- Some facility data include all the major species and associated life stages present at an individual facility, whereas others include only data for selected species and/or life stages. The identification of important species can be a valid method for determining the overall effectiveness of a technology if the criteria used for selection are valid. In some studies, target species are identified but no reason for their selection is given.

• Many of the data were collected in the 1970s and early 1980s when existing facilities were required to complete their initial 316(b) demonstrations. In addition, the focus of these studies was not the effectiveness of a particular technology but rather the overall performance of a facility in terms of rates of impingement and entrainment.

• Some facility data includes only initial survival results, whereas other facilities have 48- to 96-hour survival data. These longer-term survival data are relevant because some technologies can exhibit significant latent mortality after initial survival.

• Analytical methods and collection procedures, including quality assurance/quality control protocols, are not always present or discussed in summary documentation. Where possible, EPA has reviewed study methods and parameters to determine qualifications, if any, that must be applied to the final results.

• Some data come from laboratory and pilot-scale testing rather than full-scale evaluations. Laboratory studies offer unique opportunities to control and alter the various inputs to the study but might not be able to mimic the real-world variables that could be present at an actual site. Although EPA recognizes the value of laboratory studies and does not discount their results, *in situ* evaluations remain the preferred method for gauging the effectiveness of a technology.

• Survival rates calculated in individual studies can vary as to their true meaning. In some instances, the survival rate for a given species (initial or latent) has been corrected to account for the mortality rate observed in a control group. Other studies explicitly note that no control groups have been used. These data are important because overall mortality, especially for younger and more fragile species, can be adversely affected by the collection and observation process–factors that would not affect mortality under unobserved conditions.

EPA recognizes that the practicality or effectiveness of alternative technologies might not be uniform under all conditions. The chemical and physical nature of the waterbody, facility intake requirements, climatic conditions, and biology of the area all affect feasibility and performance. Despite the above limitations, however, EPA has concluded that significant general performance expectations can be inferred for the range of technologies and that one or more technologies (or groups of technologies) can provide significant impingement and/or entrainment protection at most sites. In addition, in EPA's view many of the technologies have the potential for even greater applicability and higher performance when facilities optimize their use.

The remainder of this chapter is organized by groups of technologies. A brief description of conventional, once-through traveling screens is provided for comparison purposes. Fact sheets describing each technology, available performance data, and design requirements and limitations are provided in Attachment A. It is important to note that this chapter does not provide descriptions of all potential cooling water intake structure (CWIS) technologies. (ASCE 1982 generally provides such an all-inclusive discussion.) Instead, EPA has focused on those technologies that have shown significant promise at the laboratory, pilot-scale, or full-scale levels in consistently minimizing impingement and/or entrainment. In addition, this chapter does not identify every facility where alternative technologies have been used but rather only those where some measure of performance in comparison to conventional screens has been made. The chapter concludes with a brief discussion of how the location of intakes (as well as the timing of water withdrawals) can also be used to limit potential impingement and/or entrainment effects. Habitat restoration projects are an additional means to comply with this rule. Such projects, however, have not had widespread application at existing facilities. Because the nature, feasibility, and likely effectiveness of such projects would be highly site-specific, EPA has not attempted to quantify their expected performance level in this document.

1.4 CONVENTIONAL TRAVELING SCREENS

For impingement control technologies, performance is compared to conventional (unmodified) traveling screens, the baseline technology. These screens are the most commonly used intake technology at older existing facilities, and their operational performance is well established. In general, these technologies are designed to prevent debris from entering the cooling water system, not to minimize I&E. The most common intake designs include front-end trash racks (usually consisting of fixed bars) to prevent large debris from entering the system. The traveling screens are equipped with screen panels mounted on an endless belt that rotates through the water vertically. Most conventional screens have 3/8-inch mesh that prevents smaller debris from clogging the condenser tubes. The screen wash is typically high-pressure (80 to 120 pounds per square inch [psi]). Screens are rotated and washed intermittently, and fish that are impinged often die because they are trapped on the stationary screens for extended periods. The high-pressure wash also frequently kills fish, or they are re-impinged on the screens. Approximately 89 percent of all existing facilities within the scope of this rule use conventional traveling screens.

1.5 CLOSED-CYCLE WET COOLING SYSTEM PERFORMANCE

Although flow reduction serves the purpose of reducing both impingement and entrainment, flow reduction requirements function foremost as a reliable entrainment reduction technology. Throughout this chapter, EPA compares the performance of entrainment-reducing technologies to that of recirculating wet cooling towers. To evaluate the feasibility of regulatory options with flow reduction requirements and to allow comparison of costs and benefits of alternatives, EPA determined the likely range in flow reductions between wet, closed-cycle cooling systems and once through systems. In closed-cycle systems, certain chemicals will concentrate as they continue to be recirculated through the tower. Excess buildup of such chemicals, especially total dissolved solids, affects the tower's performance. Therefore, some water (blowdown) must be discharged and make-up water added periodically to the system. An additional question that EPA has considered is the feasibility of constructing salt-water make-up cooling towers. For the development of the New Facility 316(b) rule, EPA contacted Marley Cooling Tower (Marley), which is one of the largest cooling tower manufacturers in the world. Marley provided a list of facilities (Marley 2001) that have installed cooling towers that use marine or otherwise high total dissolved solids/brackish make-up water. It is important to recognize the facilities listed represent only a selected group of facilities for which Marley has constructed cooling towers worldwide.

2.0 ALTERNATIVE TECHNOLOGIES

2.1 MODIFIED TRAVELING SCREENS AND FISH HANDLING AND RETURN SYSTEMS

Technology Overview

Conventional traveling screens can be modified so that fish impinged on the screens can be removed with minimal stress and mortality. Ristroph screens have water-filled lifting buckets that collect the impinged organisms and transport them to a fish return system. The buckets are designed such that they will hold approximately 2 inches of water once they have cleared the surface of the water during the normal rotation of the traveling screens. The fish bucket holds the fish in water until the screen rises to a point at which the fish are spilled onto a bypass, trough, or other protected area (Mussalli, Taft, and Hoffman 1978). Fish baskets are another modification of a conventional traveling screen and may be used in conjunction with fish buckets. Fish baskets are separate framed screen panels attached to vertical traveling screens. An essential feature of modified traveling screens is continuous operation during periods when fish are being impinged. Conventional traveling screens typically operate intermittently. (EPRI 2000, 1989; Fritz 1980). Removed fish are typically returned to the source waterbody by sluiceway or pipeline. ASCE (1982) provides guidance on the design and operation of fish return systems.

Technology Performance

A wide range of facilities nationwide have used modified screens and fish handling and return systems to minimize impingement mortality. Although many factors influence the overall performance of a given technology, modified screens with a fish return capability have been deployed with success under varying waterbody conditions. In recent years, some researchers, primarily Fletcher (1996), have evaluated the factors that affect the success of these systems and described how they can be optimized for specific applications. Fletcher cited the following as key design factors:

- Shaping fish buckets or baskets to minimize hydrodynamic turbulence within the bucket or basket.
- Using smooth-woven screen mesh to minimize fish descaling.
- Using fish rails to keep fish from escaping the buckets or baskets.
- Performing fish removal prior to high-pressure washing for debris removal.
- Optimizing the location of spray systems to provide a more gentle fish transfer to sloughs.
- Ensuring proper sizing and design of return troughs, sluiceways, and pipes to minimize harm.

2.1.1 EXAMPLE STUDIES

Salem Generating Station

Salem Generating Station, on the Delaware Bay estuary in New Jersey, converted 6 of its 12 conventional traveling screen assemblies to a modified design that incorporated improved fish buckets constructed of a lighter composite material (which improved screen rotation efficiency), smooth-woven mesh material, an improved spray wash system (both low- and high-pressure), and flap seals to improve the delivery of impinged fish from the fish buckets to the fish return trough.

The initial study period consisted of 19 separate collection events during mid-summer 1996. The configuration of the facility at the time of the study (half of the screens had been modified) allowed for a direct comparison of the effectiveness of the modified and unmodified screens on impingement mortality rates. The limited sampling timeframe enabled the analysis of only the species present in numbers sufficient to support any statistical conclusions. 1,082 juvenile weakfish were collected from the unmodified screens while 1,559 were collected from the modified structure. Analysts held each sample group separately for 48 hours to assess overall mortality due to impingement on the screens. Results showed that use of the modified screens had increased overall survival by as much as 20 percent over the use of the unmodified screens. Approximately 58 percent of the weakfish impinged on the unmodified screens survived, whereas the new screens had a survival rate approaching 80 percent. Both rates were based on 48-hour survival and not adjusted for the mortality of control samples.

Water temperature and fish length are two independent factors cited in the study as affecting overall survival. Researchers noted that survival rates decreased somewhat as the water temperature increased, possibly as a result of lower levels of dissolved oxygen. Survival rates decreased to a low of 56 percent for the modified screens when the water temperature reached its maximum of 80°F. At the same temperature, the survival rate on the unmodified screens were 35 percent. Differences in survival rates were also attributable to the size of the fish impinged. In general, small fish (< 50 mm) fared better on both the modified and unmodified screens than large fish (> 50 mm). The survival rates of the two size categories did not differ significantly for the modified screens (85 percent survival for small, 82 percent for large), although a more pronounced difference was evident on the unmodified screens (74 percent survival for small, 58 percent for large).

Salem Generating Station conducted a second series of impingement sampling from 1997 to 1998. By that time all screen assemblies had been modified to include fish buckets and a fish return system as described above. Additional modifications to the system sought to enhance the chances of survival of fish impinged against the screens. One modification altered the fish return slide to reduce the stress on fish being delivered to the collection pool. Flap seals were improved to better seal gaps between the fish return and debris trough, thus preventing debris from affecting returning fish. Researchers used a smaller mesh screen in the collection pools during the 1997-1998 sampling events than had been used during the 1995 studies. The study notes that the larger mesh used in 1995 might have enabled smaller fish to escape the collection pool. Since smaller fish typically have a higher mortality rate due to physical stress than larger fish, the actual mortality rates may have been greater than those found in the 1995 study.

The second impingement survival study analyzed samples collected from October through December 1997 and April through September 1998. Samples were collected twice per week and analyzed for survival at 24- and 48-hour intervals. Six principal species were identified as constituting the majority of the impinged fish during the sampling periods: weakfish, white perch, bay anchovy, Atlantic croaker, spot, and *Alosa* spp. Fish were sorted by species and size, classified by their condition, and placed in holding tanks.

For most species, survival rates varied noticeably depending on the season. For white perch, survival was above 90 percent throughout the sample period (as high as 98 percent in December). Survival rates for weakfish varied from a low of 18 percent in July to a high of 88 percent in September. Although the number of weakfish collected in September was approximately one-fifth of the number collected in July, a possible explanation for the variation in survival rates is the modifications to the collection system described above, which were implemented during the study period. Similarly, bay anchovy fared worst during the warmer months, dropping to a 20 percent survival rate in July while achieving a 72 percent rate during November. Rates for Atlantic croaker varied from 58 percent in April to 98 percent in November. Spot were collected in only one month (November) and had a survival rate of 93 percent. The survival rate for the *Alosa* spp. (alewife, blueback herring, and American shad) remained relatively consistent, ranging from 82 percent in April to 78 percent in November.

For all species in the study, with the exception of weakfish, survival rates improved markedly with the use of the modified screen system when compared to data from 1978-1982, when the unmodified system was still in use.

Mystic Station

Mystic Station, on the Mystic River in Massachusetts, converted one of its two conventional traveling screen assemblies to a modified system incorporating fish collection buckets and a return system in 1981 to enable a side-by-side comparison of impingement survival. Fish buckets were attached to each of the screen panels. Low-pressure spray (10 psi) nozzles were installed to remove fish from the buckets and into the collection trough. The screen system was modified to include a two-speed motor with a four-speed transmission to enable various rotation speeds for the traveling screens.

The goal of the study was to determine the optimal screen rotation speed and rotation interval that could achieve the greatest survival rate without affecting the screen performance. The study analyzes 2-, 4- and 8-hour rotation intervals as well as continuous rotation. Samples were collected from October 7, 1980 to April 27, 1981. Fish collected from the screens were sorted several times per week, classified, and placed into holding tanks for 96 hours to observe latent mortality.

Results from the study indicated that impingement of the various species was highly seasonal in nature. Data from Unit 7 during the sample period indicate that in terms of both biomass and raw numbers, the majority of fish are present in the vicinity, and thus susceptible to impingement, during the fall and early winter. Almost 50 percent of the *Alosa* spp. were collected during one week in November, while 75 percent of the smelt were collected in a 5-week period in late fall. Likewise, nearly 60 percent of the winter flounder were collected in January. These data suggest that optimal rotation speeds and intervals, whatever they might be, might not be necessary throughout the year.

Continuous rotation of the screens, regardless of speed, resulted in a virtual elimination of impingement mortality for winter flounder. For all other species, survival generally increased with screen speed and rotation interval, with the best 96-hour survival rate (50 percent) occurring at a continuous rotation at 15 ft/sec. The overall survival rate is affected by the high latent mortality of *Alosa* spp. in the sample. The study speculates that the overall survival rates would be markedly higher under actual (unobserved) operating conditions, given the high initial survival for large *Alosa* spp. Fragile species such as *Alosa* can be adversely affected by the stresses of collection and monitoring and might exhibit an abnormally higher mortality rate as a result.

Indian Point Unit 2

Indian Point is located on the eastern shore of the Hudson River in New York. In 1985, the facility modified the intake for Unit 2 to include a fish lifting trough fitted to the face of the screen panels. Two low-pressure (10 psi) spray nozzles removed collected fish into a separate fish return sluiceway. A high-pressure spray flushed other debris into a debris trough. The new screen also incorporated a variable speed transmission, enabling the rotation of the screen panels at speeds of up to 20 ft/min. For the study period, screens were continuously rotated at a speed of 10 ft/min.

The sampling period lasted from August 15, 1985 to December 7, 1985. Fish were collected from both the fish trough and the debris trough, though survival rates are presented for the fish collected from the fish trough only. The number of fish collected from the debris trough was approximately 45 percent of the total collected from the fish trough; the survival rate of these fish is unknown. Control groups were not used to monitor the mortality associated with natural environmental factors such as salinity, temperature, and dissolved oxygen. Collected fish were held in observation tanks for 96 hours to determine a latent survival rate.

White perch composed the majority (71 percent) of the overall sample population. Survival rates ranged from 63 percent in November to 90 percent in August. It should be noted that during the month with the greatest abundance (December), the survival rate was 67 percent. This generally represents the overall survival rate for this species because 75 percent of white perch collected during the sample period were collected during December. Weakfish were the next most abundant species, with an overall survival rate of 94 percent. A statistically significant number of weakfish were collected only during the month of August. Atlantic tomcod and blueback herring were reported to have survival rates of 73 percent and 65 percent, respectively. Additional species present in small numbers had widely varying survival rates, from a low of 27 percent for alewife to a high of over 95 percent for bluegill and hogchoker.

A facility-wide performance level is not presented for Indian Point, but a general inference can be obtained from the survival rates of the predominant species. A concern is raised, however, by the exclusion of fish collected from the debris trough. Their significant number might affect the overall mortality of each species. Because the fish in the debris trough have been subjected to high-pressure spray washes as well as any large debris removed from the screens, mortality rates for these fish are likely to be higher, thereby reducing the overall effectiveness of the technology as deployed. The experiences of other facilities suggest that modifications to the system might be able to increase the efficiency of moving impinged fish to the fish trough. In general, species survival appeared greater during late summer than in early winter. Samples were collected during one 5-month period. It is not known from the study how the technology would perform in other seasons.

Roseton Generating Station

Roseton Generating Station is located on the eastern shore of the Hudson River in New York. In 1990, the facility replaced two of eight conventional traveling screens with dual-flow screens that included water-retaining fish buckets, a low-pressure (10 psi) spray system, smooth-woven mesh screen panels, and a separate fish return trough. The dual-flow screens were also equipped with variable speed motors to achieve faster rotational speeds. For the study period, screens were continuously rotated at a speed of 10.2 ft/minute.

Impingement samples were collected during two periods in 1990: May 9 to August 30 and September 30 to November 29. A total of 529 paired samples were collected for the first period and 246 paired samples for the second period. Initial mortality was recorded at the Roseton facility. Collected samples were not held on site but rather transported to the fish laboratory at Danskammer Point, where they were observed for latent mortality. Latent mortality observations were made at 48- and 96-hour intervals. A control study using a mark-recapture method was conducted simultaneously to measure the influence, if any, that water quality factors and collection and handling procedures might have had on overall mortality rates. Based on the results of this study, the post-impingement survival rates did not need to be adjusted for a deviation from the control mortality.

Blueback herring, bay anchovy, American shad, and alewife composed the majority of the sample population in both sampling periods. Latent survival rates ranged from 0 percent to 6 percent during the summer and were somewhat worse during the fall. The other two predominant species, white perch and striped bass, fared better, having survival rates as high as 53 percent. Other species that composed less than 2 percent of the sample population survived at considerably higher rates (98 percent for hogchoker).

It is unclear why the more fragile species (alewife, blueback herring, American shad, and bay anchovy) had such high mortality rates. The study notes that debris had been collecting in the fish return trough and was disrupting the flow of water and fish to the collection tanks. Water flow was increased through the trough to prevent accumulation of debris. No information is presented to indicate the effect of this modification. Also noted is the effect of temperature on initial survival. An overall initial survival rate of 90 percent was achieved when the ambient water temperature was 54°F. Survival rates decreased markedly as water temperature increased, and the lowest initial survival rate (6 percent) was recorded at the highest temperature.

Surry Power Station

Surry Power Station is located on the James River in Virginia. Each of the two units has 3/8-inch mesh Ristroph screens with a fish return trough. A combined spray system removes impinged organisms and debris from the screens. Spray nozzle pressures range from 15 to 20 psi. During the first several months of testing, the system was modified to improve fish transfer to the sluiceway and increase the likelihood of post-impingement survival. A flap seal was added to prevent fish from falling between the screen and return trough during screen washing. Water volume in the return trough was increased to facilitate the transfer of fish to the river, and a velocity-reduction system was added to the trough to reduce the speed of water and fish entering the sample collecting pools.

Samples were collected daily during a 6-month period from May to November 1975. Initial mortality was observed and recorded after a 15-minute period during which the water and fish in the collection pools were allowed to settle. The average survival rate for the 58 different species collected was 93 percent, although how this average was calculated was not noted. Bay anchovy and the *Alosa* spp. constituted the majority of the sample population and generally had the lowest initial survival rates at 83 percent. The study does not indicate whether control samples were used and whether mortality rates were adjusted accordingly. A noticeable deficiency of the study is the lack of latent mortality analysis. Consideration of latent mortality, which could be high for the fragile species typically impinged at Surry Power Station, might significantly reduce the overall impingement survival rate.

Arthur Kill Station

The Arthur Kill Station is located on the Arthur Kill estuary in New York. To fulfill the terms of a consent order, Consolidated Edison modified two of the station's dual-flow intake screens to include smooth mesh panels, fish-retention buckets, flap seals to prevent fish from falling between screen panels, a low-pressure spray wash system (10 psi), and a separate fish return sluiceway. One of the modified screens had mesh of 1/8-inch by 1/2-inch while the other had 1/4-inch by 1/2-inch while the six unmodified screens all had 1/8-inch by 1/8-inch mesh. Screens were continuously rotated at 20 ft/min during the sampling events.

The sampling period lasted from September 1991 to September 1992. Weekly samples were collected simultaneously from all screens, with the exception of 2 weeks when the facility was shut down. Each screen sample was held separately in a collection tank where initial mortality was observed. A 24-hour survival rate was calculated based on the percentage of fish alive after 24 hours versus the total number collected. Because a control study was not performed, final survival rates have not been adjusted for any water quality or collection factors. The study did not evaluate latent survival beyond the 24-hour period.

Atlantic herring, blueback herring and bay anchovy typically composed the majority (> 90 percent) of impinged species during the course of the study period. Bay anchovy alone accounted for more than 72 percent of the sample population. Overall performance numbers for the modified screens are greatly influenced by the survival rates for these three species. In general, the unmodified screens demonstrated a substantially lower impingement survival rate when compared to the modified screens. The average 24-hour survival for fish impinged on the unmodified screens was 15 percent. Fish impinged on the larger mesh (1/4") and smaller mesh (1/8") modified screens had survival average 24-hour survival rates of 92 percent and 79 percent, respectively. Most species with low survival rates on the unmodified screens showed a marked improvement on the modified screens. Bay anchovy showed a 24-hour survival rate increase from 1 percent on the unmodified screens to 50 percent on the modified screens.

The study period at the Arthur Kill station offered a unique opportunity to conduct a side-by-side evaluation of modified and unmodified intake structures. The results for 24-hour post-impingement survival clearly show a marked improvement for all species that had fared poorly on the conventional screens. The study notes that lower survival rates for fragile species such as Atlantic herring might have been adversely affected by the collection tanks and protocols. Larger holding tanks appeared to improve the survival of these species, suggesting that the reported survival rates may underrepresent the rate that would be achieved under normal (unobserved) conditions, though by how much is unclear.

Dunkirk Steam Station
Dunkirk Steam Station is located on the southern shore of Lake Erie in New York. In 1998 a modified dual-flow traveling screen system was installed on Unit 1 for an impingement mortality reduction study. The new system incorporated an improved fish bucket design to minimize turbulence caused by flow through the screen face, as well as a nose cone on the upstream wall of the screen assembly. The nose cone was installed to reduce the flow and velocity variations that had been observed across the screen face.

Samples were collected during the winter months of 1998/1999 and evaluated for 24-hour survival. Four species (emerald shiner, juvenile gizzard shad, rainbow smelt, and spottail shiner) compose nearly 95 percent of the sample population during this period. All species exhibited high 24-hour survival rates; rainbow smelt fared worst at 83 percent. The other three species had survival rates of better than 94 percent. Other species were collected during the sampling period but were not present in numbers significant enough to warrant a statistical analysis.

The results presented above represent one season of impingement sampling. Species not in abundance during cooler months might be affected differently by the intake structure. Sampling continued beyond the winter months, but EPA has not yet been reviewed by EPA.

Kintigh Station
Kintigh Station is located on the southern shore of Lake Ontario in New York. The facility operates an offshore intake in the lake with traveling screens and a fiberglass fish return trough. Fish are removed from the screens and deposited in the return trough by a low-pressure spray wash (10 psi). It is noted that the facility also operates with an offshore velocity cap. This does not directly affect the survival rate of fish impinged against the screen but might alter the distribution of species subject to impingement on the screen.

Samples were collected seasonally and held for observation at multiple intervals up to 96 hours. Most species exhibited a high variability in their rate of survival depending on the season. Rainbow smelt had a 96-hour survival rate of 95 percent in the spring and a 22 percent rate in the fall. (The rate was 1.5 percent in summer but the number of samples was small.) Alewife composed the largest number among the species in the sample population. Survival rates were generally poor (0 percent to 19 percent) for spring and summer sampling before the system was modified 1989. After the screen assembly had been modified to minimize stress associated with removal from the screen and return to the waterbody, alewife survival rates increased to 45 percent. Survival rates were not adjusted for possible influence from handling and observation stresses because no control study was performed.

Calvert Cliffs Nuclear Power Plant
Calvert Cliffs Nuclear Power Plant is located on the eastern shore of the Chesapeake Bay in Maryland. The facility used to have conventional traveling screens on its intake screen assemblies. Screens were rotated for 10 minutes every hour or when triggered by a set pressure differential across the screen surface. A spray wash system removed impinged fish and debris into a discharge trough. The original screens have since been converted to a dual-flow design. The data discussed in the 1975-1981 study period are related to the older conventional screen systems.

Sampling periods were determined to account for the varying conditions that might exist due to tides and time of day.

Impingement and survival rates were estimated monthly based on the number and weights of the individual species in the sample collection. No control studies accompanied the impingement survival evaluation although total impingement data and estimated mortalities were provided for comparative purposes. Latent survival rates were not evaluated for this study; only initial survival was included.

Five species typically constituted over 90 percent of the sample population in the study years. Spot, Atlantic menhaden, Atlantic silverside, bay anchovy, and hogchoker had composite initial survival rates of 84, 52, 54, 68 and 99 percent, respectively. Other species generally had survival rates greater than 75 percent, but these data are less significant to the facility-wide survival rate given their low percentage of the overall sample population (< 8 percent). Overall, the facility showed an initial survival rate of 73 percent for all species.

It is notable that the volume of impingement data collected by Calvert Cliffs NPP (over 21 years) has enabled the facility to anticipate possible large impingement events by monitoring fluctuations in the thermal and salinity stratification of the surrounding portion of the Chesapeake Bay. When possible, operational changes during these periods (typically mid to late summer) might allow the facility to reduce cooling water intake volume, thereby reducing the potential for impingement losses. The facility has also studied ways to maintain adequate dissolved oxygen levels in the intake canal to assist fish viability and better enable post-impingement survival and escape.

Huntley Steam Station

Huntley Steam Station is located on the Niagara River in New York. The facility recently replaced four older conventional traveling screens with modified Ristroph screens on Units 67 and 68. The modified screens are fitted with smoothly woven coarse mesh panels on a rotating belt. A fish collection basket is attached to the screen face of each screen panel. Bucket contents are removed by low-pressure spray nozzles into a fish return trough. High-pressure sprays remove remaining fish and debris into a separate debris trough. The study does not contain the rotation interval of the screen or the screen speed at the time of the study.

Samples were collected over five nights in January 1999 from the modified-screen fish return troughs. All collected fish were sorted according to initial mortality. Four targeted species (rainbow smelt, emerald shiner, gizzard shad, and alewife) were sorted according to species and size and held to evaluate 24-hour survival rates. Together, the target species accounted for less than 50 percent of all fish impinged on the screens. (An additional 6,364 fish were not held for latent survival evaluation.) Of the target species, rainbow smelt and emerald shiners composed the greatest percentage with 57 and 37 percent, respectively.

Overall, the 24-hour survival rate for rainbow smelt was 84 percent; some variation was evident for juveniles (74 percent) and adults (94 percent). Emerald shiner were present in the same general life stage and had a 24-hour survival rate of 98 percent. Gizzard shad, both juvenile and adult, fared poorly, with an overall survival of 5 percent for juveniles and 0 percent for adults. Alewife were not present in large numbers (n = 30) and had an overall survival rate of 0 percent.

The study notes the low survival rates for alewife and gizzard shad and posits the low water temperature as the principal factor. At the Huntley facility, both species are near the northern extreme of their natural ranges and are more susceptible to stresses associated with extremes in water conditions. The water temperatures at the time of collection were among the coldest of the year. Laboratory evaluations conducted on these species at the same temperatures showed high degrees of impairment that would likely adversely affect post-impingement survival. A control evaluation was performed to determine whether mortality rates from the screens would need to be adjusted for waterbody or collection and handling factors. No discrepancies were observed, and therefore no corrections were made to the final results. Also of note in the study is the inclusion of a spray wash collection efficiency evaluation. The spray wash and fish return system were evaluated to determine the proportion of impinged fish that were removed from the buckets and deposited in the fish trough instead of the debris trough. All species had suitable removal efficiencies.

2.1.2 SUMMARY

Studies conducted at steam electric power generating facilities over the past three decades have built a sizable record demonstrating the performance potential for modified traveling screens that include some form of fish return. Comprehensive studies, such as those cited above, have shown that modified screens can achieve an increase in the post-impingement survival of aquatic organisms that come under the influence of cooling water intake structures. Hardier species, as might be expected, have exhibited survival rates as high as 100 percent. More fragile species, which are typically smaller and more numerous in the source waterbody, understandably have lower survival rates. Data indicates, however, that with fine tuning, modified screen systems can increase survival rates for even the most susceptible species and bring them closer to the performance standards established under the final rule.

2.2 CYLINDRICAL WEDGEWIRE SCREENS

Technology Overview
Wedgewire screens are designed to reduce entrainment and impingement by physical exclusion and by exploitation of hydrodynamics and the natural flushing action of currents present in the source waterbody. Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. Screen mesh sizes range from 0.5 to 10 mm, with the most common slot sizes in the 1.0 to 2.0 mm range. Hydrodynamic exclusion results from maintenance of a low through-slot velocity, which, because of the screen's cylindrical configuration, is quickly dissipated. This allows organisms to escape the flow field (Weisberd et al. 1984). The name of these screens arises from the triangular or wedge-shaped cross section of the wire that makes up the screen. The screen is composed of wedgewire loops welded at the apex of their triangular cross section to supporting axial rods presenting the base of the cross section to the incoming flow (Pagano et al. 1977). Wedgewire screens are also referred to as profile screens, Johnson screens, or "vee wire".

General understanding of the efficacy of cylindrical wedgewire screens holds that in order to achieve the optimal reduction in impingement and entrainment, certain conditions must be met. First, the slot size must be small enough to physically prevent the entrainment of the organisms identified as warranting protection. Larger slot sizes might be feasible in areas where eggs, larvae, and some classes of juveniles are not present in significant numbers. Second, a low through-slot velocity must be maintained to minimize the hydraulic zone of influence surrounding the screen assembly. A general rule of thumb holds that a lower through-slot velocity, when combined with other optimal factors, will achieve significant reductions in entrainment and impingement. Third, a sufficient ambient current must be present in the source waterbody to aid organisms in bypassing the structure and to remove other debris from the screen face. A constant current also aids the automated cleaning systems that are now common to cylindrical wedgewire screen assemblies.

2.2.1 EXAMPLE STUDIES

Laboratory Evaluation (EPRI 2003)
EPRI recently published (May 2003) the results of a laboratory evaluation of wedgewire screens under controlled conditions in the Alden Research Laboratory Fish Testing Facility. A principal aim of the study was to identify the important factors that influence the relative rates of impingement and entrainment associated with wedgewire screens. The study evaluated characteristics such as slot size, through-slot velocity, and the velocity of ambient currents that could best carry organisms and debris past the screen. When each of the characteristics was optimized, wedgewire screen use became increasingly effective as an impingement reduction technology; in certain circumstances it could be used to reduce the entrainment of eggs and larvae. EPRI notes that large reductions in impingement and entrainment might occur even when all characteristics are not optimized. Localized conditions unique to a particular facility, which were not represented in laboratory testing, might also enable successful deployment. The study cautions that the available data are not sufficient to determine the biological and engineering factors that would need to be optimized, and in what manner, for future applications of wedgewire screens.

Slot sizes of 0.5, 1.0, and 2.0 mm were each evaluated at two different through-slot velocities (0.15 and 0.30 m/s) and three different channel velocities (0.08, 0.15, and 0.30 m/s) to determine the impingement and entrainment rates of fish eggs and larvae. Screen porosities increase from 24.7 percent for the 0.5 mm screens to 56.8 percent for 2.0 mm screens. The study evaluated eight species (striped bass, winter flounder, yellow perch, rainbow smelt, common carp, white sucker, alewife, and bluegill) because of their presence in a variety of waterbody types and their history of entrainment and impingement at many facilities. Larvae were studied for all species except alewife, while eggs were studied for striped bass, white sucker, and alewife. (Surrogate, or artificial, eggs of a similar size and buoyancy substituted for live striped bass eggs.)

Individual tests followed a rigorous protocol to count and label all fish eggs and larvae prior to their introduction into the testing facility. Approach and through-screen velocities in the flume were verified, and the collection nets used to recapture organisms that bypassed the structure or were entrained were cleaned and secured. Fish and eggs were released at a point upstream of the wedgewire screen selected to deliver the organisms at the centerline of the screens, which maximized the exposure of the eggs and larvae to the influence of the screen. The number of entrained organisms was estimated by counting all eggs and larvae captured on the entrainment collection net. Impinged organisms were counted by way of a plexiglass window and video camera setup.

In addition to the evaluations conducted with biological samples, Alden Laboratories developed a Computational Fluid Dynamics (CFD) model to evaluate the hydrodynamic characteristics associated with wedgewire screens. The CFD model analyzed the effects of approach velocity and through-screen velocities on the velocity distributions around the screen assemblies. Using the data gathered from the CFD evaluation, engineers were able to approximate the "zone of influence" around the wedgewire screen assembly under different flow conditions and estimate any influence on flow patterns exerted by multiple screen assemblies located in close proximity to each other.

The results of both the biological evaluation and the CFD model evaluation support many of the conclusions reached by other wedgewire screen studies, as well as in situ anecdotal evidence. In general, the lower impingement rates were achieved with larger slot sizes (1.0 to 2.0 mm), lower through-screen velocities, and higher channel velocities. Similarly, the lowest entrainment rates were seen with low through-screen velocities and higher channel velocities, although the lowest entrainment rates were achieved with smaller slot sizes (0.5 mm). Overall impingement reductions reached as high as 100 percent under optimal conditions, and entrainment reductions approached 90 percent. It should be noted that the highest reductions for impingement and entrainment were not achieved under the same conditions. Results from the biological evaluation generally agree with the predictions from the CFD model: the higher channel velocities, when coupled with lower through-screen velocities, would result in the highest rate of protection for the target organisms.

JH Campbell

JH Campbell is located on Lake Michigan in Michigan, with the intake for Unit 3 located approximately 1,000 meters from shore at a depth of 10.7 meters. The cylindrical intake structure has 9.5-mm mesh wedgewire screens and withdraws approximately 400 MGD. Raw impingement data are not available, and EPA is not aware of a comprehensive study evaluating the impingement reduction associated with the wedgewire screen system. Comparative analyses using the impingement rates at the two other intake structures (on shore intakes with conventional traveling screens) have shown that impingement of emerald shiner, gizzard shad, smelt, yellow perch, and alewife associated with the wedgewire screen intake has been effectively reduced to insignificant levels. Maintenance issues have not been shown to be problematic at JH Campbell because of the far offshore location in deep water and the periodic manual cleaning using water jets to reduce biofouling. Entrainment has not been shown to be of concern at the intake structure because of the low abundance of entrainable organisms in the immediate vicinity of the wedgewire screens.

Eddystone Generating Station

Eddystone Generating Station is located on the tidal portion of the Delaware River in Pennsylvania. Units 1 and 2 were retrofitted to include wide-mesh wedgewire screens and currently withdraw approximately 500 MGD from the Delaware River. Pre-deployment data showed that over 3 million fish were impinged on the unmodified intake structures during a single 20-month period. An automatic air burst system has been installed to prevent biofouling and debris clogging from affecting the performance of the screens. EPA has not been able to obtain biological data for the Eddystone wedgewire screens but EPRI indicates that fish impingement has been eliminated.

2.2.2 OTHER FACILITIES

Other plants with lower intake flows have installed wedgewire screens, but there are limited biological performance data for these facilities. The Logan Generating Station in New Jersey withdraws 19 MGD from the Delaware River through a 1-mm wedgewire screen. Entrainment data show 90 percent less entrainment of larvae and eggs than conventional screens. No impingement data are available. Unit 1 at the Cope Generating Station in South Carolina is a closed-cycle unit that withdraws about 6 MGD through a 2-mm wedgewire screen; however, no biological data are available. Performance data are also unavailable for the Jeffrey Energy Center, which withdraws about 56 MGD through a 10-mm screen from the Kansas River in Kansas. The system at the Jeffrey Plant has operated since 1982 with no operational difficulties. Finally, the American Electric Power Corporation has installed wedgewire screens at the Big Sandy (2 MGD) and Mountaineer (22 MGD) facilities, which withdraw water from the Big Sandy and Ohio rivers, respectively. Again, no biological test data are available for these facilities.

Wedgewire screens have been considered or tested for several other large facilities. In situ testing of 1- and 2-mm wedgewire screens was performed in the St. John River for the Seminole Generating Station Units 1 and 2 in Florida in the late 1970s. This testing showed virtually no impingement and 99 and 62 percent reductions in larvae entrainment for the 1-mm and 2-mm screens, respectively, over conventional screen (9.5-mm) systems. In 1982 and 1983 the State of Maryland conducted testing 1-, 2-, and 3-mm wedgewire screens at the Chalk Point Generating Station, which withdraws water from the Patuxent River in Maryland. The 1-mm wedgewire screens were found to reduce entrainment by 80 percent. No impingement data were available. Some biofouling and clogging were observed during the tests. In the late 1970s, Delmarva Power and Light conducted laboratory testing of fine-mesh wedgewire screens for the proposed 1,540 MW Summit Power Plant. This testing showed that entrainment of fish eggs (including striped bass eggs) could effectively be prevented with slot widths of 1 mm or less, while impingement mortality was expected to be less than 5 percent. Actual field testing in the brackish water of the proposed intake canal required the screens to be removed and cleaned as often as once every 3 weeks.

Applicability to Large-Capacity Facilities
EPA believes that cylindrical wedgewire screens can be successfully employed by large intake facilities under certain circumstances. Although many of the current installations of this technology have been at smaller-capacity facilities, EPA does not believe that the increased capacity demand of a large intake facility, in and of itself, is a barrier to deployment of this technology. Large water withdrawals can be accommodated by multiple screen assemblies in the source waterbody. The limiting factor for a larger facility may be the availability of sufficient accessible space near the facility itself because additional screen assemblies obviously consume more space on the waterbody floor and might interfere with navigation or other uses of the waterbody. Consideration of the impacts in terms of space and placement must be evaluated before selecting wedgewire screens for deployment.

Applicability in High-Debris Waterbodies
As with any intake structure, the presence of large debris poses a risk of damage to the structure if not properly managed. Cylindrical wedgewire screens, because of their need to be submerged in the water current away from shore, might be more susceptible to debris interaction than other onshore technologies. Vendor engineers indicated that large debris has been a concern at several of their existing installations, but the risk associated with it has been effectively minimized by selecting the optimal site and constructing debris diversion structures. Significant damage to a wedgewire screen is most likely to occur from fast-moving submerged debris. Because wedgewire screens do not need to be sited in the area with the fastest current, a less damage-prone area closer to shore or in a cove or constructed embayment can be selected, provided it maintains a minimum ambient current around the screen assembly. If placement in the main channel is unavoidable, deflecting structures can be employed to prevent free-floating debris from contacting the screen assembly. Typical installations of cylindrical wedgewire place them roughly parallel to the direction of the current, exposing only the upstream nose to direct impacts with debris traveling downstream. EPA has noted several installations where debris-deflecting nose cones have been installed to effectively eliminate the damage risk associated with large debris.

Apart from the damage that large debris can cause, smaller debris, such as household trash or organic matter, can build up on the screen surface, altering the through-slot velocity of the screen face and increasing the risk of entrainment and/or impingement of target organisms. Again, selection of the optimal location in the waterbody might be able to reduce the collection of debris on the structure. Ideally, cylindrical wedgewire is located away from areas with high submerged aquatic vegetation (SAV) and out of known debris channels. Proper placement alone may achieve the desired effect, although technological solutions also exist to physically remove small debris and silt. Automated air-burst systems can be built into the screen assembly and set to deliver a short burst of air from inside and below the structure. Debris is removed from the screen face by the air burst and carried downstream and away from the influence of the intake structure. Improvements to the air burst system have eliminated the timed cleaning cycle and replaced it with one tied to a pressure differential monitoring system.

Applicability in High Navigation Waterbodies
Wedgewire screens are more likely to be placed closer to navigation channels than other onshore technologies, thereby increasing the possibility of damage to the structure itself or to a passing commercial ship or recreational boat. Because cylindrical wedgewire screens need to be submerged at all times during operation, they are typically installed closer to the waterbody floor than the surface. In a waterbody of sufficient depth, direct contact with recreational watercraft or small commercial vessels is unlikely. EPA notes that other submerged structures (e.g., pipes, transmission lines) operate in many different waterbodies and are properly delineated with acceptable navigational markers to prevent accidents associated with trawling, dropping anchor, and similar activities. Such precautions would likely be taken for a submerged wedgewire screen as well.

2.2.3 SUMMARY

Cylindrical wedgewire screens have been effectively used to mitigate impingement and, under certain conditions, entrainment impacts at many different types of facilities over the past three decades. Although not yet widely used at steam electric power plants, the limited data for Eddystone and Campbell indicate that wide mesh screens, in particular, can be used to minimize impingement. Successful use of the wedgewire screens at Eddystone, as well as at Logan in the Delaware River (high debris flows), suggests that the screens can have widespread applicability. This is especially true for facilities that have relatively low intake flow requirements (closed-cycle systems). Nevertheless, the lack of more representative full-scale plant data makes it impossible to conclusively say that wedgewire screens can be used in all environmental conditions. For example, there are no full-scale data available specifically for marine environments where biofouling and clogging are significant concerns. Technological advances have been made to address such concerns. Automated cleaning systems can now be built into screen assemblies to reduce the disruptions debris buildup can cause. Likewise, vendors have been experimenting with different screen materials and coatings to reduce the on-screen growth of vegetation and other organisms (zebra mussels).

Fine-mesh wedgewire screens (0.5 - 1 mm) also have the *potential* for use to control both impingement and entrainment. EPA is not aware of the installation of any fine-mesh wedgewire screens at any power plants with high intake flows (> 100 MGD). However, such screens have been used at some power plants with lower intake flow requirements (25 to 50 MGD), which would be comparable to a very large power plant with a closed-cycle cooling system. With the exception of Logan, EPA has not identified any full-scale performance data for these systems. They could be even more susceptible to clogging than wide-mesh wedgewire screens (especially in marine environments). It is unclear whether clogging would simply necessitate more intensive maintenance or preclude their day-to-day use at many sites. Their successful application at Logan and Cope and the historical test data from Florida, Maryland, and Delaware at least suggest promise for addressing both fish impingement and entrainment of eggs and larvae. However, based on the fine-mesh screen experience at Big Bend Units 3 and 4, it is clear that frequent maintenance would be required. Therefore, relatively deep water sufficient to accommodate the large number of screen units would preferably be close to shore (readily accessible). Manual cleaning needs might be reduced or eliminated through use of an automated flushing (e.g., microburst) system.

2.3 FINE-MESH SCREENS

Technology Overview
Fine-mesh screens are typically mounted on conventional traveling screens and are used to exclude eggs, larvae, and juvenile forms of fish from intakes. These screens rely on gentle impingement of organisms on the screen surface. Successful use of fine-mesh screens is contingent on the application of satisfactory handling and return systems to allow the safe return of impinged organisms to the aquatic environment (Pagano et al. 1977; Sharma 1978). Fine-mesh screens generally include those with mesh sizes of 5 mm or less.

Technology Performance
Similar to fine-mesh wedgewire screens, fine-mesh traveling screens with fish return systems show promise for control of both impingement and entrainment. However, they have not been installed, maintained, and optimized at many facilities.

2.3.1 EXAMPLE FACILITIES

Big Bend
The most significant example of long-term use of fine-mesh screens has been at the Big Bend Power Plant in the Tampa Bay area. The facility has an intake canal with 0.5-mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. During the mid-1980s when the screens were initially installed, their efficiency in reducing I&E mortality was highly variable. The operator, Florida Power & Light (FPL) evaluated different approach velocities and screen rotational speeds. In addition, FPL recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had improved greatly. The system's efficiency in screening fish eggs (primarily drums and bay anchovy) exceeded 95 percent, with 80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primarily drums, bay anchovies, blennies, and gobies), screening efficiency was 86 percent, with 65 percent latent survival for drums and 66 percent for bay anchovy. (Note that latent survival in control samples was also approximately 60 percent). Although more recent data are generally not available, the screens continue to operate successfully at Big Bend in an estuarine environment with proper maintenance.

2.3.2 OTHER FACILITIES

Although egg and larvae entrainment performance data are not available, fine-mesh (0.5-mm) Passavant screens (single entry/double exit) have been used successfully in a marine environment at the Barney Davis Station in Corpus Christi, Texas. Impingement data for this facility show an overall 86 percent initial survival rate for bay anchovy, menhaden, Atlantic croaker, killfish, spot, silverside, and shrimp.

Additional full-scale performance data for fine-mesh screens at large power stations are generally not available. However, some data are available from limited use or study at several sites and from laboratory and pilot-scale tests. Seasonal use of fine mesh on two of four screens at the Brunswick Power Plant in North Carolina has shown 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1-mm screens at the Chalk Point Generating Station in Maryland. At the Kintigh Generating Station in New Jersey, pilot testing indicated that 1-mm screens provided 2 to 35 times the reduction in entrainment over conventional 9.5-mm screens. Finally, Tennessee Valley Authority (TVA) pilot-scale studies performed in the 1970s showed reductions in striped bass larvae entrainment of up to 99 percent for a 0.5-mm screen and 75 and 70 percent for 0.97-mm and 1.3-mm screens, respectively. A full-scale test by TVA at the John Sevier Plant showed less than half as many larvae entrained with a 0.5-mm screen than with 1- and 2-mm screens combined.

2.3.3 SUMMARY

Despite the lack of full-scale data, the experiences at Big Bend (as well as Brunswick) show that fine-mesh screens can reduce entrainment by 80 percent or more. This reduction is contingent on optimized operation and intensive maintenance to avoid biofouling and clogging, especially in marine environments. It might also be appropriate to use removable fine mesh that is installed only during periods of egg and larval abundance, thereby reducing the potential for clogging and wear and tear on the systems.

2.4 FISH NET BARRIERS

Technology Overview
Fish net barriers are wide-mesh nets that are placed in front of the entrance to intake structures. The size of the mesh needed is a function of the species present at a particular site and varies from 4 mm to 32 mm (EPRI 2000). The mesh must be sized to prevent fish from passing through the net, which could cause them to be gilled. Relatively low velocities are maintained because the area through which the water can flow is usually large. Fish net barriers have been used at numerous facilities and lend themselves to intakes where the seasonal migration of fish and other organisms requires fish diversion facilities at only specific times of the year.

Technology Performance
Barrier nets can provide a high degree of impingement reduction by preventing large fish from entering the vicinity of the intake structure. Because of typically wide openings, they do not reduce entrainment of eggs and larvae. A number of barrier net systems have been used or studied at large power plants.

2.4.1 EXAMPLE STUDIES

JP Pulliam Station
The JP Pulliam Station is located on the Fox River in Wisconsin. Two separate nets with 6-mm mesh are deployed on opposite sides of a steel grid supporting structure. The operation of a dual net system facilitates the cleaning and maintenance of the nets without affecting the overall performance of the system. Under normal operations, nets are rotated at least two times per week to facilitate cleaning and repair. The nets are typically deployed when the ambient temperature of the intake canal exceeds 37°F. This usually occurs between April 1 and December 1.

Studies undertaken during the first 2 years after deployment showed an overall net deterrence rate of 36 percent for targeted species (noted as commercially or recreationally important, or forage species). Improvements to the system in subsequent years consisted of a new bulkhead to ensure a better seal along the vertical edge of the net and additional riprap along the base of the net to maintain the integrity of the seal along the bottom of the net. The improvements resulted in a deterrence rate of 98 percent for some species; no species performed at less than 85 percent. The overall effectiveness for game species was better than 90 percent while forage species were deterred at a rate of 97 percent or better.

JR Whiting Plant
The JR Whiting Plant is located on Maumee Bay of Lake Erie in Michigan. A 3/8-inch mesh barrier net was deployed in 1980 as part of a best technology available determination by the Michigan Water Resources Commission. Estimates of impingement reductions were based on counts of fish impinged on the traveling screens inside the barrier net. Counts in years after the deployment were compared to data from the year immediately prior to the installation of the net when over 17

million fish were impinged. Four years after deployment, annual impingement totals had fallen by 98 percent.

Bowline Point

Bowline Point is located on the Hudson River in New York. A 150-foot long, 0.95-cm mesh net has been deployed in a V-shaped configuration around the intake pump house. The area of the river in which the intake is located has currents that are relatively stagnant, thus limiting the stresses to which the net might be subjected. Relatively low through-net velocities (0.5 ft/s) have been maintained across a large portion of the net because of low debris loadings. Debris loads directly affecting the net were reduced by including a debris boom outside the main net. An air bubbler was also added to the system to reduce the buildup of ice during cold months.

The facility has attempted to evaluate the reduction in the rate of impingement by conducting various studies of the fish populations inside and outside the barrier net. Initial data were used to compare impingement rates from before and after deployment of the net and showed a deterrence of 91 percent for targeted species (white perch, striped bass, rainbow smelt, alewife, blueback herring, and American shad). In 1982 a population estimate determined that approximately 230,000 striped bass were present in the embayment outside the net area. A temporary mesh net was deployed across the embayment to prevent fish from leaving the area. A 9-day study found that only 1.6 percent of the estimated 230,000 fish were ultimately impinged on the traveling screens. A mark-recapture study that released individual fish inside and outside the barrier net showed similar results, with more than 99 percent of fish inside the net impinged and less than 3 percent of fish outside the net impinged. Gill net capture studies sought to estimate the relative population densities of fish species inside and outside the net. The results agreed with those of previous studies, showing that the net was maintaining a relatively low density of fish inside the net as compared to the outside.

2.4.2 SUMMARY

Barrier nets have clearly proven effective for controlling *impingement* (i.e., more than 80 percent reductions over conventional screens without nets) in areas with limited debris flows. Experience has shown that high debris flows can cause significant damage to net systems. Biofouling can also be a concern but it can be addressed through frequent maintenance. In addition, barrier nets are also often used only seasonally where the source waterbody is subject to freezing. Fine-mesh barrier nets show some promise for entrainment control but would likely require even more intensive maintenance. In some cases, the use of barrier nets might be further limited by the physical constraints and other uses of the waterbody.

2.5 AQUATIC MICROFILTRATION BARRIERS

Technology Overview

Aquatic microfiltration barrier systems are barriers that employ a filter fabric designed to allow water to pass into a cooling water intake structure but exclude aquatic organisms. These systems are designed to be placed some distance from the cooling water intake structure within the source waterbody and act as a filter for the water that enters the cooling water system. These systems can be floating, flexible, or fixed. Because these systems usually have such a large surface area, the velocities maintained at the face of the permeable curtain are very low. One company, Gunderboom, Inc., has a patented full-water-depth filter curtain composed of polyethylene or polypropylene fabric that is suspended by flotation billets at the surface of the water and anchored to the substrate below. The curtain fabric is manufactured as a matting of minute unwoven fibers with an apparent opening size of 20 microns. Gunderboom systems also employ an automated “air burst” system to periodically shake the material and pass air bubbles through the curtain system to clean off of sediment buildup and release any other material back into the water column.

Technology Performance

EPA has determined that microfiltration barriers, including the Gunderboom, show significant *promise* for minimizing entrainment. EPA acknowledges, however, that the Gunderboom technology is currently “experimental in nature.” At this juncture, the only power plant where the Gunderboom has been used at a full-scale level is the Lovett Generating Station along the Hudson River in New York, where pilot testing began in the mid-1990s. Initial testing at that facility showed significant potential for reducing entrainment. Entrainment reductions of up to 82 percent were observed for eggs and larvae, and these levels were maintained for extended month-to-month periods during1999 through 2001. At Lovett, some operational difficulties have affected long-term performance. These difficulties, including tearing, overtopping, and plugging/clogging, have been addressed, to a large extent, through subsequent design modifications. Gunderboom, Inc. specifically has designed and installed a microburst cleaning system to remove particulates. Each of the challenges encountered at Lovett could be of significantly greater concern at marine sites with higher wave action and debris flows.

Gunderboom systems have been otherwise deployed in marine conditions to prevent migration of particulates and bacteria. They have been used successfully in areas with waves up to 5 feet. The Gunderboom system is being tested for potential use at the Contra Costa Plant along the San Joaquin River in Northern California.

An additional question related to the utility of the Gunderboom and other microfiltration systems is sizing and the physical limitations and other uses of the source waterbody. With a 20-micron mesh, 100,000 and 200,000 gpm intakes would require filter systems 500 and 1,000 feet long (assuming a 20-foot depth). In some locations, this may preclude the successful deployment of the system because of space limitations or conflicts with other waterbody uses.

2.6 LOUVER SYSTEMS

Technology Overview
Louver systems consist of series of vertical panels placed at 90 degree angles to the direction of water flow (Hadderingh 1979). The placement of the louver panels provides both changes in both the flow direction and velocity, which fish tend to avoid. The angles and flow velocities of the louvers create a current parallel to the face of the louvers that carries fish away from the intake and into a fish bypass system for return to the source waterbody.

Technology Performance
Louver systems can reduce impingement losses based on fishes' abilities to recognize and swim away from the barriers. Their performance, i.e., guidance efficiency, is highly dependant on the length and swimming abilities of the resident species. Because eggs and early stages of larvae cannot swim away, they are not affected by the diversions and there is no associated reduction in entrainment.

Although louver systems have been tested at a number of laboratory and pilot-scale facilities, they have not been used at many full-scale facilities. The only large power plant facility where a louver system has been used is San Onofre Units 2 and 3 (2,200 MW combined) in Southern California. The operator initially tested both louver and wide mesh, angled traveling screens during the 1970s. Louvers were subsequently selected for full-scale use at the intakes for the two units. In 1984 a total of 196,978 fish entered the louver system with 188,583 returned to the waterbody and 8,395 impinged. In 1985, 407,755 entered the louver system; 306,200 were returned and 101,555 impinged. Therefore, the guidance efficiencies in 1984 and 1985 were 96 and 75 percent, respectively. However, 96-hour survival rates for some species, i.e., anchovies and croakers, was 50 percent or less. The facility has also encountered some difficulties with predator species congregating in the vicinity of the outlet from the fish return system. Louvers were originally considered for use at San Onofre because of 1970s pilot testing at the Redondo Beach Station in California, where maximum guidance efficiencies of 96 to 100 percent were observed.

EPRI (2000) indicated that louver systems could provide 80-95 percent diversion efficiency for a wide variety of species under a range of site conditions. These findings are generally consistent with the American Society of Civil Engineers' (ASCE) findings from the late 1970s, which showed that almost all systems had diversion efficiencies exceeding 60 percent with many more than 90 percent. As indicated above, much of the EPRI and ASCE data come from pilot/laboratory tests and hydroelectric facilities where louver use has been more widespread than at steam electric facilities. Louvers were specifically tested by the Northeast Utilities Service Company in the Holyoke Canal on the Connecticut River for juvenile clupeids (American shad and blueback herring). The overall guidance efficiency was found to be 75 to 90 percent. In the 1970s Alden Research Laboratory observed similar results for Hudson River species, including alewife and smelt. At the Tracy Fish Collection Facility along the San Joaquin River in California, testing was performed from 1993 and 1995 to determine the guidance efficiency of a system with primary and secondary louvers. The results for green and white sturgeon, American shad, splittail, white catfish, delta smelt, chinook salmon, and striped bass showed mean diversion efficiencies ranging from 63 percent (splittail) to 89 percent (white catfish). Also in the 1990s, an experimental louver bypass system was tested at the USGS Conte Anadromous Fish Research Center in Massachusetts. This testing showed guidance efficiencies for Connecticut River species of 97 percent for a "wide array" of louvers and 100 percent for a "narrow array." Finally, at the T.W. Sullivan Hydroelectric Plant along the Williamette River in Oregon, the louver system is estimated to be 92 percent effective in diverting spring chinook, 82 percent for all Chinook, and 85 percent for steelhead. The system has been optimized to reduce fish injuries such that the average injury occurrence is only 0.44 percent.

Overall, the above data indicate that louvers can be highly effective (more than 70 percent) in diverting fish from potential impingement. Latent mortality is a concern, especially where fragile species are present. Similar to modified screens with fish return systems, operators must optimize louver system design to minimize fish injury and mortality.

2.7 ANGLED AND MODULAR INCLINED SCREENS

Technology Overview
Angled traveling screens use standard through-flow traveling screens in which the screens are set at an angle to the incoming flow. Angling the screens improves the fish protection effectiveness because the fish tend to avoid the screen face and move toward the end of the screen line, assisted by a component of the inflow velocity. A fish bypass facility with independently induced flow must be provided (Richards 1977). Modular inclined screens (MISs) are a specific variation on angled traveling screens, in which each module in the intake consists of trash racks, dewatering stop logs, an inclined screen set at a 10 to 20 degree angle to the flow, and a fish bypass (EPRI 1999).

Technology Performance
Angled traveling screens with fish bypass and return systems work similarly to louver systems. They also provide only potential reductions in impingement mortality because eggs and larvae will not generally detect the factors that influence diversion. Like louver systems, they were tested extensively at the laboratory and pilot scales, especially during the 1970s and early 1980s. Testing of angled screens (45 degrees to the flow) in the 1970s at San Onofre showed poor to good guidance (0 to 70 percent) for northern anchovies and moderate to good guidance (60 to 90 percent) for other species. Latent survival varied by species: fragile species had only 25 percent survival, while hardy species showed greater than 65 percent survival. The intake for Unit 6 at the Oswego Steam plant along Lake Ontario in New York has traveling screens angled at 25 degrees. Testing during 1981 through 1984 showed a combined diversion efficiency of 78 percent for all species, ranging from 53 percent for mottled sculpin to 95 percent for gizzard shad. Latent survival testing results ranged from 22 percent for alewife to nearly 94 percent for mottled sculpin.

Additional testing of angled traveling screens was performed in the late 1970s and early 1980s for power plants on Lake Ontario and along the Hudson River. This testing showed that a screen angled at 25 degrees was 100 percent effective in diverting 1- to 6- inch-long Lake Ontario fish. Similar results were observed for Hudson River species (striped bass, white perch, and Atlantic tomcod). One-week mortality tests for these species showed 96 percent survival. Angled traveling screens with a fish return system have been used on the intake from Brayton Point Unit 4. Studies that evaluated the angled screens from 1984 through 1986 showed a diversion efficiency of 76 percent with a latent survival of 63 percent. Much higher results were observed excluding bay anchovy.

Finally, 1981 full-scale studies of an angled screen system at the Danskammer Station along the Hudson River in New York showed diversion efficiencies of 95 to 100 percent with a mean of 99 percent. Diversion efficiency combined with latent survival yielded a total effectiveness of 84 percent. Species included bay anchovy, blueback herring, white perch, spottail shiner, alewife, Atlantic tomcod, pumpkinseed, and American shad.

During the late 1970s and early 1980s, Alden Research Laboratories conducted a range of tests on a variety of angled screen designs. Alden specifically performed screen diversion tests for three northeastern utilities. In initial studies for Niagara Mohawk, diversion efficiencies were found to be nearly 100 percent for alewife and smolt. Followup tests for Niagara Mohawk confirmed 100 percent diversion efficiency for alewife with mortalities only 4 percent higher than those in control samples. Subsequent tests by Alden for Consolidated Edison, Inc. using striped bass, white perch, and tomcod also found nearly 100 percent diversion efficiency with a 25 degree angled screen. The 1-week mean mortality was only 3 percent. Alden performed further tests during 1978 to 1990 to determine the effectiveness of fine-mesh, angled screens.

In 1978, tests were performed with striped bass larvae using both 1.5- and 2.5-mm mesh and different screen materials and approach velocity. Diversion efficiency was found to clearly be a function of larvae length. Synthetic materials were also found to be more effective than metal screens. Subsequent testing using only synthetic materials found that 1-mm screens can provide post larvae diversion efficiencies of greater than 80 percent. The tests found, however, that latent mortality for diverted species was also high. Finally, EPRI tested MIS in a laboratory in the early 1990s. Most fish had diversion efficiencies of 47 to 88 percent. Diversion efficiencies of greater than 98 percent were observed for channel catfish, golden shiner, brown trout, Coho and Chinook salmon, trout fry and juveniles, and Atlantic salmon smolts. Lower diversion efficiency and higher mortality were found for American shad and blueback herring, but the mortalities were comparable to control mortalities. Based on the laboratory data, an MIS system was pilot-tested at a Niagara Mohawk hydroelectric facility on the Hudson River. This testing showed diversion efficiencies and survival rates approaching 100 percent for golden shiners and rainbow trout. High diversion and survival were also observed for largemouth and smallmouth bass, yellow perch, and bluegill. Lower diversion efficiency and survival were found for herring.

In October 2002, EPRI published the results of a combined louver/angled screen assembly study that evaluated the diversion efficiencies of various configurations of the system. In 1999, fish guidance efficiency was evaluated with two bar rack configurations (25- and 50-mm spacings) and one louver configuration (50-mm clearance), with each angled at 45 degrees to the approach flow. In 2000, the same species were evaluated with the 50-mm bar racks and louvers angled at 15 degrees to the approach flow. Diversion efficiencies were evaluated at various approach velocities ranging from 0.3 to 0.9 m/s.

Guidance efficiency was lowest, generally lower than 50 percent, for the 45 degree louver/bar rack array, with efficiencies distributed along a bell shaped curve according to approach velocity. For the 45 degree array, diversion efficiency was best at 0.6 m/s, with most species approaching 50 percent. All species except one (lake sturgeon) experienced higher diversion efficiencies with the louver/bar rack array set at 15 degrees to the approach flow. With the exception of lake sturgeon, species were diverted at 70 percent or better at most approach velocities.

Similar to louvers, angled screens show potential to minimize impingement by greater than 80 to 90 percent. More widespread full-scale use is necessary to determine optimal design specifications and verify that they can be used on a widespread basis.

2.8 VELOCITY CAPS

Technology Description

A velocity cap is a device that is placed over a vertical inlet at an offshore intake. This cover converts vertical flow into horizontal flow at the entrance to the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow but are less able to detect and avoid vertical velocity vectors. Velocity caps have been installed at many offshore intakes and have usually been successful in minimizing impingement.

Technology Performance

Velocity caps can reduce the number of fish drawn into intakes based on the concept that they tend to avoid rapid changes in horizontal flow. They do not provide reductions in entrainment of eggs and larvae, which cannot distinguish flow characteristics. As noted in ASCE (1981), velocity caps are often used in conjunction with other fish protection devices, such as screens with fish returns. Therefore, there are somewhat limited data on their performance when used alone. Facilities that have velocity caps include the following:

- Oswego Steam Units 5 and 6 in New York (combined with angled screens on Unit 6).
- San Onofre Units 2 and 3 in California (combined with louver system).
- El Segundo Station in California
- Huntington Beach Station in California
- Edgewater Power Plant Unit 5 in Wisconsin (combined with 9.5-mm wedgewire screen)
- Nanticoke Power Plant in Ontario, Canada
- Nine Mile Point in New York
- Redondo Beach Station in California
- Kintigh Generation Station in New York (combined with modified traveling screens)
- Seabrook Power Plant in New Hampshire
- St. Lucie Power Plant in Florida
- Palisades Nuclear Plant in Michigan

At the Huntington Beach and Segundo stations in California, velocity caps have been found to provide 80 to 90 percent reductions in fish entrapment. At Seabrook, the velocity cap on the offshore intake has minimized the number of pelagic fish entrained except for pollock. Finally, two facilities in England each have velocity caps on one of two intakes. At the Sizewell Power Station, intake B has a velocity cap, which reduces impingement about 50 percent compared to intake A. Similarly, at the Dungeness Power Station, intake B has a velocity cap, which reduces impingement about by 62 percent compared to intake A.

2.9 POROUS DIKES AND LEAKY DAMS

Technology Overview

Porous dikes, also known as leaky dams or dikes, are filters that resemble a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel that permits free passage of water. The dike acts as both a physical and a behavioral barrier to aquatic organisms. Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. The major problems associated with porous dikes come from clogging by debris and silt, ice buildup, and colonization by fish and plant life.

Technology Performance
Porous dike technologies work on the premise that aquatic organisms will not pass through physical barriers in front of an intake. They also operate with low approach velocity, further increasing the potential for avoidance. They will not, however, prevent entrainment by nonmotile larvae and eggs. Much of the research on porous dikes and leaky dams was performed in the 1970s. This work was generally performed in a laboratory or on a pilot level, and the Agency is not aware of any full-scale porous dike or leaky dam systems currently used at power plants in the United States. Examples of early study results include:

- Studies of porous dike and leaky dam systems by Wisconsin Electric Power at Lake Michigan plants showed generally lower I&E rates than those for other nearby onshore intakes.

- Laboratory work by Ketschke showed that porous dikes could be a physical barrier to juvenile and adult fish and a physical or behavioral barrier to some larvae. All larvae except winter flounder showed some avoidance of the rock dike.

- Testing at the Brayton Point Station showed that densities of bay anchovy larvae downstream of the dam were reduced by 94 to 99 percent. For winter flounder, downstream densities were lower by 23 to 87 percent.

Entrainment avoidance for juvenile and adult finfish was observed to be nearly 100 percent. As indicated in the above examples, porous dikes and leaky dams show *potential* for use in limiting the passage of adult and juvenile fish and, to some degree, motile larvae. However, the lack of more recent, full-scale performance data makes it difficult to predict their widespread applicability and specific levels of performance.

2.10 BEHAVIORAL SYSTEMS

Technology Overview
Behavioral devices are designed to enhance fish avoidance of intake structures or to promote attraction to fish diversion or bypass systems. Specific technologies that have been considered include:

- Light Barriers: Light barriers consist of controlled application of strobe lights or mercury vapor lights to lure fish away from the cooling water intake structure or deflect natural migration patterns. This technology is based on research that shows that some fish species avoid light; however, it is also known that some species are attracted by light.

- Sound Barriers: Sound barriers are noncontact barriers that rely on mechanical or electronic equipment that generates various sound patterns to elicit avoidance responses in fish. Acoustic barriers are used to deter fish from entering cooling water intake structures. The most widely used acoustical barrier is a pneumatic air gun or “popper.”

- Air bubble barriers: Air bubble barriers consist of an air header with jets arranged to provide a continuous curtain of air bubbles over a cross sectional area. The general purpose of air bubble barriers is to repel fish that might attempt to approach the face of a CWIS.

Technology Performance
Many studies have been conducted and reports prepared on the application of behavioral devices to control I&E, see, for example, EPRI 2000. For the most part, these studies have been inconclusive or have shown no significant reduction in impingement or entrainment. As a result, the full-scale application of behavioral devices has been limited. Where data are available, performance appears to be highly dependent on the types and sizes of species and environmental conditions. One exception might be the use of sound systems to divert alewife. In tests at the Pickering Station in Ontario, poppers were found to be effective in reducing alewife I&E by 73 percent in 1985 and 76 percent in 1986. No impingement reductions were observed for rainbow smelt and gizzard shad. Testing of sound systems in 1993 at the James A. Fitzpatrick Station in New York showed similar results, i.e., 85 percent reductions in alewife I&E through use of a high-frequency sound system. At the Arthur Kill Station, pilot- and full-scale high-frequency sound tests showed comparable results for alewife to those for Fitzpatrick and Pickering. Impingement of gizzard shad was also three times lower than that without the system. No deterrence was observed for American shad or bay anchovy using the full-scale system. In contrast, sound provided little or no deterrence for any species at the Roseton Station in New York. Overall, the Agency expects that behavioral systems

would be used in conjunction with other technologies to reduce I&E and perhaps targeted toward an individual species (e.g., alewife).

2.11 OTHER TECHNOLOGY ALTERNATIVES

Use of variable speed pumps can provide for greater system efficiency and have reduced flow requirements (and associated entrainment) by 10 to 30 percent. EPA Region 4 estimated that use of variable speed pumps at the Canaveral and Indian River stations in the Indian River estuary would reduce entrainment by 20 percent. Presumably, such pumps could be used in conjunction with other technologies to meet the performance standards.

Perforated pipes draw water through perforations or elongated slots in a cylindrical section placed in the waterway. Early designs of this technology were not efficient, velocity distribution was poor; and the pipes were specifically designed to screen out detritus, not to protect fish (ASCE 1982). Inner sleeves were subsequently added to perforated pipes to equalize the velocities entering the outer perforations. These systems have historically been used at locations requiring small amounts of make-up water; experience at steam electric plants is very limited (Sharma 1978). Perforated pipes are used on the intakes for the Amos and Mountaineer stations along the Ohio River, but I&E performance data for these facilities are unavailable. In general, EPA projects that perforated pipe system performance should be comparable to that of wide mesh wedgewire screens (e.g., at Eddystone Units 1 and 2 and Campbell Unit 3).

At the Pittsburg Plant in California, impingement survival was studied for continuously rotated screens versus intermittent rotation. Ninety-six-hour survival for young-of-year white perch was 19 to 32 percent for intermittent screen rotation versus 26 to 56 percent for continuous rotation. Striped bass latent survival increased from 26 to 62 percent when continuous rotation was used. Similar studies were also performed at Moss Landing Units 6 and 7, where no increased survival was observed for hardy and very fragile species; there was, however, a substantial increase in impingement survival for surfperch and rockfish.

Facilities might be able to use recycled cooling water to reduce their intake flow needs. The Brayton Point Station has a "piggyback" system in which the entire intake requirements for Unit 4 can be met by recycled cooling water from Units 1 through 3. The system has been used sporadically since 1993, and it reduces the make-up water needs (and thereby entrainment) by 29 percent.

2.12 INTAKE LOCATION

Beyond design alternatives for CWISs, an operator might be able to relocate CWISs offshore or in others areas that minimize I&E (compared to conventional onshore locations). In conjunction with offshore inlet technologies such as cylindrical wedgewire t-screens or velocity caps, the relocated offshore intake could be quite effective at reducing impingement and/or entrainment effects. However, the action of relocating at existing facilities is costly due to significant civil engineering works. It is well known that there are certain areas within every waterbody with increased biological productivity, and therefore where the potential for I&E of organisms is higher.

In large lakes and reservoirs, the littoral zone (the shore zone areas where light penetrates to the bottom) serves as the principal spawning and nursery area for most species of freshwater fish and is considered one of the most productive areas of the waterbody. Fish of this zone typically follow a spawning strategy wherein eggs are deposited in prepared nests, on the bottom, or are attached to submerged substrates where they incubate and hatch. As the larvae mature, some species disperse to the open water regions, whereas many others complete their life cycle in the littoral zone. Clearly, the impact potential for intakes located in the littoral zone of lakes and reservoirs is high. The profundal zone of lakes and reservoirs is the deeper, colder area of the waterbody. Rooted plants are absent because of insufficient light, and for the same reason, primary productivity is minimal. A well-oxygenated profundal zone can support benthic macroinvertebrates and cold-water fish; however, most of the fish species seek shallower areas to spawn (either in littoral areas or in adjacent streams and rivers). Use of the deepest open water region of a lake or reservoir (e.g., within the profundal zone) as a source of cooling water typically offers lower I&E impact potential than use of littoral zone waters.

As with lakes and reservoirs, rivers are managed for numerous benefits, which include sustainable and robust fisheries. Unlike lakes and reservoirs, the hydrodynamics of rivers typically result in a mixed water column and overall unidirectional flow. There are many similarities in the reproductive strategies of shoreline fish populations in rivers and the reproductive strategies of fish within the littoral zone of lakes and reservoirs. Planktonic movement of eggs, larvae, post larvae, and early juvenile organisms along the shore zone is generally limited to relatively short distances. As a result, the shore zone placement of CWISs in rivers might potentially impact local spawning populations of fish. The impact potential associated with entrainment might be diminished if the main source of cooling water is recruited from near the bottom strata of the open water channel region of the river. With such an intake configuration, entrainment of shore zone eggs and larvae, as well as the near-surface drift community of ichthyoplankton, is minimized. Impacts could also be minimized by controlling the timing and frequency of withdrawals from rivers. In temperate regions, the number of entrainable or impingeable organisms of rivers increases during spring and summer (when many riverine fishes reproduce). The number of eggs and larvae peak at that time, whereas entrainment potential during the remainder of the year can be minimal.

In estuaries, species distribution and abundance are determined by a number of physical and chemical attributes, including geographic location, estuary origin (or type), salinity, temperature, oxygen, circulation (currents), and substrate. These factors, in conjunction with the degree of vertical and horizontal stratification (mixing) in the estuary, help dictate the spatial distribution and movement of estuarine organisms. With local knowledge of these characteristics, however, the entrainment effects of a CWIS could be minimized by adjusting the intake design to areas (e.g., depths) least likely to affect concentrated numbers and species of organisms.

In oceans, nearshore coastal waters are typically the most biologically productive areas. The euphotic zone (zone light available for photosynthesis) typically does not extend beyond the first 100 meters (328 feet) of depth. Therefore, inshore waters are generally more productive due to photosynthetic activity and due to the input from estuaries and runoff of nutrients from land.

There are only limited published data quantifying the locational differences in I&E rates at individual power plants. Some information, however, is available for selected sites. For example,

- For the St. Lucie plant in Florida, EPA Region 4 permitted the use of a once through cooling system instead of closed-cycle cooling by locating the outfall 1,200 feet offshore (with a velocity cap) in the Atlantic Ocean. This approach avoided impacts on the biologically sensitive Indian River estuary.

- In *Entrainment of Fish Larvae and Eggs on the Great Lakes, with Special Reference to the D.C. Cook Nuclear Plant, Southeastern Lake Michigan* (1976), researchers noted that larval abundance is greatest within the area from the 12.2-m (40-ft) contour to shore in Lake Michigan and that the abundance of larvae tends to decrease as one proceeds deeper and farther offshore. This finding led to the suggestion of locating CWISs in deep waters.

- During biological studies near the Fort Calhoun Power Station along the Missouri River, results of transect studies indicated significantly higher fish larvae densities along the cutting bank of the river, adjacent to the station's intake structure. Densities were generally were lowest in the middle of the channel.

3.0 CONCLUSION

As suggested by the technology studies evaluated in this chapter, the technologies presented can substantially reduce impingement mortality and entrainment. With proper design, installation, and operation and maintenance, a facility can realize marked reductions. However, EPA recognizes that there is a high degree of variability in the performance of each technology, which is in part due to the site-specific environmental conditions at a given facility. EPA also recognizes that much of the data cited in this document was collected under a variety of performance standards and study protocols that have arisen over the years since EPA promulgated its last guidance in 1977.

EPA believes that these technologies can meet the performance standards established in today's final rule. While EPA acknowledges that site-specific factors may affect the efficacy of impingement and entrainment reduction technologies, EPA believes that there are a reasonable number of options available from which most facilities may choose to meet the performance standards. EPA also believes that, in cases where one technology can not meet the performance standards alone, a combination of additional intake technologies, operational measures and/or restoration measures can be employed to meet the performance standards.

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Attachment A to Chapter 4

Cooling Water Intake Structure Technology Fact Sheets

Intake Screening Systems	**Fact Sheet No. 1: Single-Entry, Single-Exit Vertical Traveling Screens (Conventional Traveling Screens)**

Description:

The single-entry, single-exit vertical traveling screens (conventional traveling screens) consist of screen panels mounted on an endless belt; the belt rotates through the water vertically. The screen mechanism consists of the screen, the drive mechanism, and the spray cleaning system. Most of the conventional traveling screens are fitted with 3/8-inch mesh and are designed to screen out and prevent debris from clogging the pump and the condenser tubes. The screen mesh is usually supplied in individual removable panels referred to as " baskets" or "trays".

The screen washing system consists of a line of spray nozzles operating at a relatively high pressure of 80 to 120 pounds per square inch (psi). The screens are usually designed to rotate at a single speed. The screens are rotated either at predetermined intervals or when a predetermined differential pressure is reached across the screens based on the amount of debris in the intake waters.

Because of this intermittent operation of the conventional traveling screens, fish can become impinged against the screens during the extended period of time while the screens are stationary and eventually die. When the screens are rotated the fish are removed from the water and then subjected to a high pressure spray; the fish may fall back into the water and become re-impinged or they may be damaged (EPA, 1976, Pagano et *al*, 1977).

Testing Facilities and/or Facilities Using the Technology:

- The conventional traveling screens are the most common screening device presently used at steam electric power plants. Sixty percent of all the facilities use this technology at their intake structure (EEI, 1993).

Research/Operation Findings:

- The conventional single-entry single screen is the most common device resulting in impacts from entrainment and impingement (Fritz, 1980).

Design Considerations:

- The screens are usually designed structurally to withstand a differential pressure across their face of 4 to 8 feet of water.

- The recommended normal maximum water velocity through the screen is about 2.5 feet per second (ft/sec). This recommended velocity is where fish protection is not a factor to consider.

- The screens normally travel at one speed (10 to 12 feet per minute) or two speeds (2.5 to 3 feet per minute and 10 to 12 feet per minute). These speeds can be increased to handle heavy debris load.

Intake Screening Systems	Fact Sheet No. 1: Single-Entry, Single-Exit Vertical Traveling Screens (Conventional Traveling Screens)

Advantages:

- Conventional traveling screens are a proven "off-the-shelf" technology that is readily available.

Limitations:

- Impingement and entrainment are both major problems in this unmodified standard screen installation, which is designed for debris removal not fish protection.

References:

ASCE. Design of Water Intake Structures for Fish Protection. Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulic Division of the American Society of Civil Engineers, New York, NY. 1982.

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Intake Screening Systems	Fact Sheet No. 2: Modified Vertical Traveling Screens

Description:

Modified vertical traveling screens are conventional traveling screens fitted with a collection "bucket" beneath the screen panel. This intake screening system is also called a bucket screen, Ristroph screen, or a Surry Type screen. The screens are modified to achieve maximum recovery of impinged fish by maintaining them in water while they are lifted to a release point. The buckets run along the entire width of the screen panels and retain water while in upward motion. At the uppermost point of travel, water drains from the bucket but impinged organisms and debris are retained in the screen panel by a deflector plate. Two material removal systems are often provided instead of the usual single high pressure one. The first uses low-pressure spray that gently washes fish into a recovery trough. The second system uses the typical high-pressure spray that blasts debris into a second trough. Typically, an essential feature of this screening device is continuous operation which keeps impingement times relatively short (Richards, 1977; Mussalli, 1977; Pagano et al., 1977; EPA , 1976).

Testing Facilities and/or Facilities Using the Technology:

Facilities which have tested the screens include: the Surry Power Station in Virginia (White et al, 1976) (the screens have been in operation since 1974), the Madgett Generating Station in , Wisconsin, the Indian Point Nuclear Generating Station Unit 2 in New York, the Kintigh (formerly Somerset) Generating Station in New Jersey, the Bowline Point Generating Station (King et al, 1977), the Roseton Generating Station in New York, the Danskammer Generating Station in New York (King et al, 1977), the Hanford Generating Plant on the Columbia River in Washington (Page et al, 1975; Fritz, 1980), the Salem Genereating on the Delaware River in New Jersey, and the Monroe Power Plant on the Raisin River in Michigan.

Research/Operation Findings:

Modified traveling screens have been shown to have good potential for alleviating impingement mortality. Some information is available on initial and long-term survival of impinged fish (EPRI, 1999; ASCE, 1982; Fritz, 1980). Specific research and operation findings are listed below:

- In 1986, the operator of the Indian Point Station redesigned fish troughs on the Unit 2 intake to enhance survival. Impingement injuries and mortality were reduced from 53 to 9 percent for striped bass, 64 to14 percent for white perch, 80 to 17 percent for Atlantic tomcod, and 47 to 7 percent for pumpkinseed (EPRI, 1999).

- The Kintigh Generating Station has modified traveling screens with low pressure sprays and a fish return system. After enhancements to the system in 1989, survivals of generally greater than 80 percent have been observed for rainbow smelt, rock bass, spottail shiner, white bass, white perch, and yellow perch. Gizzard shad survivals have been 54 to 65 percent and alewife survivals have been 15 to 44 percent (EPRI, 1999).

Intake Screening Systems	Fact Sheet No. 2: Modified Vertical Traveling Screens

- Long-term survival testing was conducted at the Hanford Generating Plant on the Columbia River (Page et al, 1975; Fritz, 1980). In this study, 79 to 95 percent of the impinged and collected Chinook salmon fry survived for over 96 hours.

- Impingement data collected during the 1970s from Dominion Power's Surry Station indicated a 93.8 percent survival rate of all fish impinged. Bay anchovies had the lowest survival rate of 83 percent. The facility has modified Ristroph screens with low pressure wash and fish return systems (EPRI 1999).

- At the Arthur Kill Station, 2 of 8 screens are modified Ristroph type; the remaining six screens are conventional type. The modified screens have fish collection troughs, low pressure spray washes, fish flap seals, and separate fish collection sluices. 24-hour survival for the unmodified screens averages 15 percent, while the two modified screens have 79 and 92 percent average survival rates (EPRI 1999).

Design Considerations:

- The same design considerations as for Fact Sheet No. 1: Conventional Vertical Traveling Screens apply (ASCE, 1982).

Advantages:

- Traveling screens are a proven "off-the-shelf" technology that is readily available. An essential feature of such screens is continuous operation during periods where fish are being impinged compared to conventional traveling screens which operate on an intermittent basis

Limitations:

- The continuous operation can result in undesirable maintenance problems (Mussalli, 1977).

- Velocity distribution across the face of the screen is generally very poor.

Latent mortality can be high, especially where fragile species are present.

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Intake Screening Systems	**Fact Sheet No. 2: Modified Vertical Traveling Screens**

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Intake Screening Systems	Sheet No. 3: Inclined Single-Entry, Single-Exit Traveling Screens (Angled Screens)

Description:

Inclined traveling screens utilize standard through-flow traveling screens where the screens are set at an angle to the incoming flow as shown in the figure below. Angling the screens improves the fish protection effectiveness of the flush mounted vertical screens since the fish tend to avoid the screen face and move toward the end of the screen line, assisted by a component of the inflow velocity. A fish bypass facility with independently induced flow must be provided. The fish have to be lifted by fish pump, elevator, or conveyor and discharged to a point of safety away from the main water intake (Richards, 1977).

Testing Facilities and/or Facilities Using the Technology:

Angled screens have been tested/used at the following facilities: the Brayton Point Station Unit 4 in Massachusetts; the San Onofre Station in California; and at power plants on Lake Ontario and the Hudson River (ASCE, 1982; EPRI, 1999).

Research/operation Findings:

- Angled traveling screens with a fish return system have been used on the intake for Brayton Point Unit 4. Studies from 1984 through 1986 that evaluated the angled screens showed a diversion efficiency of 76 percent with latent survival of 63 percent. Much higher results were observed excluding bay anchovy. Survival efficiency for the major taxa exhibited an extremely wide range, from 0.1 percent for bay anchovy to 97 percent for tautog. Generally, the taxa fell into two groups: a hardy group with efficiency greater than 65 percent and a sensitive group with efficiency less than 25 percent (EPRI, 1999).

- Southern California Edison at its San Onofre steam power plant had more success with angled louvers than with angled screens. The angled screen was rejected for full-scale use because of the large bypass flow required to yield good guidance efficiencies in the test facility.

Design Considerations:

Many variables influence the performance of angled screens. The following recommended preliminary design criteria were developed in the studies for the Lake Ontario and Hudson River intakes (ASCE, 1982):

- Angle of screen to the waterway: 25 degrees

- Average velocity of approach in the waterway upstream of the screens: 1 foot per second

- Ratio of screen velocity to bypass velocity: 1:1

Intake Screening Systems	**Sheet No. 3: Inclined Single-Entry, Single-Exit Traveling Screens (Angled Screens)**

- Minimum width of bypass opening: 6 inches

Advantages:

- The fish are guided instead of being impinged.
- The fish remain in water and are not subject to high pressure rinsing.

Limitations:

- Higher cost than the conventional traveling screen
- Angled screens need a stable water elevation.
- Angled screens require fish handling devices with independently induced flow (Richards, 1977).

References:

ASCE. Design of Water Intake Structures for Fish Protection. Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulic Division of the American Society of Civil Engineers, New York, NY. 1982.

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Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

Description:

Fine mesh screens are used for screening eggs, larvae, and juvenile fish from cooling water intake systems. The concept of using fine mesh screens for exclusion of larvae relies on gentle impingement on the screen surface or retention of larvae within the screening basket, washing of screen panels or baskets to transfer organisms into a sluiceway, and then sluicing the organisms back to the source waterbody (Sharma, 1978). Fine mesh with openings as small as 0.5 millimeters (mm) has been used depending on the size of the organisms to be protected. Fine mesh screens have been used on conventional traveling screens and single-entry, double-exit screens. The ultimate success of an installation using fine mesh screens is contingent on the application of satisfactory handling and recovery facilities to allow the safe return of impinged organisms to the aquatic environment (Pagano et al, 1977).

Testing Facilities and/or Facilities Using the Technology:

The Big Bend Power Plant along Tampa Bay area has an intake canal with 0.5-mm mesh Ristroph screens that are used seasonally on the intakes for Units 3 and 4. At the Brunswick Power Plant in North Carolina, fine mesh used seasonally on two of four screens has shown 84 percent reduction in entrainment compared to the conventional screen systems.

Research/Operation Findings:

- During the mid-1980s when the screens were initially installed at Big Bend, their efficiency in reducing impingement and entrainment mortality was highly variable. The operator evaluated different approach velocities and screen rotational speeds. In addition, the operator recognized that frequent maintenance (manual cleaning) was necessary to avoid biofouling. By 1988, system performance had improved greatly. The system's efficiency in screening fish eggs (primarily drums and bay anchovy) exceeded 95 percent with 80 percent latent survival for drum and 93 percent for bay anchovy. For larvae (primarily drums, bay anchovies, blennies, and gobies), screening efficiency was 86 percent with 65 percent latent survival for drum and 66 percent for bay anchovy. Note that latent survival in control samples was also approximately 60 percent (EPRI, 1999).

- At the Brunswick Power Plant in North Carolina, fine mesh screen has led to 84 percent reduction in entrainment compared to the conventional screen systems. Similar results were obtained during pilot testing of 1-mm screens at the Chalk Point Generating Station in Maryland. At the Kintigh Generating Station in New Jersey, pilot testing indicated 1-mm screens provided 2 to 35 times reductions in entrainment over conventional 9.5-mm screens (EPRI, 1999).

- Tennessee Valley Authority (TVA) pilot-scale studies performed in the 1970s showed reductions in striped bass larvae entrainment up to 99 percent using a 0.5-mm screen and 75 and 70 percent for 0.97-mm and 1.3-mm screens. A full-scale

Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

test by TVA at the John Sevier Plant showed less than half as many larvae entrained with a 0.5-mm screen than 1.0 and 2.0-mm screens combined (TVA, 1976).

- Preliminary results from a study initiated in 1987 by the Central Hudson and Gas Electric Corporation indicated that the fine mesh screens collect smaller fish compared to conventional screens; mortality for the smaller fish was relatively high, with similar survival between screens for fish in the same length category (EPRI, 1989).

Design Considerations:

Biological effectiveness for the whole cycle, from impingement to survival in the source water body, should be investigated thoroughly prior to implementation of this option. This includes:

- The intake velocity should be low so that if there is any impingement of larvae on the screens, it is gentle enough not to result in damage or mortality.
- The wash spray for the screen panels or the baskets should be low-pressure so as not to result in mortality.
- The sluiceway should provide smooth flow so that there are no areas of high turbulence; enough flow should be maintained so that the sluiceway is not dry at any time.
- The species life stage, size and body shape and the ability of the organisms to withstand impingement should be considered with time and flow velocities.
- The type of screen mesh material used is important. For instance, synthetic meshes may be smooth and have a low coefficient of friction, features that might help to minimize abrasion of small organisms. However, they also may be more susceptible to puncture than metallic meshes (Mussalli, 1977).

Advantages:

- There are indications that fine mesh screens reduce entrainment.

Limitations:

- Fine mesh screens may increase the impingement of fish, i.e., they need to be used in conjunction with properly designed and operated fish collection and return systems.
- Due to the small screen openings, these screens will clog much faster than those with conventional 3/8-inch mesh. Frequent maintenance is required, especially in marine environments.

Intake Screening Systems	Fact Sheet No.4: Fine Mesh Screens Mounted on Traveling Screens

References:

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Passive Intake Systems	Fact Sheet No. 5: Wedgewire Screens

Description:

Wedgewire screens are designed to reduce entrainment by physical exclusion and by exploiting hydrodynamics. Physical exclusion occurs when the mesh size of the screen is smaller than the organisms susceptible to entrainment. Hydrodynamic exclusion results from maintenance of a low through-slot velocity, which, because of the screen's cylindrical configuration, is quickly dissipated, thereby allowing organisms to escape the flow field (Weisberd et al, 1984). The screens can be fine or wide mesh. The name of these screens arise from the triangular or "wedge" cross section of the wire that makes up the screen. The screen is composed of wedgewire loops welded at the apex of their triangular cross section to supporting axial rods presenting the base of the cross section to the incoming flow (Pagano et al, 1977). A cylindrical wedgewire screen is shown in the figure below. Wedgewire screens are also called profile screens or Johnson screens.

Testing Facilities and/or Facilities Using the Technology:

Wide mesh wedgewire screens are used at two large power plants, Eddystone and Campbell. Smaller facilities with wedgewire screens include Logan and Cope with fine mesh and Jeffrey with wide mesh (EPRI 1999).

Research/Operation Findings:

- In-situ observations have shown that impingement is virtually eliminated when wedgewire screens are used (Hanson, 1977; Weisberg et al, 1984).
- At Campbell Unit 3, impingement of gizzard shad, smelt, yellow perch, alewife, and shiner species is significantly lower than Units 1 and 2 that do not have wedgewire screens (EPRI, 1999).
- The cooling water intakes for Eddystone Units 1 and 2 were retrofitted with wedgewire screens because over 3 million fish were reportedly impinged over a 20-month period. The wedgewire screens have generally eliminated impingement at Eddystone (EPRI, 1999).
- Laboratory studies (Heuer and Tomljanovitch, 1978) and prototype field studies (Lifton, 1979; Delmarva Power and Light, 1982; Weisberg et al, 1983) have shown that fine mesh wedgewire screens reduce entrainment.
- One study (Hanson, 1977) found that entrainment of fish eggs (striped bass), ranging in diameter from 1.8 mm to 3.2 mm, could be eliminated with a cylindrical wedgewire screen incorporating 0.5 mm slot openings. However, striped bass larvae, measuring 5.2 mm to 9.2 mm were generally entrained through a 1 mm slot at a level exceeding 75 percent within one minute of release in the test flume.

Passive Intake Systems	Fact Sheet No. 5: Wedgewire Screens

- At the Logan Generating Station in New Jersey, monitoring shows shows 90 percent less entrainment of larvae and eggs through the 1 mm wedgewire screen then conventional screens. In situ testing of1 and 2-mm wedgewire screens was performed in the St. John River for the Seminole Generating Station Units 1 and 2 in Florida in the late 1970s. This testing showed virtually no impingement and 99 and 62 percent reductions in larvae entrainment for the 1-mm and 2-mm screens, respectively, over conventional screen (9.5 mm) systems (EPRI, 1999).

Design Considerations:

- To minimize clogging, the screen should be located in an ambient current of at least 1 feet per second (ft/sec).

- A uniform velocity distribution along the screen face is required to minimize the entrapment of motile organisms and to minimize the need of debris backflushing.

- In northern latitudes, provisions for the prevention of frazil ice formation on the screens must be considered.

- Allowance should be provided below the screens for silt accumulation to avoid blockage of the water flow (Mussalli et al, 1980).

Advantages:

C Wedgewire screens have been demonstrated to reduce impingement and entrainment in laboratory and prototype field studies.

Limitations:

- The physical size of the screening device is limiting in most passive systems, thus, requiring the clustering of a number of screening units. Siltation, biofouling and frazil ice also limit areas where passive screens such as wedgewire can be utilized.

- Because of these limitations, wedgewire screens may be more suitable for closed-cycle make-up intakes than once-through systems. Closed-cycle systems require less flow and fewer screens than once-through intakes; back-up conventional screens can therefore be used during maintenance work on the wedge-wire screens (Mussalli et al, 1980).

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Passive Intake Systems	**Fact Sheet No. 5: Wedgewire Screens**

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Passive Intake Systems	Fact Sheet No. 6: Perforated Pipes

Description:

Perforated pipes draw water through perforations or slots in a cylindrical section placed in the waterway. The term "perforated" is applied to round perforations and elongated slots as shown in the figure below. The early technology was not efficient: velocity distribution was poor, it served specifically to screen out detritus, and was not used for fish protection (ASCE, 1982). Inner sleeves have been added to perforated pipes to equalize the velocities entering the outer perforations. Water entering a single perforated pipe intake without an internal sleeve will have a wide range of entrance velocities and the highest will be concentrated at the supply pipe end. These systems have been used at locations requiring small amounts of water such as make-up water. However, experience at steam electric plants is very limited (Sharma, 1978).

Testing Facilities And/or Facilities Using the Technology:

Nine steam electric units in the U.S. use perforated pipes. Each of these units uses closed-cycle cooling systems with relatively low make-up intake flow ranging from 7 to 36 MGD (EEI, 1993).

Research/Operation Findings:

- Maintenance of perforated pipe systems requires control of biofouling and removal of debris from clogged screens.
- For withdrawal of relatively small quantities of water, up to 50,000 gpm, the perforated pipe inlet with an internal perforated sleeve offers substantial protection for fish. This particular design serves the Washington Public Power Supply System on the Columbia River (Richards, 1977).
- No information is available on the fate of the organisms impinged at the face of such screens.

Design Considerations:

The design of these systems is fairly well established for various water intakes (ASCE, 1982).

Advantages:

The primary advantage is the absence of a confined channel in which fish might become trapped.

Limitations:

Clogging, frazil ice formation, biofouling and removal of debris limit this technology to small flow withdrawals.

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Passive Intake Systems	Fact Sheet No. 6: Perforated Pipes

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Passive intake Systems	Fact Sheet No. 7: Porous Dikes/Leaky Dams

Description:

Porous dikes, also known as leaky dams or leaky dikes, are filters resembling a breakwater surrounding a cooling water intake. The core of the dike consists of cobble or gravel, which permits free passage of water. The dike acts both as a physical and a behavioral barrier to aquatic organisms and is depicted in the figure below. The filtering mechanism includes a breakwater or some other type of barrier and the filtering core (Fritz, 1980). Tests conducted to date have indicated that the technology is effective in excluding juvenile and adult fish. However, its effectiveness in screening fish eggs and larvae is not established (ASCE, 1982).

Testing Facilities and/or Facilities Using the Technology:

- Two facilities which are both testing facilities and have used the technology are: the Point Beach Nuclear Plant in Wisconsin and the Baily Generating Station in Indiana (EPRI, 1985). The Brayton Point Generating Station in Massachusetts has also tested the technology.

Research/Operation Findings:

- Schrader and Ketschke (1978) studied a porous dike system at the Lakeside Plant on Lake Michigan and found that numerous fish penetrated large void spaces, but for most fish accessibility was limited.

- The biological effectiveness of screening of fish larvae and the engineering practicability have not been established (ASCE, 1982).

- The size of the pores in the dike dictates the degree of maintenance due to biofouling and clogging by debris.

- Ice build-up and frazil ice may create problems as evidenced at the Point Beach Nuclear Plant (EPRI, 1985).

Design Considerations:

- The presence of currents past the dike is an important factor which may probably increase biological effectiveness.

- The size of pores in the dike determines the extent of biofouling and clogging by debris (Sharma, 1978).

- Filtering material must be of a size that permits free passage of water but still prevents entrainment and impingement.

Passive intake Systems	Fact Sheet No. 7: Porous Dikes/Leaky Dams

Advantages:

- Dikes can be used at marine, fresh water, and estuarine locations.

Limitations:

- The major problem with porous dikes comes from clogging by debris and silt, and from fouling by colonization of fish and plant life.
- Backflushing, which is often used by other systems for debris removal, is not feasible at a dike installation.
- Predation of organisms screened at these dikes may offset any biological effectiveness (Sharma, 1978).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 8: Louver Systems

Description:

Louver systems are comprised of a series of vertical panels placed at an angle to the direction of the flow (typically 15 to 20 degrees). Each panel is placed at an angle of 90 degrees to the direction of the flow (Hadderingh, 1979). The louver panels provide an abrupt change in both the flow direction and velocity (see figure below). This creates a barrier, which fish can immediately sense and will avoid. Once the change in flow/velocity is sensed by fish, they typically align with the direction of the current and move away laterally from the turbulence. This behavior further guides fish into a current created by the system, which is parallel to the face of the louvers. This current pulls the fish along the line of the louvers until they enter a fish bypass or other fish handling device at the end of the louver line. The louvers may be either fixed or rotated similar to a traveling screen. Flow straighteners are frequently placed behind the louver systems.

These types of barriers have been very successful and have been installed at numerous irrigation intakes, water diversion projects, and steam electric and hydroelectric facilities. It appears that this technology has, in general, become accepted as a viable option to divert juvenile and adult fish.

Testing Facilities and/or Facilities Using the Technology:

Louver barrier devices have been tested and/or are in use at the following facilities: the California Department of Water Resource's Tracy Pumping Plant; the California Department of Fish and Game's Delta Fish Protective Facility in Bryon; the Conte Anadromous Fish Research Center in Massachusetts, and the San Onofre Nuclear Generating Station in California (EPA, 1976; EPRI, 1985; EPRI, 1999). In addition, three other plants also have louvers at their facilities: the Ruth Falls Power Plant in Nova Scotia, the Nine Mile Point Nuclear Power Station on Lake Erie, and T.W. Sullivan Hydroelectric Plant in Oregon. Louvers have also been tested at the Ontario Hydro Laboratories in Ontario, Canada (Ray et al, 1976).

Research/Operation Findings:

Research has shown the following generalizations to be true regarding louver barriers:
1) the fish separation performance of the louver barrier decreases with an increase in the velocity of the flow through the barrier; 2) efficiency increases with fish size (EPA, 1976; Hadderingh, 1979); 3) individual louver misalignment has a beneficial effect on the efficiency of the barrier; 4) the use of center walls provides the fish with a guide wall to swim along thereby improving efficiency (EPA, 1976); and 5) the most effective slat spacing and array angle to flow depends upon the size, species and ability of the fish to be diverted (Ray et al, 1976).

In addition, the following conclusions were drawn during specific studies:

- Testing of louvered intake structures offshore was performed at a New York facility. The louvers were spaced 10 inches apart to minimize clogging. The array was angled at 11.5 percent to the flow. Center walls were provided for fish guidance to the bypass. Test species included alewife and rainbow smelt. The mean efficiency predicted was between 22 and 48 percent (Mussalli 1980).

Fish Diversion or Avoidance Systems	**Fact Sheet No. 8: Louver Systems**

- During testing at the Delta Facility's intake in Byron California, the design flow was 6,000 cubic feet per second (cfs), the approach velocity was 1.5 to 3.5 feet per second (ft/sec), and the bypass velocities were 1.2 to 1.6 times the approach velocity. Efficiencies were found to drop with an increase in velocity through the louvers. For example, at 1.5 to 2 ft/sec the efficiency was 61 percent for 15 millimeter long fish and 95 percent for 40 millimeter fish. At 3.5 ft/sec, the efficiencies were 35 and 70 percent (Ray et al. 1976).
- The efficiency of a louver device is highly dependent upon the length and swimming performance of a fish. Efficiencies of lower than 80 percent have been seen at facilities where fish were less than 1 to 1.6 inches in length (Mussalli, 1980).
- In the 1990s, an experimental louver bypass system was tested at the USGS' Conte Anadromous Fish Research Center in Massachusetts. This testing showed guidance efficiencies for Connecticut River species of 97 percent for a "wide array" of louvers and 100 percent for a "narrow array" (EPRI, 1999).
- At the Tracy Fish Collection Facility located along the San Joaquin River in California, testing was performed from 1993 and 1995 to determine the guidance efficiency of a system with primary and secondary louvers. The results for green and white sturgeon, American shad, splittail, white catfish, delta smelt, Chinook salmon, and striped bass showed mean diversion efficiencies ranging from 63 (splittail) to 89 percent (white catfish) (EPRI, 1999).
- In 1984 at the San Onofre Station, a total of 196,978 fish entered the louver system with 188,583 returned to the waterbody and 8,395 impinged. In 1985, 407,755 entered the louver system with 306,200 returned and 101,555 impinged. Therefore, the guidance efficiencies in 1984 and 1985 were 96 and 75 percent, respectively. However, 96-hour survival rates for some species, i.e., anchovies and croakers, were 50 percent or less. Louvers were originally considered for use at San Onofre because of 1970s pilot testing at the Redondo Beach Station in California where maximum guidance efficiencies of 96-100 percent were observed. (EPRI, 1999)
- At the Maxwell Irrigation Canal in Oregon, louver spacing was 5.0 cm with a 98 percent efficiency of deflecting immature steelhead and above 90 percent efficiency for the same species with a louver spacing of 10.8 cm.
- At the Ruth Falls Power Plant in Nova Scotia, the results of a five-year evaluation for guiding salmon smelts showed that the optimum spacing was to have wide bar spacing at the widest part of the louver with a gradual reduction in the spacing approaching the bypass. The site used a bypass:approach velocity ratio of 1.0 : 1.5 (Ray et al, 1976).
- Coastal species in California were deflected optimally (Schuler and Larson, 1974 in Ray et al, 1976) with 2.5 cm spacing of the louvers, 20 degree louver array to the direction of flow and approach velocities of 0.6 cm per second.
- At the T.W. Sullivan Hydroelectric Plant along the Williamette River in Oregon, the

Fish Diversion or Avoidance Systems	Fact Sheet No. 8: Louver Systems

louver system is estimated to be 92 percent effective in diverting spring Chinook, 82 percent for all Chinook, and 85 percent for steelhead. The system has been optimized to reduce fish injuries such that the average injury occurrence is only 0.44 percent (EPRI, 1999).

Design Considerations:

The most important parameters of the design of louver barriers include the following:

- The angle of the louver vanes in relation to the channel velocity ,
- The spacing between the louvers which is related to the size of the fish,
- Ratio of bypass velocity to channel velocity,
- Shape of guide walls,
- Louver array angles, and
- Approach velocities.

Site-specific modeling may be needed to take into account species-specific considerations and optimize the design efficiency (EPA, 1976; O'Keefe, 1978).

Advantages:

- Louver designs have been shown to be very effective in diverting fish (EPA, 1976).

Limitations:

- The costs of installing intakes with louvers may be substantially higher than other technologies due to design costs and the precision required during construction.
- Extensive species-specific field testing may be required.
- The shallow angles required for the efficient design of a louver system require a long line of louvers increasing the cost as compared to other systems (Ray et al, 1976).
- Water level changes must be kept to a minimum to maintain the most efficient flow velocity.

Fish Diversion or Avoidance Systems	Fact Sheet No. 8: Louver Systems

- Fish handling devices are needed to take fish away from the louver barrier.

- Louver barriers may, or may not, require additional screening devices for removing solids from the intake waters. If such devices are required, they may add a substantial cost to the system (EPA, 1976).

- Louvers may not be appropriate for offshore intakes (Mussalli, 1980).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 9: Velocity Cap

Description:

A velocity cap is a device that is placed over vertical inlets at offshore intakes (see figure below). This cover converts vertical flow into horizontal flow at the entrance into the intake. The device works on the premise that fish will avoid rapid changes in horizontal flow. Fish do not exhibit this same avoidance behavior to the vertical flow that occurs without the use of such a device. Velocity caps have been implemented at many offshore intakes and have been successful in decreasing the impingement of fish.

Testing Facilities And/or Facilities Using the Technology:

The available literature (EPA, 1976; Hanson, 1979; and Pagano et al, 1977) states that velocity caps have been installed at offshore intakes in Southern California, the Great Lakes Region, the Pacific Coast, the Caribbean and overseas; however, exact locations are not specified.

Velocity caps are known to have been installed at the El Segundo, Redondo Beach, and Huntington Beach Steam Electric Stations and the San Onofre Nuclear Generation Station in Southern California (Mussalli, 1980; Pagano et al, 1977; EPRI, 1985).

Model tests have been conducted by a New York State Utility (ASCE, 1982) and several facilities have installed velocity caps in the New York State /Great Lakes Area including the Nine Mile Point Nuclear Station, the Oswego Steam Electric Station, and the Kintigh Generating Station (EPRI, 1985).

Additional known facilities with velocity caps include the Edgewater Generation Station in Wisconsin, the Seabrook Power Plant in New Hampshire, and the Nanticoke Thermal Generating Station in Ontario, Canada (EPRI, 1985).

Research/Operation Findings:

- Horizontal velocities within a range of 0.5 to 1.5 feet per second (ft/sec) did not significantly affect the efficiency of a velocity cap tested at a New York facility; however, this design velocity may be specific to the species present at that site (ASCE, 1982).

- Preliminary decreases in fish entrapment averaging 80 to 90 percent were seen at the El Segundo and Huntington Beach Steam Electric Plants (Mussalli, 1980).

- Performance of the velocity cap may be associated with cap design and the total volumes of water flowing into the cap rather than to the critical velocity threshold of the cap (Mussalli, 1980).

Design Considerations:

- Designs with rims around the cap edge prevent water from sweeping around the

Fish Diversion or Avoidance Systems	Fact Sheet No. 9: Velocity Cap

edge causing turbulence and high velocities, thereby providing more uniform horizontal flows (EPA, 1976; Mussalli, 1980).

- Site-specific testing should be conducted to determine appropriate velocities to minimize entrainment of particular species in the intake (ASCE, 1982).
- Most structures are sized to achieve a low intake velocity between 0.5 and 1.5 ft/sec to lessen the chances of entrainment (ASCE, 1982).
- Design criteria developed for a model test conducted by Southern California Edison Company used a velocity through the cap of 0.5 to 1.5 ft/sec; the ratio of the dimension of the rim to the height of the intake areas was 1.5 to 1 (ASCE, 1982; Schuler, 1975).

Advantages:

- Efficiencies of velocity caps on West Coast offshore intakes have exceeded 90 percent (ASCE, 1982).

Limitations:

- Velocity caps are difficult to inspect due to their location under water (EPA, 1976).
- In some studies, the velocity cap only minimized the entrainment of fish and did not eliminate it. Therefore, additional fish recovery devices are be needed in when using such systems (ASCE, 1982; Mussalli, 1980).
- Velocity caps are ineffective in preventing passage of non-motile organisms and early life stage fish (Mussalli, 1980).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 10: Fish Barrier Nets

Description:

Fish barrier nets are wide mesh nets, which are placed in front of the entrance to an intake structure (see figure below). The size of the mesh needed is a function of the species that are present at a particular site. Fish barrier nets have been used at numerous facilities and lend themselves to intakes where the seasonal migration of fish and other organisms require fish diversion facilities for only specific times of the year.

Testing Facilities And/or Facilities Using the Technology:

The Bowline Point Generating Station, the J.P. Pulliam Power Plant in Wisconsin, the Ludington Storage Plant in Michigan, and the Nanticoke Thermal Generating Station in Ontario use barrier nets (EPRI, 1999).

Barrier Nets have been tested at the Detroit Edison Monroe Plant on Lake Erie and the Chalk Point Station on the Patuxent River in Maryland (ASCE, 1982; EPRI, 1985). The Chalk Point Station now uses barrier nets seasonally to reduce fish and Blue Crab entry into the intake canal (EPRI, 1985). The Pickering Generation Station in Ontario evaluated rope nets in 1981 illuminated by strobe lights (EPRI, 1985).

Research/Operation Findings:

- At the Bowline Point Generating Station in New York, good results (91 percent impingement reductions) have been realized with a net placed in a V arrangement around the intake structure (ASCE, 1982; EPRI, 1999).
- In 1980, a barrier net was installed at the J.R. Whiting Plant (Michigan) to protect Maumee Bay. Prior to net installation, 17,378,518 fish were impinged on conventional traveling screens. With the net, sampling in 1983 and 84 showed 421,978 fish impinged (97 percent effective), sampling in 1987 showed 82,872 fish impinged (99 percent effective), and sampling in 1991 showed 316,575 fish impinged (98 percent effective) (EPRI, 1999).
- Nets tested with high intake velocities (greater than 1.3 feet per second) at the Monroe Plant have clogged and subsequentially collapsed. This has not occurred at facilities where the velocities are 0.4 to 0.5 feet per second (ASCE, 1982).
- Barrier nets at the Nanticoke Thermal Generating Station in Ontario reduced intake of fish by 50 percent (EPRI, 1985).
- The J.P Pulliam Generating Station in Wisconsin uses dual barrier nets (0.64 centimeters stretch mesh) to permit net rotation for cleaning. Nets are used from April to December or when water temperatures go above 4 degrees Celsius. Impingement has been reduced by as much as 90 percent. Operating costs run about $5,000 per year, and nets are replaced every two years at $2,500 per net (EPRI, 1985).
- The Chalk Point Station in Maryland realized operational costs of $5,000-10,000 per

Fish Diversion or Avoidance Systems	Fact Sheet No. 10: Fish Barrier Nets

year with the nets being replaced every two years (EPRI, 1985). However, crab impingement has been reduced by 84 percent and overall impingrment liability has been reduced from $2 million to $140,000 (EPRI, 1999).

- The Ludington Storage Plant (Michigan) provides water from Lake Michigan to a number of power plant facilities. The plant has a 2.5-mile long barrier net that has successfully reduced impingement and entrainment. The overall net effectiveness for target species (five salmonids, yellow perch, rainbow smelt, alewife, and chub) has been over 80 percent since 1991 and 96 percent since 1995. The net is deployed from mid-April to mid-October, with storms and icing preventing use during the remainder of the year (EPRI, 1999).

Design Considerations:

- The most important factors to consider in the design of a net barrier are the site-specific velocities and the potential for clogging with debris (ASCE, 1982).

- The size of the mesh must permit effective operations, without excessive clogging. Designs at the Bowline Point Station in New York have 0.15 and 0.2 inch openings in the mesh nets, while the J.P. Pulliam Plant in Wisconsin has 0.25 inch openings (ASCE, 1982).

Advantages:

- Net barriers, if operating properly, should require very little maintenance.

- Net barriers have relatively little cost associated with them.

Limitations:

- Net barriers are not effective for the protection of the early life stages of fish or zooplankton (ASCE, 1982).

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Fish Diversion or Avoidance Systems	Fact Sheet No. 11: Aquatic Filter Barrier Systems

Description:

Aquatic filter barrier systems are barriers that employ a filter fabric designed to allow for passage of water into a cooling water intake structure, but exclude aquatic organisms. These systems are designed to be placed some distance from the cooling water intake structure within the source waterbody and act as a filter for the water that enters into the cooling water system. These systems may be floating, flexible, or fixed. Since these systems generally have such a large surface area, the velocities that are maintained at the face of the permeable curtain are very low. One company, Gunderboom, Inc., has a patented full-water-depth filter curtain comprised of polyethylene or polypropylene fabric that is suspended by flotation billets at the surface of the water and anchored to the substrate below. The curtain fabric is manufactured as a matting of minute unwoven fibers with an apparent opening size of 20 microns. The Gunderboom Marine/Aquatic Life Exclusion System (MLES)™ also employs an automated "air burst"™ technology to periodically shake the material and pass air bubbles through the curtain system to clean it of sediment buildup and release any other material back in to the water column**.**

Testing Facilities and/or Facilities Using the Technology:

- Gunderboom MLES ™ have been tested and are currently installed on a seasonal basis at Unit 3 of the Lovett Station in New York**.** Prototype testing of the Gunderboom system began in 1994 as a means of lowering ichthyoplankton entrainment at Unit 3. This was the first use of the technology at a cooling water intake structure. The Gunderboom tested was a single layer fabric. Material clogging resulted in loss of filtration capacity and boom submergence within 12 hours of deployment. Ichthyoplankton monitoring while the boom was intact indicated an 80 percent reduction in entrainable organisms (Lawler, Matusky, and Skelly Engineers, 1996).

- A Gunderboom MLES ™ was effectively deployed at the Lovett Station for 43 days in June and July of 1998 using an Air-Burst cleaning system and newly designed deadweight anchoring system. The cleaning system coupled with a perforated material proved effective at limiting sediment on the boom, however it required an intensive operational schedule (Lawler, Matusky, and Skelly Engineers, 1998).

- A 1999 study was performed on the Gunderboom MLES ™ at the Lovett Station in New York to qualitatively determine the characteristics of the fabric with respect to the impingement of ichthyoplankton at various flow regimes. Conclusions were that the viability of striped bass eggs and larvae were not affected (Lawler, Matusky, and Skelly Engineers, 1999).

- Ichthyoplankton sampling at Unit 3 (with Gunderboom MLES ™ deployed) and Unit 4 (without Gunderboom) in May through August 2000 showed an overall effectiveness of approximately 80 percent. For juvenile fish, the density at Unit 3 was 58 percent lower. For post yolk-sac larvae, densities were 76 percent lower. For yolk-sac larvae, densities were 87 percent lower (Lawler, Matusky & Skelly

Fish Diversion or Avoidance Systems	Fact Sheet No. 11: Aquatic Filter Barrier Systems

Engineers 2000).

Research/operation Findings:

Extensive testing of the Gunderboom MLES ™ has been performed at the Lovett Station in New York. Anchoring, material, cleaning, and monitoring systems have all been redesigned to meet the site-specific conditions in the waterbody and to optimize the operations of the Gunderboom. Although this technology has been implemented at only one cooling water intake structure, it appears to be a promising technology to reduce impingement and entrainment impacts. It is also being evaluated for use at the Contre Costa Power Plant in California.

Design Considerations:

The most important parameters in the design of a Gunderboom ® Marine/Aquatic Life Exclusion System include the following (Gunderboom, Inc. 1999):

- Size of booms designed for 3-5 gpm per square foot of submerged fabric. Flows greater than 10-12 gallons per minute.
- Flow-through velocity is approximately 0.02 ft/s.
- Performance monitoring and regular maintenance.

Advantages:

- Can be used in all waterbody types.
- All larger and nearly all other organisms can swim away from the barrier because of low velocities.
- Little damage is caused to fish eggs and larvae if they are drawn up against the fabric.
- Modulized panels may easily be replaced.
- Easily deployed for seasonal use.
- Biofouling appears to be controllable through use of the sparging system.
- Impinged organisms released back into the waterbody.
- Benefits relative to cost appear to be very promising, but remain unproven to date.
- Installation can occur with no or minimal plant shutdown.

Fish Diversion or Avoidance Systems	Fact Sheet No. 11: Aquatic Filter Barrier Systems

Limitations:

- Currently only a proven technology for this application at one facility.
- Extensive waterbody-specific field testing may be required.
- May not be appropriate for conditions with large fluctuations in ambient flow and heavy currents and wave action.
- High level of maintenance and monitoring required.
- Recent studies have asserted that biofouling can be significant**.**
- Higher flow facilities may require very large surface areas; could interfere with other waterbody uses.

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Fish Diversion or Avoidance Systems	Fact Sheet No. 12: Sound Barriers

Description:

Sound barriers are non-contact barriers that rely on mechanical or electronic equipment that generates various sound patterns to elicit avoidance responses in fish. Acoustic barriers are used to deter fish from entering industrial water intakes and power plant turbines. Historically, the most widely-used acoustical barrier is a pneumatic air gun or "popper." The pneumatic air gun is a modified seismic device which produces high-amplitude, low-frequency sounds to exclude fish. Closely related devices include "fishdrones" and “fishpulsers" (also called "hammers”). The fishdrone produces a wider range of sound frequencies and amplitudes than the popper. The fishpulser produces a repetitive sharp hammering sound of low-frequency and high-amplitude. Both instruments have ahd limited effectiveness in the field (EPRI, 1995; EPRI, 1989; Hanson, et al., 1977; EPA, 1976; Taft, et al., 1988; ASCE, 1992).

Researchers have generally been unable to demonstrate or apply acoustic barriers as fish deterrents, even though fish studies showed that fish respond to sound, because the response varies as a function of fish species, age, and size as well as environmental factors at specific locations. Fish may also acclimate to the sound patterns used (EPA, 1976; Taft et al., 1988; EPRI, 1995; Ray at al., 1976; Hadderingh, 1979; Hanson et al., 1977; ASCE, 1982).

Since about 1989, the application of highly refined sound generation equipment originally developed for military use (e.g., sonar in submarines) has greatly advanced acoustic barrier technology. Ibis technology has the ability to generate a wide array of frequencies, patterns, and volumes, which are monitored and controlled by computer. Video and computer monitoring provide immediate feedback on the effectiveness of an experimental sound pattern at a given location. In a particular environment, background sounds can be accounted for, target fish species or fish populations can quickly be characterized, and the most effective sound pattern can be selected (Menezes, at al., 1991; Sonalysts, Inc.).

Testing Facilities and/or Facilities with Technology in Use:

No fishpulsers and pneumatic air guns are currently in use at power plant water intakes.

Research facilities that have completed studies or have on-going testing involving fishpulsers or pneumatic air guns include the Ludington Storage Plant on Lake Michigan; Nova Scotia Power; the Hells Gate Hydroelectric Station on the Black River; the Annapolis Generating Station on the Bay of Fundy; Ontario Hydro's Pickering Nuclear Generating station; the Roseton Generating Station in New York; the Seton Hydroelectric Station in British Columbia; the Surry Power Plant in Virginia; the Indian Point Nuclear Generating Station Unit 3 in New York; and the U.S. Army Corps of Engineers on the Savannah River (EPRI, 1985; EPRI, 1989; EPRI, 1988; and Taft, et al., 1998).

Updated acoustic technology developed by Sonalysts, Inc. has been applied at the James A. Fitzpatrick Nuclear Power Plant in New York on Lake Ontario; the Vernon Hydroelectric plant on the Connecticut River (New England Power Company, 1993; Menezes, et al., 1991; personal communication with Sonalysts, Inc., by SAIC, 1993); and in a quarry in

Fish Diversion or Avoidance Systems	Fact Sheet No. 12: Sound Barriers

Verplank, New York (Dunning, et al., 1993).

Research/operation Findings:

- Most pre-1976 research was related to fish response to sound rather than on field applications of sound barriers (EPA, 1976; Ray et al., 1976; Uziel, 1980; Hanson, et al., 1977).

- Before 1986, no acoustic barriers were deemed reliable for field use. Since 1986, several facilities have tried to use pneumatic poppers with limited successes. Even in combination with light barriers and air bubble barriers, poppers and fishpulsers, were ineffective for most intakes (Taft and Downing, 1988; EPRI, 1985; Patrick, et al., 1988; EPRI, 1989; EPRI, 1988; Taft, et al., 1988; McKinley and Patrick, 1998; Chow, 1981).

- A 1991 full-scale 4-month demonstration at the James A. FitzPatrick (JAF) Nuclear Power Plant in New York on Lake Ontario showed that the Sonalysts, Inc. FishStartle System reduced alewife impingement by 97 percent as compared to a control power plant located 1 mile away. (Ross, et al., 1993; Menezes, et al., 1991). JAF experienced a 96 percent reduction compared to fish impingement when the acoustic system was not in use. A 1993 3-month test of the system at JAF was reported to be successful, i.e., 85 percent reduction in alewife impingement. (Menezes, et al., 1991; EPRI, 1999).

- In tests at the Pickering Station in Ontario, poppers were found to be effective in reducing alewife impingement and entrainment by 73 percent in 1985 and 76 percent in 1986. No benefits were observed for rainbow smelt and gizzard shad. Sound provided little or no deterrence for any species at the Roseton Generating Station in New York.

- During marine construction of Boston's third Harbor Tunnel in 1992, the Sonalysts, Inc. FishStartle System was used to prevent shad, blueback herring, and alewives from entering underwater blasting areas during the fishes' annual spring migration. The portable system was used prior to each blast to temporarily deter fish and allow periods of blastmg as necessary for the construction of the tunnel (personal communication to SAIC from M. Curtin, Sonalysts, Inc., September 17, 1993).

- In fall 1992, the Sonalysts, Inc. FishStartle System was tested in a series of experiments conducted at the Vernon Hydroelectric plant on the Connecticut River. Caged juvenile shad were exposed to various acoustical signals to see which signals elicited the strongest reactions. Successful in situ tests involved applying the signals with a transducer system to divert juvenile shad from the forebay to a bypass pipe. Shad exhibited consistent avoidance reactions to the signals and did not show evidence of acclimation to the source (New England Power Company, 1993).

Design Considerations:

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- Sonalysts Inc.'s FishStartle system uses frequencies between 15 hertz to130 kilohertz at sound pressure levels ranging from 130 to 206+ decibels referenced to one micropascal (dB//uPa). To develop a site-specific FishStartle program, a test program using frequencies in the low frequency portion of the spectrum between 25 and 3300 herz were used. Fish species tested by Sonalysts, Inc. include white perch, striped bass, atlantic tomcod, spottail shiner, and golden shiner (Menezes et al., 1991).

- Sonalysts' FishStartle system used fixed programming contained on Erasable Programmable Read Only Memory (EPROM) micro circuitry. For field applications, a system was developed using IBM PC compatible software. Sonalysts' FishStartle system includes a power source, power amplifiers, computer controls and analyzer in a control room, all of which are connected to a noise hydrophone in the water. The system also uses a television monitor and camera controller that is linked to an underwater light and camera to count fish and evaluate their behavior.

- One Sonalysts, Inc. system has transducers placed 5 m from the bar rack of the intake.

- At the Seton Hydroelectric Station in British Columbia, the distance from the water intake to the fishpulser was 350 m (1150 ft); at Hells Gate, a fishpulser was installed at a distance of 500 feet from the intake.

- The pneumatic gun evaluated at the Roseton intake had a 16.4 cubic cm (1.0 cubic inch) chamber connected by a high pressure hose and pipe assembly to an Air Power Supply Model APS-F2-25 air compressor. The pressure used was a line pressure of 20.7 MPa (3000 psi) (EPRI, 1988).

Advantages:

- The pneumatic air gun, hammer, and fishpulser are easily implemented at low costs.

- Behavioral barriers do not require physical handling of the fish.

Limitations:

- The pneumatic air gun, hammer, and fishpulser are not considered reliable.

- Sophisticated acoustic sound generating system require relatively expensive systems, including cameras, sound generating systems, and control systems. No cost information is available since a permanent system has yet to be installed.

- Sound barrier systems require site-specific designs consisting of relatively high technology equipment that must be maintained at the site.

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