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A REMEDIAL ACTION PROGRAM NEW BEDFORD HARBOR SUPERFUND SITE

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October 16, 1989
Balsam Project 6292.05/2397

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ACKNOWLEDGEMENTS

This remedial action plan for the New Bedford Harbor Superfund site was prepared by Balsam Environmental Consultants, Inc. (Balsam) under the direction of Dr. Weldon S. Bosworth and Leonard C. Sarapas, Balsam Project Managers. Significant assistance was provided by Dr. Louis Thibodeaux in evaluating capping effectiveness and participating in the innovative design for the New Bedford Harbor contaminant containment system. Dr. Anna Yoakum provided important input in terms of performing state-of-the-science evaluation of New Bedford Harbor chromatograms, demonstrating widespread PCB biodegradation in sediment throughout New Bedford Harbor. Applied Science Associates, Inc. performed surface water modeling to assist Balsam in cap design and performed modeling to determine post-capping water quality. Terra, Inc. provided toxicological expertise during this project and prepared the site exposure assessment and risk assessment demonstrating the effectiveness of this remedial approach in terms of human health risk. Nutter, McClennen & Fish provided legal evaluation and analysis and served as the prime authors of Sections 5.2, 5.4 and 5.8 of this report.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE OF CONTENTS (continued)

LIST OF FIGURES

TABLE OF CONTENTS (continued)

LIST OF FIGURES

TABLE OF CONTENTS (continued)

LIST OF ATTACHMENTS

EXECUTIVE SUMMARY

An in-place containment remedial action program has been developed for the New Bedford Harbor Superfund site to address potential threats posed to human health and the environment by contaminants present in harbor sediments.

In summary, this remedial alternative involves containment of contaminated Upper Estuary sediment by placement of a cap of clean sediment and geofabric over areas designated for remediation. In addition, erosion protection and additional saltmarsh will be established to stabilize portions of the capped areas. This remedial approach was developed in response to likely adverse impacts associated with the handling and movement of large volumes of contaminated sediment. Specifically, in-place containment was selected as the basis for site remediation due to the potential for contaminant release and migration through exposure of presently buried sediments, either to air (volatilization or windblown dusts), or to water (resuspension, volatilization and dissolution). Additionally, this remedial design was performed in part because the U.S. Environmental Protection Agency (EPA) has not retained an in-place containment remedial alternative in feasibility study findings released to date.

The in-place containment remedial alternative entails integration of the use of hydraulic controls and sediment capping to remediate the New Bedford Harbor site. The initial step in this remedial alternative involves the installation of a variable weir dam at the Coggeshall Street bridge. This dam will allow control of tidal flow through the Upper Estuary and serve to reduce estuary dynamics to allow controlled placement of the sediment cap, as well as to minimize the release of any contaminants from the estuary during construction. In addition to this variable weir dam, upstream hydraulic control measures will be implemented at the New Bedford Reservoir Dam, Hamlin Street Dam, and/or the Saw Mill Dam; these measures will allow some added control over Acushnet River storm discharge during remedial program implementation.

The next component of this remedial system involves construction of a 140 acre sediment containment cap over Upper Estuary sediments. Twenty-two acres of the cap will be constructed with erosion resistant materials to protect portions of the containment cap from erosion during extreme surface water discharge events, as well as to provide an additional measure of safety in areas with higher reported levels of polychlorinated biphenyl (PCB). Nineteen acres of the cap will be planted with saltmarsh grass to increase stability of the cap as well as to mitigate for impacts to Acushnet River estuary.

Based upon a review of studies performed by the U. S. Army Corps of Engineers (USACE) as well as independent evaluation of these and other data, a 45-centimeter cap has been selected as appropriate for containment of contaminants present in Upper Estuary sediments. Of this 45 centimeters, 25 centimeters will provide a chemical barrier and safety zone to contain contaminants while the upper 20 centimeter will provide a protection zone for active bioturbation (biological movement of sediment). A sandy material will be employed for cap construction because its properties will facilitate placement and will lead to rapid cap consolidation and effectiveness in containing site contaminants. Cap placement will be performed using hydraulic methods, or in northern portions of the Upper Estuary, dry placement techniques.

A geofabric will be installed under the clean sediment cap to prevent intermixing between the clean cap material and existing contaminated sediment. Installation of this underlying geofabric will significantly limit the resuspension of contaminated sediments during cap installation, and will provide higher structural integrity to the capping system.

Precedents for the implementation of capping at other sites is well established in the literature. Examples of sites where capping has been implemented include

James River in Virginia, the New York Bight Mud Dump Site, and the Simpson Tacoma Kraft Company/St. Paul Waterway. At the James River, where sediments had become contaminated with Kepone, EPA decided to implement a no action remedial alternative which involved natural sediment accretion. Site monitoring initiated in 1980 has shown that Kepone levels in the water column have decreased to levels below the chronic water quality criteria, and that concentrations in surface sediments and finfish have also significantly declined, testifying to the fact that the Kepone-contaminated sediments are effectively being immobilized through a natural capping process.

At the New York Bight mud dump site, contaminated dredge spoil disposal and capping has been studied for nearly 10 years. Results of these studies have indicated that sediment containment caps have been effective in serving as a chemical barrier, and possess physical integrity when subjected to extreme hydrodynamic (hurricane) forces.

At the Simpson Tacoma Kraft site, PCB and PAH contaminated intertidal sediments were capped with medium grained sands. The ability to install such a sediment containment cap over contaminated sediment was demonstrated during this project.

In designing the proposed multi-media cap, the ability of the capping system to effectively contain contaminants present in Upper Estuary sediments was identified as a critical factor. To be effective, the cap must chemically isolate the underlying contaminated sediments, provide sufficient depth so that biological activity of benthic fauna (bioturbation) does not compromise the chemical barrier, and be of sufficient depth of design so that neither erosion nor human impacts affect performance of either the "chemical barrier" or "bioturbation zone." Qualitative assessments of the significance of 10 potential PCB transport mechanisms were performed based on a review of studies performed by EPA and others. As a result of this assessment, molecular diffusion and bioturbation were considered to be the two principle mechanisms responsible for the majority of PCB flux from Upper Estuary sediments to the overlying water column. Of these two mechanisms, bioturbation within the contaminated sediment is presently the primary determinant of the rate of PCB flux. Thus, by providing a cap which effectively elevates the bioturbated zone above the contaminated sediment zone, diffusion becomes the primary determinant of PCB flux within the sediment. Due to the very slow nature of diffusive contaminant transport mechanisms, it was concluded that separation of bioturbation activity from contaminant-effected sediments would result in containment of PCBs in estuary sediment.

An extensive evaluation was performed of benthic species and bioturbation activity which may exist in the Upper Estuary. Based on the results of this evaluation, a 20-centimeter-thick layer of surfical sediment was selected as the bioturbation zone. The conclusion to use 20 centimeters as the thickness for the bioturbation layer is also consistent with the USACE (1988) recommendation based upon their review of the potential for benthic penetration of a cap.

Similarly, an extensive evaluation was performed to assess the thickness of the chemical barrier of the cap. Theoretical contaminant transport considered in combination with high-resolution site specific data as well as laboratory tests performed by the USACE (1988) resulted in the selection of a cap chemical barrier thickness of 25 centimeters. An analysis of this 45 centimeter thick cap by Thibodeaux (1989) indicated that PCB breakthrough would not occur through the cap for a period of approximately 1,000 years. Following the occurrence of PCB breakthrough, PCB flux through the entire 140 acre containment cap was estimated to be less than 300 grams per year.

The extent of the containment cap would include all areas within the Upper Estuary reported to contain greater than 50 parts per million (ppm) PCB. An analysis by Thibodeaux indicated that 99 percent of the current PCB flux from Upper Estuary sediment is attributed to sediment containing 50 ppm PCB or greater. Thus, capping these sediments would effectively eliminate 99 percent of the current PCB flux from the Upper Estuary. First-order modeling of post-remedial water quality by ASA indicated PCB concentrations in the Upper Estuary ranged from 17 to 25 nanograms per liter (ng/l), a significant reduction from current levels.

In order to evaluate the acceptability of a 50 ppm PCB clean up level for remediation of Superfund sites, a review of recent post SARA decisions by EPA at sites similar in nature to the New Bedford Harbor site was made. Based on this review, the Waukegan Harbor Superfund site located on Lake Michigan in Waukegan, Illinois was found to be most comparable to the New Bedford Harbor site. As part of a 1988 consent order, a 50 ppm PCB action level was selected as the limit for remediation in the harbor. Based in part on the similarities between the New Bedford Harbor site and the Waukegan Harbor site including geography, natural resource value, public use and contaminant nature, as well as the timeliness of the 1988 EPA decision for cleanup of Waukegan Harbor, a 50 ppm PCB clean up level was judged to be appropriate for the New Bedford Harbor site.

The in-place containment remedial alternative will be constructed utilizing proven construction techniques. Subaqueous installation of geotextile has successfully been performed internationally for over 20 years. Methods for geotextile placement have been developed which will result in minimal resuspension of bottom sediments. As previously discussed, subaqueous caps for containment of contaminated media have been constructed at numerous sites. Experience at these sites has demonstrated that such caps can be constructed without the resuspension of significant amounts of contaminated sediment. In addition, installation of geofabric prior to placement of the sediment cap as part of the New Bedford Harbor remedial program should further reduce the potential for bottom sediment resuspension.

Because proven construction means will be used to place the containment cap, and because the Upper Estuary is well suited for the installation of this type of cap, it has been estimated that the containment cap can be constructed in a period of two to three years. Construction costs have been estimated at $17,000,000 to $19,000,000, which includes a 30 percent contingency factor and costs for long-term site monitoring.

The principle objective in performing remediation for a Superfund site is to reduce potential threats which may be posed by the site to human health and the environment. Accordingly, post-remedial risks were estimated by Terra, Inc. (Terra) for this proposed remedial alternative. Based on Terra's evaluation, post-remedial risks due to direct contact with sediments were calculated to be below the 1×10^{-5} risk level. Similarly, post-remedial risks for consumption of seafood caught solely from the Upper Estuary were calculated. Risk estimates calculated using a Terra-derived PCB cancer potency factor were 1.87×10^{-6} to 1.66×10^{-8}. Risks calculated using the EPA cancer potency factor were within the range of risks considered acceptable by EPA. Significant short-term impacts to human health were not identified relating to implementation of this remedial alternative.

As discussed above, capping the Upper Estuary should result in a substantial reduction of PCB flux from Upper Estuary sediments. This will be reflected in significantly improved water quality in all regions of the estuary. PCB levels in the water column should decrease to approximately 17-25 ng/l in the Upper Estuary and 14-31 ng/l in the Middle and Lower Harbor; this is a reduction of about 100 fold in PCB concentration in the Upper Estuary and 10 fold in the Middle and Lower Harbor, respectively. Reduction in water column PCB concentration will result in a concomitant decrease in PCB body burden of aquatic organisms; based upon bioconcentration factors calculated by Battelle, PCB levels in edible tissue of important aquatic species should decrease below the FDA limit of 2 ppm.

Compliance of the in-place containment remedial alternative with applicable or relevant and appropriate requirements was evaluated. This evaluation indicated that this alternative would satisfy this Superfund criterion.

Similarly, an assessment was performed of the ability of the remedial action to reduce the toxicity, mobility or volume of contaminants present at the New Bedford Harbor Superfund site. As previously discussed, the proposed cap will effectively immobilize PCBs contained in Upper Estuary sediments for a period of approximately 1,000 years. During this period of containment, anaerobic PCB biodegradation processes demonstrated to exist within New Bedford Harbor sediments should proceed. Accordingly, implementation of this remedial alternative should result in the reduction of the toxicity, mobility and volume of PCBs contained beneath the cap.

In summary, the in-place remedial alternative has been shown to be capable of effectively remediating PCB contamination present within the New Bedford Harbor Superfund site without the creation of significant adverse impacts. The remedial alternative can be implemented in a relatively short period of time utilizing existing construction techniques, resulting in acceptable post-remedial levels of risk to human health and the environment, and would be judged as cost effective when compared with alternatives involving the dredging, disposal and treatment of harbor sediments.

A REMEDIAL ACTION PROGRAM
NEW BEDFORD HARBOR
SUPERFUND SITE

1.0 INTRODUCTION AND SITE DESCRIPTION

A remedial action program has been developed for the New Bedford Harbor Superfund site to address potential threats posed to human health and the environment by harbor sediments. This remedial program has been developed by combining a number of currently existing and proven engineering and remedial technologies to form a system for the effective long-term containment of targeted contaminants present at the site. The plan has been developed to reduce both short and long-term adverse impacts potentially associated with remedial program implementation. A number of evaluative techniques have been used to assure that the remedial system is capable of achieving contaminant reduction goals. Consideration has been given to site specific characteristics such that the remedial alternative design provides for integrity of the remedial system well into the future.

In summary, the remedial alternative described in this report involves in place containment of contaminated Upper Estuary sediments by placement of a cap of geofabric and clean sediments over areas designated for remediation. In addition, following the placement of clean sediments over areas to be capped, erosion protection and additional saltmarsh will be established to stabilize portions of the capped areas. A detailed description of the nature of this remedial approach, and the reasons why it has been judged to be effective, are presented in this report.

Because EPA proposals for remedial action evaluated or considered to date have focused on remediation of polychlorinated biphenyls (PCBs) (NUS, 1984; EPA, 1989; EBASCO, 1989), this proposal has likewise done so. However, since one of the key features of this alternative is that it remediates contamination without disturbing sediments, it also provides an effective solution for a broad range of sediment constituents found in New Bedford Harbor such as metals and polycyclic aromatic hydrocarbons (PAHs).

1.1 BASIS FOR REMEDIAL ALTERNATIVE DEVELOPMENT: REMEDIAL ACTION GOALS

The first step in the process of development and evaluation of remedial action alternatives for a Superfund site is the identification of remedial action objectives and evaluative criteria suited to specific conditions present at the site. While refinement of specific remedial action goals (e.g., chemical-specific action levels) appropriately may be achieved at a later stage of the Remedial Investigation/Feasibility Study (RI/FS) process, it is necessary at the outset to define generally the fundamental goals of the program and the criteria by which the effectiveness and implementability of remedial action alternatives will be judged.

Accordingly, at the inception of this study, an effort was made to develop a list of goals and evaluative criteria to be applied both in review of remedial action alternatives developed by the U. S. Environmental Protection Agency (EPA) in its RI/FS, and in the evaluation of any remedial action approach independently developed. In view of the status of New Bedford Harbor as a "National Priority List" site, the principal source of legal guidance in formulating goals and evaluative criteria has been the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), 42 U.S.C. Section 9601 et seq. together with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300, promulgated thereunder. Additional federal guidance has been derived from EPA's proposed revised NCP (Proposed Rule, 53 Fed. Reg. 51394, December 21, 1988) and from EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final," dated October 1988.

Further legal guidance in the formation of remedial action goals and evaluative criteria also has been taken from the Massachusetts Oil and Hazardous Material Release Prevention and Response Act, M.G.L. Chapter 21E, Section 1 et seq., and the Massachusetts Contingency Plan (MCP), 310 CMR 40.000. Finally, specific characteristics of the New Bedford Harbor site such as the distribution of contaminants within the site, the hydrodynamic characteristics of the harbor, PCB transport mechanisms, and land use in the vicinity of the site were also included in the selection of remedial action program goals.

Based on this evaluation, six principal goals were identified. These goals are:

- o Protection of human health and the environment,
- o Protection of commercial environmental resources present in the area,
- o Minimization of site disturbance and contaminant release during remedial program implementation,
- o Cost effectiveness,
- o Consistency with legal requirements, and
- o Use of a proven technology with rapid implementation possible.

Following the identification and selection of these remedial action goals, numerous remedial technologies and remedial action approaches were considered, including those developed to date in EPA's RI/FS. With the exception of a no action alternative and a capping/hydraulic control alternative, all comprehensive remedial alternatives investigated to date in the course of the EPA RI/FS for the New Bedford Harbor Superfund site as a whole have involved dredging and moving contaminated sediments to a disposal area either within the harbor or off site. The handling and movement of large volumes of contaminated sediments is expected, however, to have some very direct and measurable adverse impacts. These impacts include increased potential for contaminant release and migration through exposure of presently buried sediments, either to air (volatilization or windblown dusts) or to water (resuspension, volatilization and dissolution), and very certainly, increased remedial action costs. (EBASCO, 1987; EBASCO, 1989; Thibodeaux, 1989)

After evaluation of the alternatives presently under consideration by EPA, both for the "Hot Spot" area and the Acushnet River Estuary, it was concluded that a remedial alternative which minimized the disturbance of contaminated sediments would best satisfy many of the remedial action goals by: (1) decreasing the potential for contaminant release and migration during implementation; (2) eliminating the risks and costs of dredging, handling and subsequent storage and disposal of contaminated sediments, and (3) achieving an environmentally preferred result which would minimize environmental receptor exposure to contaminants and potential impacts to the estuarine environment. Following an evaluation of numerous approaches to contain contaminated sediments in place, an approach which yields optimal achievement of the various objectives was developed.

1.2 SITE DESCRIPTION

The New Bedford Harbor Superfund site is located in eastern Massachusetts on the Atlantic Ocean. New Bedford Harbor is bounded on the west by the city of New Bedford, and on the east by the towns of Acushnet and Fairhaven. The location of the site is shown in Figure 1.1. The site area is shown in Figure 1.2.

New Bedford Harbor is an active harbor which opens to Buzzards Bay. The harbor area has a long history of human use. During the early 1800's, the greater New Bedford area was a major port for whaling, fishing and commerce. During the later 1800's, the city of New Bedford developed an industrial base consisting principally of textile mills and metal works. Beginning in the 1930's, the industrial base of New Bedford became more varied. Since that time, industrial diversification has continued in the greater New Bedford area. New Bedford Harbor continues to serve as a significant fishing port, with recent commercial landings having the largest dollar value of fish landings in any port in the continental United States. (Santos, 1981; Weaver, 1982)

Because the size of the New Bedford Harbor site is in excess of 1,000 acres, designations have been used in this study for portions of the site. These site areas are presented in Figure 1.3. The Acushnet River Upper Estuary, or Upper Estuary, is the portion of the site between the Wood Street Bridge and the Coggeshall Street Bridge. This portion of the site is approximately 189 acres, as defined by Mean High Water (MHW). In addition to this 189 acre area, approximately 50 acres of saltmarsh exist on the eastern shore of the Upper Estuary in Acushnet and Fairhaven. A site plan of the Upper Estuary showing existing habitats is included as Figure 1.4.

The area south of the Upper Estuary between the I-195 bridge and Route 6 bridge has been designated as the Middle Harbor. The Middle Harbor is approximately 280 acres in size. Unlike the Upper Estuary which currently supports no commercial and little recreational boat traffic, this portion of the harbor is both commercially and recreationally active.

The area south of the Middle Harbor between the Route 6 bridge and the Hurricane Barrier has been designated as the Lower Harbor. This portion of the site is approximately 480 acres. Like the Middle Harbor, this part of the harbor supports a large amount of commercial and recreational boat traffic.

South of the Hurricane Barrier, New Bedford Harbor opens to Buzzards Bay. Because contaminant levels are relatively low in this area, no formal boundaries were developed for this portion of the site, referred to as the Outer Harbor. A limited portion of this part of the site, approximately 430 acres, has been studied more closely by the EPA through a GZA Drilling (GZAD) study, and is referred to as the Outer Harbor Area.

Numerous studies have been undertaken to characterize the nature and extent of contamination present in New Bedford Harbor sediments. Due to the reported toxicity and persistence of PCBs in the environment, the majority of these studies have focused on PCBs. A significant database has been generated by EPA as part of the New Bedford Harbor site RI/FS currently underway describing PCB sediment concentrations. Based on review and evaluation of these data, PCB sediment concentration plots have been prepared for the New Bedford Harbor site by Balsam Environmental Consultants, Inc. (Balsam). Figures describing total PCB concentrations in New Bedford Harbor sediments for the Upper Estuary, Middle Harbor, Lower Harbor and Outer Harbor Area are presented as Figures 1.5, 1.6, 1.7 and 1.8, respectively.

A review of the EPA sediment quality database indicates that the vast majority of PCBs present at the New Bedford Harbor site exist in the upper 12 inches of sediment; little PCB has been found to exist in sediments at depths greater than 12 inches (Balsam, 1989). Additionally, as can be seen in Figures 1.5, 1.6, 1.7 and 1.8, the highest concentrations of PCBs have been observed in sediments in the northern portion of the Upper Estuary. Based on an evaluation of these EPA data, it is estimated that approximately 90 percent of all PCBs present in the New Bedford Harbor site study area exist in the Upper Estuary (EBASCO, 1989; Balsam 1989). Relatively low concentrations of PCBs exist throughout the remainder of the study area. For this reason, the focus of the remedial program has centered on the Upper Estuary. A site plan of the Upper Estuary is presented as Figure 1.9.

The majority of the Upper Estuary sediments are fine grain particles. These sediments are relatively unconsolidated. One notable exception to this is the eastern shore of the Upper Estuary adjacent to the Acushnet and Fairhaven saltmarsh where sediments are primarily medium grain, consolidated sands with small amounts of silt. (EPA, 1987; USACE, 1986; USACE, 1987; Woodward-Clyde Consultants, Inc., 1987)

Sediments in the Middle Harbor, Lower Harbor and Outer Harbor Area are principally silty sands and sands. Sediments present in the Middle and Lower Harbor areas are approximately 60 percent sand on average, while sediment samples from the Outer Harbor Area were reported to consist of up to 90 percent sand. (EPA, 1987)

The Acushnet River Upper Estuary can best be characterized as a small urban estuary. Circulation within the estuary is primarily driven by tidal currents. The principal fresh water input to the estuary is the Acushnet River; however, the average fresh water input from the Acushnet River to the estuary is quite small. Estimates of the average annual fresh water discharge from the river are in the range of 10 to 30 cubic feet per second (cfs) (Balsam, 1989).

The Upper Estuary is protected from storm surges through a series of restrictions in the harbor. The principal restriction to the harbor is a hurricane barrier which was constructed by the U. S. Army Corps of Engineers (USACE) during the 1960's. This barrier significantly restricts water movement into the harbor, and is closed in anticipation of extreme high water or storm events. In addition to the hurricane barrier, tidal movement in the harbor and Upper Estuary is further dampened by earthen embankments and bridges constructed across the harbor. The Route 6 bridge, I-195 bridge and Coggeshall Street bridge all serve to constrict circulation in the Upper Estuary. Water depths in the Upper Estuary are relatively shallow, ranging from 1 to 3 feet throughout the majority of the estuary at mean low water (MLW). A former dredged channel with an average depth of 8 ft (MLW) and a maximum depth of 15 ft (MLW) also exists in the Upper Estuary. Water depths in the Upper Estuary at MLW are shown on Figure 1.10.

The Upper Estuary is depositional in nature. Studies have indicated the net sediment depositional rate in the Upper Estuary to be from 0.3 centimeters (cm) to approximately 1 cm per year. It is expected that there is some spatial variability in deposition within the Upper Estuary. (Summerhayes, 1977; Teeter, 1988)

Hydrodynamic studies performed for the Upper Estuary indicate that average tidal currents are relatively low (1 to 3 cm per second) throughout the majority of the Upper Estuary (Teeter, 1988; ASA, 1986, 1987). Hydraulic constrictions created by the embankments of the Coggeshall Street and I-195 Bridges result in localized higher tidal velocities.

Sediment erosion studies based on both analytical methods and laboratory bench top studies indicate an erosion velocity for Upper Estuary fine grain sediments of about 28 cm per second. With the exception of a localized area adjacent to the opening underneath the Coggeshall Street Bridge, tidally driven currents are not expected to exceed this critical erosion velocity (ASA, 1987).

Modeling and field studies have also been conducted to predict and measure the maximum ebb and flood tidal velocities occurring in the Acushnet River Upper Estuary. Maximum tidal currents at the Coggeshall Street Bridge, central portion of the Upper Estuary, and northern portion of the Upper Estuary ranged from 46 to 99 cm per second, 10 to 15 cm per second, and 5 to 7 cm per second, respectively (ASA, 1986; Jason Cortell and Associates, Inc., 1982; and EPA, 1983).

In summary, the Upper Estuary area can be described as a relatively shallow urban estuary with a sediment bed consisting primarily of underconsolidated fine grain sediments, possessing a low energy, sediment-depositional regime.

2.0 IN PLACE CONTAINMENT ALTERNATIVE DESCRIPTION AND SCREENING EVALUATION

2.1 INTRODUCTION

After development of remedial action objectives and characterization of the site, the next step in the RI/FS process is the development and screening of alternatives (EPA RI/FS Guidance, 1988). The development of alternatives involves identification of general response actions that may be taken to satisfy remedial action objectives for the site, and available technologies to carry out such actions. The identified technologies are then combined into remedial action alternatives, and the alternatives thus assembled are subjected to an initial screening evaluation against the short and long-term aspects of three criteria: effectiveness, implementability and cost (EPA, 1988).

Because EPA has assumed the role of lead agency for the New Bedford Harbor site, and has undertaken the preparation of the RI/FS, this document does not contain descriptions and evaluations of a full range of remedial alternatives. Rather, the alternatives being developed and screened by EPA are being evaluated separately in AVX Corporation's comments on EPA's "Hot Spot Feasibility Study," both to determine whether all appropriate alternatives have been developed, and to ascertain whether the results of EPA's screening are appropriate. This document presents and evaluates a remedial action alternative which EPA has yet to fully consider for purposes of Acushnet River Upper Estuary remediation, and which EPA did not consider in detail for purposes of "Hot Spot" remediation.

Accordingly, while this report does not present a range of alternatives, and consequently there is no occasion for a comparative screening, it provides a summary description of the in place containment remedial alternative, and presents the application of the screening evaluation criteria to that alternative.

These subjects are discussed in the subsections that follow, and in much greater detail in Section 5.0.

2.2 SUMMARY DESCRIPTION

The in place containment of sediments present in the Upper Estuary involves placement of a clean sediment and geofabric cap over designated areas, subsequent planting of a saltmarsh over portions of the cap, and construction of an erosion-resistant zone to carry peak Acushnet River flows through the capped area. This remedial alternative effectively immobilizes sediments with the highest reported levels of PCBs, minimizes the need for major engineering design and construction, limits future potential exposure to these contaminated sediments, and mitigates impacts to the wetlands by creation of additional saltmarsh.

The initial step in this remedial alternative involves the installation of a variable weir dam at the Coggeshall Street bridge. This dam will allow control of tidal flow through the Upper Estuary and serve to reduce estuary dynamics to allow controlled placement of the sediment cap, as well as to minimize the release of contaminants from the estuary during construction. This hydraulic control structure will consist of a steel sheetpile or wooden sheeting wall incorporating three weir openings. These weirs will be used to control water level in the Upper Estuary and to reduce the tidal dynamics of the Upper Estuary.

While the variable weir dam is being constructed, upstream hydraulic control measures will be implemented at the New Bedford Reservoir Dam, Hamlin Street Dam, and/or the Sawmill Dam. These measures should allow some added control over Acushnet River storm water discharge during remedial program implementation. Agreements will be negotiated with the owners and operators to permit use of these upstream dams to moderate Acushnet River storm water flows. A more detailed discussion of these hydraulic control measures is presented in Section 3.3.

The next component of the sediment containment system involves placement of a sediment containment cap over Upper Estuary sediments. Based upon an evaluation of PCB flux from Upper Estuary sediments, 70 percent of the Upper Estuary sediments produce approximately 99 percent of all current PCB flux from the estuary (Thibodeaux, 1989). This portion of the estuary, which roughly corresponds to the area with reported PCB levels of 50 parts per million (ppm) or more, constitutes approximately 135 acres of the 189-acre Upper Estuary. On this basis, capping of this portion of the Upper Estuary was judged to meet identified program objectives. A more complete discussion of cap design and performance is presented in Sections 3.1 and 3.4. A separate report describing PCB sediment concentrations and mass within the Upper Estuary is presented as Attachment A.

Based upon a review of studies performed by the USACE, as well as independent evaluation of these and other data, a 45-centimeter-thick cap has been selected as appropriate for containment of contaminants present in Upper Estuary sediments. Of this 45-centimeter thickness, 25 centimeters will provide a chemical barrier and safety zone to contain contaminants, and the upper 20 centimeters will provide a protection zone for active bioturbation (biological movement of sediment). As a result of this cap, the bioturbated zone will be "elevated" approximately 25 centimeters from the contaminated sediment. A sandy material with slight amounts of finer particles and some organic content will be employed for cap construction due to the ease of placement of this type of material and properties of this material which will lead to rapid cap consolidation and effectiveness of containing site contaminants.

A geofabric will be installed over portions of the estuary which will be capped in order to preclude erosion and mixing of sediments with cap material as fill is laid over these sediments. In addition, this geofabric will increase the integrity of the sediment containment system. The entire area of the Upper Estuary to be capped will be overlain with a geofabric prior to the placement of fill material.

In a limited area within the northern portion of the Upper Estuary, elevated flow rates and velocities associated with extreme rainstorm discharges from the Acushnet River may occur. In order to prevent the sediment containment cap from scouring due to erosive forces associated with such peak discharges, a portion of the northernmost Upper Estuary will be protected by integrating an armored layer consisting of geofabric, geoweb and stone into the sediment cap. An area of approximately 22 acres will be covered with larger diameter stone, some of which will be placed in a geoweb, to protect the sediment cap from scour.

Cap placement will be performed using hydraulic methods or, in the northern portions of the Upper Estuary, dry placement techniques. Placement of a 45-centimeter cap over approximately 140 acres of the Upper Estuary, 135 acres of sediment reported to contain greater than 50 ppm of PCBs and 5 additional contiguous acres of sediment along the eastern shore of the estuary, will require approximately 340,000 cubic yards of sandy fill material.

Placement of the cap material in some nearshore areas will result in the creation of additional intertidal wetland areas. Thus, as a final construction element of this remedial program, newly created intertidal areas within the Upper Estuary will be developed into a cord grass (Spartina alterniflora) saltmarsh through planting of seed or seedlings. A more complete discussion of this project aspect is contained in Section 3.4.6.

Since the early 1900's, a ban on all fishing has been imposed within New Bedford Harbor due to sewage pollution. Current fishing bans are due not only to PCB contamination but also to continued sewage discharge into the harbor and Upper Estuary. It is anticipated that institutional control will be maintained in the Upper Estuary until cap effectiveness and stability have been demonstrated, sufficient benthic recolonization of the area has occurred, and sewage discharges to the harbor and estuary have ceased.

This in-place containment alternative appears especially well suited for the New Bedford Harbor site because it:

- Effectively immobilizes much of the PCB contaminated sediment and the vast majority of PCBs present at the site;
- Minimizes migration of contaminants present in Upper Estuary sediments to ambient air, the harbor and Buzzards Bay;
- Results in decreased engineering design costs and remedial program costs associated with dredging, spoil handling/treatment and disposal alternatives;
- Limits future potential exposure to these contaminated sediments; and
- Mitigates impacts to saltmarsh by development of additional saltmarsh wetlands.

2.3 APPLICATION OF SCREENING CRITERIA

2.3.1 Effectiveness Evaluation

In order to be retained for detailed analysis, a remedial alternative must be judged effective in achieving remedial action goals, while not giving rise to significant adverse impacts to public health or the environment during implementation. The effectiveness evaluation at the screening stage is, in essence, a more generalized treatment of the five effectiveness-related detailed analysis criteria, i.e., overall protection of human health and the environment, compliance with applicable or relevant and appropriate legal standards or requirements (ARARs), long-term effectiveness and permanence, reduction of contaminant toxicity, mobility or volume, and short-term effectiveness. The in place containment alternative was judged effective for the long term since it will eliminate direct contact between human or environmental receptors and capped sediments, and will significantly reduce PCB migration from the contaminated sediment to the overlying water column. It was judged effective in the short term because use of a variable weir dam system, placement of granular capping materials and geofabric, and use of selected construction techniques will result in minimal disturbance and resuspension of contaminated estuary bottom sediments into the water column and the associated PCB solute and particulate transport into the harbor and Buzzards Bay. A more thorough and specific discussion of the effectiveness of the in-place containment alternative is provided in Section 5.3 in the context of a discussion of the detailed analysis criteria, as well as in Section 3.1.

2.3.2 Implementability Evaluation

Implementability is a measure of the technical and administrative feasibility (or regulatory acceptance) of implementing a remedial alternative. A central concept of implementability is consideration of whether the remedial alternative utilizes accepted engineering practices and reliable construction methods. The proposed in place containment remedial alternative utilizes a number of existing and proven engineering and construction methodologies. Although the overall conceptual design is innovative in nature, each of the component parts of this remedial alternative have been demonstrated to be both implementable and practical. A review of other projects involving these engineering methods has indicated that obtaining permits to conduct these activities was feasible, and that documentation of field implementation of these methods is available for several aquatic sediment sites. A summary of this experience is discussed in Section 2.3.4 below.

Considered in conjunction with the discussion of wetlands impacts and mitigation efforts presented below, experience at other sites demonstrates that this alternative should be acceptable to regulatory agencies.

2.3.3 Cost Evaluation

In deciding whether a given remedial alternative should be retained for detailed analysis, a general estimate of the likely cost of the alternative must be made. Since little refinement of specifics of the remedial alternatives is reached at this point in the FS screening analysis, absolute cost estimate accuracy is neither possible nor necessary. On this basis, an initial cost comparison was made with other potential Upper Estuary remedial alternatives. This preliminary evaluation indicated that capping was more cost-effective than other remedial measures involving dredging, sediment handling, and sediment treatment/disposal. Because this remedial alternative was also found to perform as effectively as these other remedial measures at comparable action levels, this alternative was judged to be cost-effective. The expected costs of the in-place containment alternative are discussed in detail in Section 5.7.

2.3.4 Use of Capping for Contaminant Containment at Other Sites

2.3.4.1 Introduction

An additional element in determining the appropriateness of in place containment as a viable remedial approach for the New Bedford Harbor Superfund site was a review of capping of contaminated sediments at other aquatic sites. Although capping contaminated sediments in place is a relatively new remedial technology, capping as a means of containing contaminated dredge spoils has been used extensively around the world for at least the last fifteen years, and numerous studies have been conducted on various aspects of capping. Additionally, capping in place either through natural sedimentation or under controlled engineered conditions as a remedial action has been performed at several sites. This section discusses the use of capping with regard to precedent, engineering design aspects and performance evaluation.

2.3.4.2 Precedents

Precedents for the implementation of capping technologies at other sites are well established in the literature. Examples of sites where capping has been implemented include: James River, Virginia; New York Bight Mud Dump Site; and Simpson Tacoma Kraft Company/St. Paul Waterway. Each of these sites is discussed briefly below.

During the period 1966-1975, the James River was contaminated through the discharge and disposal of the pesticide, Kepone. Findings of an initial EPA investigation concluded that widespread Kepone contamination of the water column, bed sediments and finfish had occurred. Following this initial investigation, the EPA (1978) conducted a Kepone mitigation feasibility study to investigate and evaluate various methods for the clean-up of Kepone from the James River system. The alternatives considered included no-action, stabilizing sediments with molten sulfur, dredging and using retrievable sorbents. The large expected costs for these remedial actions (excluding no-action), coupled with the fact that any alternative selected with the exception of no-action would have an adverse biological impact on the river, resulted in the decision that a no-action remedial alternative, depending upon natural sediment accretion, was the most cost-effective and posed the least threat to the environment and public health.

In 1979, seven private applicants for permits for New York harbor dredging of PCB contaminated sediment were given permits for ocean disposal of the dredge spoils. The applicants had demonstrated that while the dredge spoils had the potential to cause unacceptable levels of bioaccumulation of PCB, the sediment was not toxic to biota. Because of the demonstrated need for the dredging and the lack of acceptable disposal alternatives, the ocean disposal was permitted provided that a 60-cm cap was used to prevent burrowing organisms from reaching the underlying contaminated material (Mansky, 1984). Sixty (60) cm presumably provided a margin to allow for some erosion of the cap in the open waters of Long Island Sound since Pratt and O'Conner (1973) have found that most benthic species in Long Island occur at depths less than 10 cm.

A 1988 Consent Decree was signed between the State of Washington and Simpson Tacoma Kraft Company (Simpson) (Ficklin, 1989, personal communication). Simpson owns and operates a pulp and paper mill near the mouths of the Waterways and Puyallup River and had been discharging inorganic and organic contaminants including PAH and PCB to nearshore sediments. Following review of nine potentially feasible remedial alternatives, capping was selected because it was considered to be the least environmentally damaging and more technically feasible alternative. A clean sediment source (Puyallup River) was readily available in quantities suitable for a capping project of its size. In addition, there was no future need to dredge the site due to the shallow water depths near the site. Because no future dredging of the site was anticipated, the use of alternatives that involved in place capping was allowed. It was noted that capping would afford long term effectiveness, result in prompt reduction of existing health risks when compared to other alternatives, and would avoid off-site transport, disposal and treatment of contaminated materials (Simpson Tacoma Kraft Company, 1987).

2.3.4.3 Engineering Consideration

Engineering design for capping involves evaluation of cap material, cap placement and cap thickness. Each of these criteria is discussed below.

2.3.4.3.1 Cap Material

Cap materials, cap construction and cap thickness vary from site to site. Brannon et al. (1985) evaluated three capping materials, sand, clay (New Haven sediment) and silt (Vicksburg silt), in terms of their efficiency in preventing transfer of contaminants from contaminated sediments into the overlying water column and biota. In the presence of bioturbating polychaetes (Nereis virens) at densities of 100 per square meter, a 50 cm cap of any of the three materials tested in large chamber (250-liter) experiments was effective in preventing the transfer of chemical constituents and microbial spores to the overlying water column and nonburrowing biota. A review of sites employing a remedial action cap indicates that a wide range of materials, including fine sands (New York Bight), medium sands (St. Paul Waterway), sand with oyster shells (Hiroshima Bay), silt (Stamford-New Haven-South) and clay (Rotterdam Harbor), have been successfully used.

2.3.4.3.2 Cap Placement

The method and rate of placing capping material over a site, especially one in which hydraulically dredged spoil sediments have been disposed, have been identified as areas of concern. Dumping of cap materials over unconsolidated sediments is likely to result in increased turbidity and displacement of contaminated materials, particularly at shallow water sites. Two capping demonstration projects in Hiroshima Bay directly addressed this problem (Togashi, 1983 and Kikegawa, 1983). Both projects involved capping contaminated bottom sediment in place with clean capping sand. In the first case, a gravity fed tremmie pipe was extended through the water column and capping sand fed into it by a conveyor/barge system. In the second project, a submerged spreader bar with diffuser ports was used to spread capping materials. In both cases, controlled placement of a uniform cap approximately 50 cm thick was achieved.

In the Duwamish Waterway, contaminated shoal sediments were dredged mechanically with a split-hull barge and accurately placed in an existing depression. Capping sands were then placed incrementally over PCB-contaminated sediments with another split hull barge over several days. The sand exited the barge hull slowly and was sprinkled through the water column. Dispersion was minimal and three discrete overlapping disposal sequences were used to ensure adequate coverage.

At Rotterdam Harbor, capping projects were conducted at Botlek Harbor and First Petroleum Harbor (d'Angremond, 1984; EPA, 1988). At both sites, the excavation of confined aquatic disposal (CAD) areas revealed a surplus of clean cohesive clay that was incorporated into the cap design as a low permeability capping material. Approximately 1,200,000 and 620,000 cubic yards, respectively, of contaminated sediments from these two harbors were section dredged and hydraulically placed within the CAD sites with a submerged diffuser. Barge loads of the clay were then deposited on the bottom adjacent to the CAD sites and subsequently raked over the contaminated sediment using a towed drag. Though this technique resulted in localized increases in turbidity during cap construction, it demonstrated that a cap could effectively be placed in this manner.

At the Simpson Tacoma Kraft paper and pulp mill, contaminated intertidal sediments were capped with medium-grained sands from the mouth of the Puyallup River (J. Ficklin, 1989 personal communication). Cap placement techniques consisted of dredging cap materials from the mouth of the Puyallup River channel by a small hydraulic dredge, and then placing them over the contaminated sediments through a downpipe diffuser. The downpipe diffuser extended from the water surface to within a few feet of bottom. It discharged cap material over areas of small size to allow for reduction of discharge velocity and to facilitate controlled settling of cap materials. The diffuser also prevented erosion and disturbance of nearby bottom sediments. The cap materials were placed in lifts (layers) of 2 feet or more with the diffuser before moving to a new area. Positioning for dredging of the cap material and placement of the cap was accomplished with a computer controller.

At the Port of Portland, Oregon, a riverbank area having contaminated soft clay silt sediments was successfully capped with sandy sediments from the Willamette River Channel (Hardin and Hartman, 1989). The sandy river sediments were transferred to the bottom using a hydraulic dredge equipped with a 80 foot downpipe diffuser. Using this technique, coarse sediments were placed on top of fine sediments with little disruption of the fine grain fractions. The purpose of this project was to meet water quality criteria by capping of the contaminated sediments.

In the Central Long Island Sound Disposal (CLIS) area, numerous capping projects have been performed since the mid-1970's under the auspices of the Disposal Area Monitoring Systems (DAMOS) program (SAIC, 1985). The DAMOS program was initiated by the New England Division of the U. S. Army Corps of Engineers (USACE). The purpose of the DAMOS program was to address problems arising from management of dredged material disposal. Contaminated materials were dredged by clamshell dredge and placed at the spoil site using point dump procedures (bulk release by hopper dredges at marked coordinates). Capping materials consisting of silts and sands were also placed over contaminated sediments with scows. In most cases, a Loran-C precision navigation system was employed to position and control placement of capping material.

At the New York Bight Mud Dump Site, the 60 cm cap was placed after establishing fixed disposal points using a taut-moored system. First, 224,000 cubic meters of clean fine grain material was deposited by scow to create an intermediate layer. Second, 1,172,000 cubic meters of sand was placed over the disposal site (Mansky, 1984).

2.3.4.3.3 Cap Thickness

Since the objective of capping is to permanently isolate chemically contaminated sediments from biota and the overlying water column, the thickness of a sediment cap needs to be evaluated to identify the minimum thickness required to accomplish this objective. The U. S. Army Corps of Engineers, Waterways Experimental Station (WES) has conducted numerous laboratory tests to determine minimum necessary cap thickness by measuring the movement of contaminants through a sediment cap. To simulate contaminant movement through a cap, WES used chemical tracers such as ammonium-nitrogen, dissolved oxygen depletion and orthophosphate-phosphorous. A cap thickness that was effective in preventing the movement of these tracers was determined to be effective in preventing the movement of organic contaminants such as PAHs, PCBs and petroleum hydrocarbons (Brannon et al., 1985, 1986; Gunnison et al., 1986).

WES used a small-scale reaction column to predict the cap thickness required to chemically isolate contaminated Everett Harbor sediment from the overlying water column (U. S. Navy, 1986). DO depletion rates and release rates of ammonium nitrogen and orthophosphate-phosphorous were used as tracers in this test. The results of the predictive tests indicated clean Everett Harbor native sediments were effective in isolating contaminated sediments from the water column. Increasing the cap thickness further retarded the release of the tracers from the sediment to the overlying water column. It was determined that the minimum effective cap thickness for short-term isolation of chemically contaminated sediments was approximately 1 ft (30 cm).

Similar studies were performed by WES to better evaluate the long-term effectiveness of capping (Brannon et al., 1986). The objective of this study was to assess the effectiveness of capping in chemically and biologically isolating PCB and PAH contaminated dredged Dutch Kills sediment in New York Harbor. Two cap thicknesses were tested, a 4 inch (10 cm) and a 18 inch (50 cm) thickness. Relatively clean cap materials consisting of fine silt and sand sediment were taken from nearby Buttermilk Channel. The ability of Buttermilk Channel cap materials to isolate contaminated Dutch Kills sediment was assessed in a large laboratory reactor through tracking the movement of chemical contaminants and microbial spores into the overlying water column, and by monitoring the biological uptake of chemical contaminants by clams and polychaetes. The results of this study indicate that both the 10 cm cap and 50 cm cap of Buttermilk Channel sediment were effective in preventing the transfer of chemical contaminants to the overlying water column and biota, even when the cap was penetrated by polychaetes (Brannon et al., 1986).

In summary, the results of the separate studies of Everett Harbor and Dutch Kills sediment indicate capping in the absence of bioturbation will prevent the movement of contaminants into the water column and biota over a short time period. Adding additional depth to a minimum cap thickness served to isolate burrowing organisms from the contaminated material and prevent the movement of contaminants into the water and biota (Brannon et al., 1986).

2.3.4.3.4 Performance Evaluation

Monitoring of capping projects involves assessing the physical stability and integrity of the cap, effects of bioturbation, if any, and whether the cap is providing a sufficient chemical seal to contaminant migration.

In the Duwamish Waterway, settlement plates indicated little change in cap thickness. Chemical monitoring of the sediment cap and dredged contaminated material was also performed through the collection of core samples. Core samples were analyzed for PCBs, copper, lead and zinc with results indicating the dredged and cap materials forming a sharp, relatively unmixed interface after about one year (Truitt, 1986). At the Simpson mill site near Tacoma, Washington, core sampling has indicated there has been negligible infiltration of inorganic and organic contaminants into the cap. Additionally, bathymetric surveys have indicated the cap has remained largely in place (J. Ficklin, 1989 personal communication).

Physical stability of a sediment cap within the CLIS was also observed following Hurricane David in 1979 and Hurricane Gloria in 1985. Silt and sand caps were constructed in 1979 at the Stamford/New Haven-South and Stamford/New Haven-North sites, respectively. Following Hurricane David in 1979, the silt cap was partially eroded whereas the sand cap was largely unaffected. Similar results were obtained following Hurricane Gloria; sand caps were more stable and benthic communities successfully recolonized them after a short time. Regardless of cap composition, Hurricane Gloria did not result in major movement of cap sediments or compromise the containment character of the CLIS site (SAIC, 1986).

Biological monitoring has also been conducted to determine if contaminants are being released into the environment. At several sites (Stamford/New Haven North and South, Norwalk), the blue mussel Mytilus edulis has been used as a biological monitor to quantify contaminant release. The mussels are typically deployed in mesh bags attached to a platform which is suspended above the sea floor. Results of the Mussel Watch program in the CLIS Norwalk and Stamford/New Haven sites conducted during 1980-1981 indicate there has been negligible transfer of contaminants to the overlying cap. The trace metal concentrations in the mussels employed at the experimental and reference stations showed no significant increase after one year. There was also little difference in metal concentrations in mussels deployed at three experimental sites regardless of the varying amounts of dredged spoil materials deposited at these sites. Variation in mussel metal concentrations was largely due to time and intrinsic variables such as wet/dry tissue weight ratio and shell length. Dredge volume explained only a small fraction of this variation (SAIC, 1982).

Results of monitoring studies at the New York Bight Mud Dump Site have shown the cap to be an effective chemical barrier. Studies of bioaccumulation in caged mussels at the site have shown insignificant uptake of PCB by the mussels. Monitoring of a species of bacteria found in the contaminated dredge material at the New York Dump Site indicated that they had not penetrated the cap. In addition, chemical analysis of core samples at the site revealed that movement of metals had been prevented by the sand cap. Low levels of PCB in the cap material were attributed to the extrusion of pore water from the contaminated dredge material during consolidation of the cap and underlying material (Mansky, 1984).

Perhaps the best example of the effectiveness of capping is found in the results of the experience at James River, Virginia, where capping through natural sedimentation has been effective in substantially limiting the transport of Kepone into the water column, sediment surface and finfish (VWCB, 1980; 1982; 1987). Kepone, like PCB, has a low solubility in water and has an affinity for particulate matter and fine grain sediments. Monitoring studies have shown that over the last 10 years, Kepone levels in the water column quickly decreased to a level below chronic water quality criteria (VWCB, 1980), and continue to decrease. Monitoring of the water column was suspended in 1981 because of the low Kepone levels observed during site monitoring.

Kepone concentrations in surface sediments and finfish have also significantly declined since the monitoring study was initiated in 1980, testifying to the fact that release of Kepone through the sediment column into the aquatic environment is being substantially limited by the natural capping.

3.0 REMEDIAL ALTERNATIVES CONCEPT DESIGN

3.1 CONCEPT DESIGN INTRODUCTION

One of the most important design criteria related to the capping remedial alternative is selection of the nature and thickness of the cap. To be effective, the cap must chemically isolate the underlying contaminated sediments, provide sufficient depth so that biological activity of benthic fauna (bioturbation) does not compromise the chemical barrier, and be of sufficient depth and design so that neither erosion nor human impacts affect performance of either the "chemical barrier" or "bioturbation zone."

In designing the proposed multimedia cap, the ability of the capping system to effectively contain contaminants present in Upper Estuary sediments, thereby significantly reducing current PCB flux (i.e., the desorption of PCBs from bed sediment into the overlying water column) from the Upper Estuary to other portions of the harbor and Buzzards Bay, is a critical factor. To achieve this goal, numerous transport mechanisms which could conceivably exist within the estuary sediment bed were evaluated as part of the design process. A total of ten processes or mechanisms were identified which could possibly affect PCB transport in or from Upper Estuary sediment (Thibodeaux, 1989). These are molecular diffusion within pore water, bioturbation, absorption/desorption between solids and pore water, advective transport due to infiltration and recharge, sediment deposition/resuspension, advective transport due to sand ripple/wave effect, chemical reaction, biodegradation, Brownian diffusion of colloidal particles, and advection of colloidal particles.

Qualitative assessments of the significance of each of these ten potential PCB transport mechanisms were performed based on a review of studies performed by EPA and others (Thibodeaux, 1989 (Attachment B)); Personal communication with L. Thibodeaux, 1989). As a result of this assessment, molecular diffusion, bioturbation and sediment deposition/resuspension were considered to be potentially significant processes occurring within the Upper Estuary. Following further review of hydrodynamic and sediment transport modeling studies, sediment deposition/resuspension was not found to be a significant factor in PCB transport from Upper Estuary sediment bed (ASA, 1987).

On this basis, it was concluded that molecular diffusion and bioturbation were the two principal mechanisms responsible for the majority of PCB flux from Upper Estuary sediments to the overlying water column or to the sediment/water interface. Of these two mechanisms, bioturbation within the contaminated sediment is presently the primary determinant of the rate of PCB flux. Bioturbation-driven transport processes are believed to be several orders of magnitude more rapid than molecular-driven processes (i.e., diffusion) for particle reactive compounds such as PCBs (Thibodeaux, 1989). By providing a cap which effectively elevates the bioturbated zone above the contaminated sediment, diffusion becomes the primary determinant of PCB flux within the sediment. Figure 3.1 depicts how molecular diffusion and bioturbation currently act together to yield current PCB flux from Upper Estuary sediments, as well as how construction of the proposed multimedia containment cap will contain the majority of PCBs present at the New Bedford Harbor site by effectively separating bioturbation activity from sediments containing contaminants. After capping, PCB flux is limited to PCB diffused through the cap into the bioturbated zone; in turn, concentrations of PCBs diffusing into pore water are limited by PCB solubility.

As discussed above, the depth and nature of the capping material necessary to preclude contaminant transport through the cap are dependent upon the nature and transport characteristics of the contaminant and the underlying sediment, and the expected depth of bioturbation of endemic species. These cap design aspects are discussed in Section 3.1.1; more detailed evaluations of these aspects were undertaken by Thibodeaux and Whitlatch and are presented in Attachments B and C, respectively. Attachment B is an evaluation by Thibodeaux of capping effectiveness in containing PCBs present in estuary sediment, and Attachment C contains an evaluation of the expected nature of bioturbation following cap placement and recolonization.

The expected hydrodynamic environment of the area to be capped, as well as the expected future public use within this area, also play an important role in the design of capping material to assure long-term effectiveness and stability of the cap. These design aspects are discussed in Sections 3.4.5, Cap Stability, and 5.3, Long-Term Effectiveness and Permanence.

3.1.1 Cap Thickness

3.1.1.1 Bioturbation and Its Relationship to Cap Thickness

The effect of benthic organisms on capping material and contaminant transport is an important factor to be considered when choosing the depth and type of capping material. In addition to the possibility of burrowing benthic organisms being exposed to underlying contaminated sediments, bioturbation could also affect the integrity of a cap. The depth of the cap needed to effectively isolate biological activities from contaminated sediments can be estimated through evaluation of the burrowing depths of species presently found in the area or likely to be found in the area after the cap is placed. The nature of the capping material also has an effect on the depth of burrowing since different species will be recruited to different types of material. For instance, sand will generally tend to attract suspension feeding organisms, which are not deep burrowers, while deposit feeders will, in general, tend to colonize a finer-grain cap.

As Whitlatch (1989) summarizes, the activities of infaunal benthic species can significantly alter sediment stability, vertical profiles of solute and particulate materials, sediment digenesis, the movement of materials across the sediment-water interface, as well as the distribution and abundance of other species in the benthic community." Bioturbation also works in a number of ways to either facilitate or impede the transport of contaminants from burrows and tubes.

Riedel (1987), for instance, reported that N. succinea affected the distribution and flux of arsenic from the sediments by its production of irrigated burrows. On the other hand, Aller (1983) indicated that, "larger molecules such as various groups of dissolved organic matter may be little affected by the presence of burrow structures because of the low permeability of burrow linings." Martin and Sales (1987) reported that some chemical species are likely to be reactive in the burrow environment, and that these chemical reactions can actually impede the sediment-sea water exchange via burrows.

The effect of bioturbation on the rate of PCB transport has been addressed by Thibodeaux (1989). From this work, it appears clear that bioturbation is likely the dominant controlling factor for the rate of release of PCBs from Upper Estuary sediments. Biological diffusion (biodiffusion) factors were summarized by Thibodeaux (1989) and Whitlatch (1989). Authors they cite have considered the combined effects of various bioturbation processes, including sediment reworking, exposure to the overlying waters, the increase in surface area in which diffusion takes place and irrigation, to develop a biological diffusion factor. Thibodeaux (1989) has used these biological diffusion factors to model PCB flux from the sediments.

Although biological diffusion factors have been used to integrate a variety of bioturbation processes, it is important to realize that both numbers of individuals of benthic species as well as their activity is significantly greater near the surface. For instance, Myers (1977) found that sediment reworking rates in Charleston Pond, Rhode Island decreased considerably with depth; sediment turnover time for the top 1 cm was 0.7 to 4 days; for the top 2 cm, 2.4 to 11.8 days; and for the top 10 cm, 0.5 to 2.4 years.

3.1.1.2 Species Composition of Proposed Cap

In order to select an appropriate cap thickness, an evaluation of the burrowing depths of species now found in the estuary, or likely to be present after capping, was conducted. Whitlatch (1989) reviewed the relationship of recolonization dynamics and bioturbation characteristics to the proposed capping of the Upper Estuary in New Bedford Harbor. He concluded that a majority of the species presently existing in the Upper Estuary were fairly typical of other regional estuaries, although their numbers, both in terms of types of species as well as abundances, were depressed, likely reflecting the stressed conditions present. He concluded that the majority of present species, or others likely to recolonize the cap, all tended to be found in the upper 5 cm of sediment. This observation is consistent with a number of other studies of intertidal and subtidal infauna in the region (Myers, 1973; Rhoads, 1974; Rhoads, et al., 1978). Whitlatch did note, however, that there were several benthic species presently inhabiting New Bedford Harbor and surrounding waters which would likely be recruited to the new cap that could potentially penetrate deeper than 10 cm. These species included the polychaetes (Nereis succinea, Glycera americana, Heteromastus filiformis, Nephty sincisa, Amphitrite ornata, and Diopatra cuprea), the molluscs (Mya arenaria, and Ensis directus), as well as the mantis shrimp (Squilla empusa). He also noted that while it was unlikely that many of the epifaunal species, including both crustaceans and fish, found in the Upper Estuary would penetrate very deeply into the sediment, it is likely some species of ducks or geese could possibly develop 15 cm deep pits as they feed.

Polychaetes

Of the infaunal polychaete species mentioned above, H. filiformis appears to be the only one that would potentially feed on subsurface sediment (Whitlatch, 1989). This capitellid (approximately 1 millimeter diameter) has thin, random burrows not associated with tubes or sheaths; it may be thought of as interstitial (Myers, 1977a). The remaining polychaete species are either suspension feeders or surface deposit feeders.

H. filiformis is presently distributed primarily in the Middle Harbor, Lower Harbor and outside the hurricane barrier (SES, 1987). This species has been reported to burrow as deep as 30 cm (Cadee, 1979); however, it feeds primarily at depths shallower than 30 cm. Cadee (1979) reports the majority of feeding being between 10 and 20 cm below the sediment surface in intertidal areas in the Dutch Wadden Sea. Myers (1977) reported that H. filiformis was found to a depth of approximately 6 cm in Charlestown Pond, Rhode Island; Rice (1986) noted that H. filiformis typically feed at a depth of 12 to 16 cm in Lowes Cove, Maine; Whitlatch (1980) found H. filiformis maximum vertical abundance at 4 to 8 cm at Barnstable Harbor; and Hines and Comtois (1985) found the majority of H. filiformis at depths of 5 to 15 cm in central Chesapeake Bay.

N. succinea are reported to burrow to a depth of approximately 30 cm in central Chesapeake Bay (Hines and Comtois, 1989); however, its peak abundance was at the 10 to 15 cm depth in that study.

Diopatra cuprea was found at only one station in the New Bedford Harbor study area (south of the hurricane barrier) during the 1987 Sanford Ecological Services (SES, 1987) study. Magnam (1968) found that D. cuprea could penetrate to depths of 50 to 60 cm, and Myers (1972) determined they could burrow to the surface when covered experimentally with 30 cm of sediment. D. cuprea is usually found subtidally on soft bottoms (Myers, 1972) and has a predilection for relatively high current (Magnam, 1968) so this species is unlikely to exist in large numbers in the Upper Estuary, if at all.

Glycera americana and Nephtys incisa are errant (highly mobile) predatory polychaetes that can be expected to burrow as deeply as 15 cm (Whitlatch, 1989) in search of prey. Amphitrite ornata is not presently found in the Upper Estuary (SES, 1987) and, given its preference for more sandy conditions, is unlikely to occur in large numbers there even after capping. Although a sandy cap will initially be placed, subsequent deposition of fine particles will result in a less sandy environment. Amphitrite ornata builds U-shaped burrows whose bases can be found as deep as 30 cm (Aller and Yingst, 1978).

Molluscs

The two bivalves which have been identified as possibly being present in the Upper Estuary following cap placement that would be capable of penetrating deeper than 10 cm into the cap are M. arenaria, the soft shell clam, and Ensis directus, the razor clam. M. arenaria is found in intertidal and shallow subtidal, muddy to sandy sediments. In general, M. arenaria is found deeper in sandy sediments than in muddy ones (Hines and Comtois, 1985). While individuals of M. arenaria found in the Upper Estuary are of the size to borrow as deeply as 15 or 20 cm, it is unlikely, given the nature of the sediment even after the cap is placed, that with the exception of a few of the larger individuals, M. arenaria would burrow much deeper. E. directus, though not currently found in the Upper Estuary (SES, 1987), could potentially be found there in small numbers after capping takes place. While E. directus is a suspension feeder and normally feeds very close to the surface, larger individuals can burrow to depths of approximately 30 cm (Schiedek, 1987).

Squilla empusa

Although S. empusa has been reported by Myers (1979) to borrow to depths as much as 4 meters, it was not found in the Upper Estuary (SES, 1987), nor is it likely that the shallow Upper Estuary would recruit S. empusa after the capping operation. This species is generally restricted to subtidal environments and since large portions of the Upper Estuary are intertidal at spring tides, S. empusa are probably restricted now and will be even more so after the cap is placed.

3.1.1.3 Depth of Bioturbation Cap

Based upon the evaluation of information available regarding potential bioturbation depths in the Upper Estuary described above, a bioturbation zone cap depth of 20 cm was selected to separate significant benthic biological activity from both underlying contaminated estuary sediments as well as the cap chemical migration barrier. This 20-cm-thick layer of surfical sediment should provide an adequate sediment zone in which the large majority of bioturbation activity and significant majority of benthic species will occur. Although some species have been identified which could recolonize the Upper Estuary following completion of remedial activities that have the potential to penetrate to depths in excess of a 20 cm, most individuals of these species are not likely to be found at depths greater than 10 to 20 cm.

The conclusion to use 20 cm as the thickness for the bioturbation layer is also consistent with the Sturgis and Gunnison (1988) recommendation based on their review of the potential for benthic penetration of the cap. As they state, "in developing a final recommendation for the thickness of cap material required to prevent breaching, it is necessary to consider the frequency of occurrence as well as the burrowing depths of most of the organisms in the area. Most of the organisms in the inner harbor area burrow to depths no greater than 20 cm."

As previously stated in Section 2.2, an erosion protection system consisting of geofabric, stone, and geoweb will be installed over portions of the cap which are subjected to elevated peak discharge flow velocities. Due to the physical and chemical makeup of this erosion protection system, primarily surface dwelling benthic species are expected to reside over this portion of the cap. Because the presence of this system is expected to substantially limit the degree and affect of bioturbation activity, this transport process should not be significant in terms of contaminant transport over this portion of the cap.

3.1.1.4 Bioturbation During Capping Operation

Whitlatch (1989) suggested that during construction of the cap, some species would have the ability to migrate through the newly deposited capping material, even at depths up to the 45 cm contemplated, thereby potentially acting as conduits for the movement of contaminants to the surrounding uncontaminated sediments. While at least one species, N. succinea, has been documented to successfully migrate through a sediment cap of this thickness, it is unlikely that this would provide a significant mechanism for contaminating overlying sediment. N. succinea burrows through the sediment without making a permanent burrow, and it is reasonable to assume that as sediment was being laid down, burrows made by an N. succinea escape would be closed by sediment movement and consolidation during the capping process. Furthermore, a geofabric will be installed as the initial component of the containment cap. Penetration of this geofabric layer by underlying species is very unlikely.

3.1.1.5 Chemical Barrier and Its Relation to the Depth of the Cap

Under present conditions, active transport mechanisms in bed sediments can cause the transfer of PCB molecules across the sediment-water interface. As previously stated, next to bioturbation, molecular diffusion appears to be the most significant contaminant flux mechanism in the Upper Estuary sediment bed (EPA, 1989; Thibodeaux, 1989). Thibodeaux's discussion of PCB flux from Upper Estuary sediments, as well as the role capping will play in reducing this flux, is included as Attachment B. A summary of this discussion is presented below.

According to Thibodeaux (1989), PCB transport across the sediment-water interface begins with PCB molecule desorption from bed particles followed by vertical movement to the sediment-water interface by molecular diffusion and bioturbation, or bioturbation alone, with bioturbation being the principal vertical transport mechanism. Compared to molecular diffusion, the rate of chemical transport associated with bioturbation is several orders of magnitude faster (Thibodeaux, 1989). Once at the sediment-water interface, PCB molecules move in solution through a water side layer (benthic boundary) prior to transport through the water column. At this juncture, PCB transport from the sediment bed may be retarded due to the fallout of depositional material onto the sediment surface. These relatively clean, newly-deposited particles are mixed downward by bioturbation, resulting in fresh sorption sites for PCB molecules and consequent concentration dilution in upper sediment layers. In addition, the deposition of new sediment effectively lengthens the transport pathway distance within the sediment. This natural capping process results in shifting the bioturbation zone upward away from the more elevated PCB contamination and significantly reduces the flux rate. In essence, natural capping can alter the transport process from one of bioturbation to molecular diffusion (Thibodeaux, 1989).

The alteration of the primary transport process from bioturbation to molecular diffusion is significant because molecular diffusion of PCB is a rate-limited process. PCB diffusion from contaminated estuary sediments into interstitial pore water is a function of several variables, including the chemical specific properties of PCBs. For diffusion to occur, PCBs must desorb from contaminated particles. This desorption process is a function of the organic content of the sediment as well as the particle grain size and charge. Particles with higher organic carbon as well as increased surface area (i.e., silts and clays) will tend to desorb less PCB compared to inorganic, coarse grain sediment. These same variables, as well as the PCB sediment concentration, also affect the equilibrium concentrations of PCBs in the interstitial water.

However, desorption of PCBs from estuary sediments to interstitial waters is limited by the low solubility of PCBs in salt water and the hydrophobic nature of PCBs. These PCB chemical specific properties serve as the limiting variables for the molecular diffusion process. Thus, even in portions of the Upper Estuary where elevated PCB sediment concentrations have been observed, or where sediment chemistry or organic nature is not favorable for sorption of PCBs, desorption of PCBs from these sediments is limited by the solubility limit of PCBs; the solubility limit of Aroclors 1242 and 1254 in sea water are 88 micrograms per liter (parts per billion) and 12 micrograms per liter, respectively (Thibodeaux, 1989).

Once dissolved into interstitial pore water, PCB molecules are free to migrate through the molecular diffusion process. This process is random in nature and results in both vertical and horizontal PCB migration. As a means of evaluating this PCB diffusive process in Upper Estuary sediment, Balsam conducted a sediment sampling program at two sites within the Upper Estuary to ascertain PCB distributional variability (Balsam, 1989); the results of this sampling program are included as Attachment D. The two sites were selected to represent two different environmental regions; these sampling sites are shown on Figure 3.2. One sampling station, designated as station FX, is located approximately adjacent to the area designated by EPA as the PCB "Hot Spot," where elevated PCB concentrations are reported to be present in estuary sediments. The other station sampled, designated as Station DR, was located in an area where sediment deposition was expected to occur and where lower PCB concentrations had been reported present. Samples collected from these two stations were subsectioned into thin layers from 1 to 4 centimeters in thickness and submitted for laboratory analyses. The results of PCB analysis for these thin layer sediment samples are depicted in Figures 3.3 and 3.4.

Thibodeaux (1989) interpreted the data generated from these two sites in terms of PCB transport mechanisms and flux. According to Thibodeaux, site FX exhibits high PCB bed sediment concentrations with decreasing levels toward the sediment-water interface. This interpretation is consistent with high pollutant loading followed by depositional capping, transport and release to the overlying water column. These findings are consistent with sedimentation and hydrodynamic studies performed by others (ASA, 1987; Teeter, 1988).

Interpretation of data from Station DR is more complex. Concentration fluctuations observed in the PCB profile at Station DR may be due to vertical sediment mixing associated with bioturbation and/or lateral PCB migration from adjacent source areas. Station DR may also currently be receiving PCB input from source areas within the Upper Estuary or Middle and Lower Harbor, suggesting periodic sediment input from higher concentration PCB source areas and/or desorption of PCBs from the water column.

The PCB analytical data collected from Stations DR and FX were helpful in evaluating the occurrence of molecular diffusion as a PCB transport mechanism within the Upper Estuary. Classical "diffusion tails" were evident for each of the Aroclors at both sites sampled from a depth of 15 centimeters and deeper (Thibodeaux, 1989). The location of PCB contaminated sediment and these diffusion tails within the sediment bed sampled, as well as the shape of these tails, are consistent with the reported discharge history of PCBs within the New Bedford Harbor area and the resultant PCB distribution profile one would expect to exist in the sediment if diffusion were occurring. These data support the finding that diffusion functions as one of the principal contaminant transport mechanisms within New Bedford Harbor sediment.

Based on laboratory tests performed by the USACE, an initial analysis was performed to select an adequate sediment cap thickness to contain PCBs in Upper Estuary sediments (Sturgis and Gunnison, 1988). Sturgis and Gunnison concluded that a cap thickness of 35 centimeters overlying contaminated New Bedford Harbor sediment prevented contaminants from entering the overlying water column. This conclusion was reached based on the result of "small-scale predictive tests" performed in the USACE WES laboratory using varying thicknesses of New Bedford Harbor sediment and highly soluble tracers (ammonium-nitrogen and orthophosphate-phosphorus). The purpose of these tests was to determine whether these highly soluble, and hence highly mobile, tracers could effectively be contained by capping with harbor sediment. The result of the tests indicated that, "with a cap thickness of 35 cm, the contaminated New Bedford Harbor sediment was not exerting any influence on the overlying water column" (Sturgis and Gunnison, 1988). Closer examination of these same data allowed the selection of a cap thickness which would effectively contain PCBs as part of the remedial process. A verification test performed by Sturgis and Gunnison using PCBs as a contaminant source and a

35 cm sediment containment cap substantiated results obtained in the small-scale predictive test. However, caps of a thickness less than 35 cm were not tested in the laboratory to assess their ability to contain PCBs.

Because the solubility, and hence mobility, of PCBs is orders of magnitude less than the two conservative tracers used by Sturgis and Gunnison in their small-scale laboratory predictive test, the results of the small-scale test provided an extremely conservative basis to determine the effectiveness of a sediment cap in containing PCB. Accordingly, an analytical assessment of the ability of caps less than 35 cm thick to contain PCBs was performed by Thibodeaux. The results of this analysis indicated that a sediment cap thickness of much less than 35 cm would be effective in containing PCBs in Upper Estuary sediments, assuming the effects of bioturbation could be removed from the contaminant-affected sediment zone (Thibodeaux, 1989). The analysis performed by Thibodeaux (1989) indicated that even a very thin cap (e.g., 5 cm) possessing 1.0 percent organic content absent bioturbation would provide approximately 100 years of containment prior to PCB breakthrough, and a cap of 10 cm possessing 1.0 percent organic content would provide approximately 500 years of PCB containment prior to the occurrence of breakthrough. Based on this analysis of site contaminant migration processes as well as the results of this USACE study and subsequent analysis, a cap thickness of 25 centimeters was selected to provide a chemical transport barrier between existing contaminated Upper Estuary sediments and the overlying 20 centimeter thick bioturbation activity layer of the containment cap.

In order to evaluate the effectiveness of this proposed capping system, analytical models were employed as tools to assess the amount of PCB flux from Upper Estuary sediments and to determine the effectiveness of the proposed capping system. As previously discussed, bioturbation was found to be the principal factor controlling PCB flux from Upper Estuary sediments to the overlying water column. However, no site specific information quantifying precise bioturbation or biodiffusion factors are available.

Thibodeaux's analysis included the comparative results of three models. To analyze PCB flux from Upper Estuary sediment, Thibodeaux selected a biosolids transport model which assumed less than complete sediment mixing. This modeling approach was simpler than other sediment flux models considered, but was considered more reliable because parameter values required for this model could be identified more conservatively. For example, this model utilized a constant diffusion coefficient throughout the sediment column to integrate the effects of bioturbation and diffusion (Thibodeaux, 1989), although a basis exists for concluding that the lower sediment layer is less bioactive. Accordingly, the results of this sediment flux model were expected to be more conservative (i.e., would provide higher PCB flux estimates.)

Thibodeaux (1989) then compared the results of the sediment flux model to estimates of sediment flux calculated from consideration of measured water column concentrations (Battelle, 1985) assuming mass balance of PCB was conserved (i.e., overall mass balance and fate analysis model). Estimates using this "water-side" mass balance model gave values near the lower end of the range predicted by sediment flux model.

Finally, Thibodeaux considered estimates of sediment flux rates calculated from direct field measurements of PCB (i.e., water-flow-by-concentration model). These estimates included those developed by the EPA Emergency Response Team (1983), Teeter (1988) and ASA (1989). The review of these data indicated a wide range of reported PCB flux rates. The average flux rate reported by EPA (1983) was 639 kilograms per year (kg/yr); the average flux reported by Teeter (1988) was 1091 kg/yr; the average reported by ASA (1989) was 317 kg/yr (See Attachment F). It was noted that the experimental design of the ASA study was far more comprehensive. Although there were problems in the experimental design of the EPA (1983) and Teeter (1988) studies, if, for purposes of this discussion only, they are considered along with the ASA (1989) data as representative flux measurements for the day the study was conducted, then the simple average of the flux during these 12 days was 590 kg/yr. This average flux rate is within the range of 200-600 kg/yr in the EPA "Hot Spot Feasibility Study".

Thibodeaux then compared the results of these three models to develop a "range-of-confidence-of-predictions" from the three models. Based upon the relative certainty of the ability to define the values for key input parameters in the model, he judged the two water-side models, the water-flow-by-concentration and the overall mass balance, to be the most probable estimator of sediment flux. For various reasons, it was felt that the upper end of the range predicted by the sediment flux model was probably unrealistically high. Thibodeaux's conclusion was that the rate of PCB leaving the sediment is most probably in the range of 500 to 6,000 kg/yr. Of that amount, approximately 41 percent of the PCB evaporates and the remainder, or about 300 to 3,500 kg/year, is transported by the water route under the Coggeshall Street bridge. This information was used to assess the effectiveness of the cap which is discussed below in Section 5.3.

3.2 EXTENT OF REMEDIAL CAP

As previously discussed, the extent of the cap will include all areas within the Upper Estuary reported to contain greater than 50 ppm PCB; in addition, portions of the eastern shore of the Upper Estuary where less than 50 ppm of PCB was reported present in sediments will also be capped to connect the cap and the existing eastern sandy shore line. On this basis, the area of the proposed cap is estimated to be approximately 140 acres. The extent of this cap is presented on Figure 3.5. The extent of the containment cap was determined primarily based on the magnitude of PCB flux reduction from the Upper Estuary, the amount of PCB which would be physically contained by the cap, and consistency with comparable recent regulatory decision.

The analysis by Thibodeaux described above indicates that 99 percent of the current PCB flux from Upper Estuary sediments is attributed to sediments containing 50 ppm PCB or greater (Thibodeaux, 1989). The results of this analysis are graphically shown in Figure 3.6. As discussed more fully in Section 5.1, Overall Protection of Human Health and the Environment, eliminating 99 percent of PCB flux from the Upper Estuary by capping sediments which contain PCB concentrations of 50 ppm or more was judged to be effective in significantly reducing potential adverse impacts from PCBs present in harbor sediment to human health and the environment. Additionally, because approximately 90 percent of all PCB present at the New Bedford Harbor site is present within the Upper Estuary, and because the substantial majority of this PCB is present in sediment with concentrations of 50 ppm or greater of PCB, the cap will remove nearly 90 percent of all PCBs from potential direct contact to human or environmental receptors (Balsam, 1989). The majority of sediments existing in intertidal or shallow portions of the remainder of the Upper Estuary and harbor site contain much lower levels of PCBs and are not expected to pose a significant health hazard to the public. Furthermore, because the Middle Harbor and Lower Harbor areas contain active large boat traffic and relatively deep water to support this traffic, sediments present in much of this portion of the site do not pose a significant threat to human health because potential exposure through direct contact with these submerged sediments is highly unlikely.

In order to evaluate the acceptability of a 50 ppm PCB clean-up level for remediation of Superfund sites, a review of recent (post-SARA) decisions by EPA at sites similar in nature to the New Bedford Harbor site was made. Based on this review, the Waukegan Harbor Superfund site, located on Lake Michigan in Waukegan, Illinois, was found to be most comparable to the New Bedford Harbor site. At the Waukegan Harbor site, Outboard Marine Corporation (OMC) was alleged to have discharged significant amounts of PCB to Waukegan Harbor; concentrations of PCBs in harbor sediments were reported to exceed 100,000 ppm. PCBs were found to have migrated from discharge areas adjacent to the OMC factory into Lake Michigan. Elevated levels of PCBs were found to exist in biota both within Waukegan Harbor as well as outside of the harbor.

One similarity between the OMC Waukegan Harbor site and the New Bedford Harbor site is the presence of recreational and commercial fisheries in close proximity to both harbors. As previously discussed, New Bedford Harbor serves as the port for a significant commercial and recreational salt water fishing fleet. Waukegan Harbor also serves as a port to both recreational and commercial fishing vessels using Lake Michigan. As such, achievement of a PCB clean-up level adequate to not only protect human health but also to protect the integrity of this fishery was a central issue in the development of an acceptable clean-up program.

Following the completion of numerous studies to evaluate clean-up of Waukegan Harbor, the EPA, State of Illinois and OMC signed a consent order in 1988 for remediation of the harbor. Prior to signing this consent order, EPA reevaluated the Record of Decision previously signed in 1984 to assure consistency of the remedy with SARA (Cleanup of Outboard Marine Corporation/Waukegan Harbor Site, Explanation of Significant Differences, EPA, September 1988). As part of the 1988 consent order, a 50 ppm PCB action level was selected as the limit for remediation in the harbor. Because the PCB contaminated portion of the harbor had active boat traffic and would likely be dredged in the future to maintain acceptable navigational depths, sediment with PCB levels above 50 ppm are to be dredged from the harbor, with some portion of these sediments being contained in an on-site containment facility.

Based in part on the similarities between the New Bedford Harbor site and the Waukegan Harbor site including geography, natural resource value, public use and contaminant nature, as well as the timeliness of the 1988 EPA decision for clean-up of Waukegan Harbor, a 50 ppm PCB clean-up level was judged to be appropriate for the New Bedford Harbor site.

3.3 HYDRAULIC SETTING AND CONTROLS

3.3.1 Description of Hydraulic Setting

The Acushnet River drainage basin is approximately 18 square miles with an average annual discharge of approximately 10 to 30 cfs (Cortell, 1982; Signell, 1986). There are no long-term gauging stations on the Acushnet River, and only short-term runoff measurements have been available for the river, which has resulted in a variable estimate of flow rate for the river. Measurements of Acushnet River flow during and after precipitation events accordingly were not available.

Existing precipitation records for the area, physical characteristics of the drainage basin and existing flow information were evaluated to estimate flow velocity and discharge rates from the Acushnet River in the Upper Estuary in response to a 50-year storm event. This evaluation was performed utilizing available historic precipitation data for the New Bedford area and the USACE HEC-1 Flood Hydrography Model (HEC-1). This modeling evaluation is included as Attachment E. The HEC-1 50-year storm predicted peak flow rate was 39.6 cubic meters per second (m^3/s) (1397 CFS), which would result in a mean flow velocity of 1.1 feet per second (fps) in one of the narrowest portions of the Upper Estuary under present conditions. This estimate does not consider the likely change in cross-sectional area of flow due to rising and expanding surface water during such a runoff event and, therefore, presents a conservative estimate since a larger cross-sectional area would reduce flow velocities at a given discharge rate. A storm runoff event will dominate flow conditions in the northern portion of the Upper Estuary during its duration and will overshadow tidal fluctuations which are occurring. The analysis was conducted assuming low water conditions to simulate highest reasonable velocity estimates. Flood tide conditions would result in larger cross-sectional flow areas for the discharge and result in lower channel flow velocities. The placement of a 45-cm cap over contaminated sediments in portions of the Upper Estuary will result in reduction of channel cross-sectional flow area, and an increase in channel flow velocities for a given discharge rate.

In order to estimate maximum post-remedial flow velocities resulting from the HEC-1 predicted 50-year storm discharge in the narrow (northern) section of the Upper Estuary, two models were employed (ASA, 1988; ASA, 1989). This modeling was performed utilizing the HEC-1 50-year storm hydrography, and assumed all capping had been completed and that primary sediment consolidation had occurred. Descriptions and results of this modeling are provided as Attachments G and H. The inlet-basin hydrodynamic model (provided as Attachment G) was initially used to estimate post-capping surface water flow velocities and predicted a mean flow velocity of 1.92 fps in the narrow channel cross section near the Aerovox Industries facility. ASA concluded that the results of this model provided good first-order estimates of flow velocities, and concluded that use of another model would provide a further basis to better estimate these flow predictions.

The National Weather Service (NWS) DAMBRK model was also applied to simulate conditions resulting from the HEC-1 predicted 50-year storm event (ASA, 1989). Results of this modeling effort are included as Attachment H. The DAMBRK model is a more sophisticated, physically-based model then the inlet-basin model and has been widely used to predict flood flows from dam breaks and runoff events. The HEC-1 predicted 50-year storm hydrography was used as the upgradient boundary condition and downstream conditions were simulated by DAMBRK. The maximum flow velocity predicted by the DAMBRK model was 4.29 fps which is more than twice as high as the value estimated from the simplified inlet basin hydrodynamic model. The DAMBRK model was run assuming low water conditions (MLW) which will result in maximum flow velocities in the river. Peak runoff flood flows which occur during other tidal stages will result in lower velocities; however, the flow directions and relative magnitudes are not expected to change significantly as a result of tidal fluctuations. Although the results of the DAMBRK model were much higher than those of the inlet-basin model, they were selected for use to design and use the cap erosion protection system to provide a conservative design basis with an adequate safety factor.

3.3.2 Hydraulic Controls

To facilitate implementation of the remedial design, hydraulic controls will be used during construction. The installation of an adjustable weir dam in the vicinity of the Coggeshall St. Bridge along with active operation of upstream dams located at the Acushnet Saw Mill, Hamlin Street and the New Bedford Reservoir allow significant control over the hydrodynamics of the Upper Estuary. Construction of an adjustable weir dam will effectively provide the ability to isolate the Upper Estuary from the lower harbor areas and will:

- Provide constant and controlled water depths for construction activities,
- Limit sediment transport from the Upper Estuary into lower harbor areas, and
- Allow further control of hurricane or storm surges or tides associated with extreme storm events.

The conceptual hydraulic control system is presented as Figure 3.7.

3.3.2.1 Coggeshall Street Weir Dam

As previously described, the Upper Estuary is a shallow basin with restricted circulation. At MLW, some portions of the Upper Estuary sediments are exposed and other areas may be submerged by less than 2 feet of water, especially in the northern part of the estuary near the Aerovox facility. These shallow water depths could affect some construction activities. Tidal velocities and dynamics, although not significant throughout most of the Upper Estuary, also could affect construction schedules and activities. Construction activity rate and efficiency could be significantly increased by providing for control of water level and tidal flow in the Upper Estuary.

An adjustable weir dam constructed north of and adjacent to the Coggeshall Street Bridge would allow for effective control of surface water elevation and tidal flow in the Upper Estuary. ASA (1988) recommended the use of a steel H-pile and Z-sheet dam with variable weirs as a means of providing this hydraulic control. One of the principle advantages of an H-Z sheet pile dam is that it could be constructed in a rapid manner from the Coggeshall Street Bridge without the need for temporary coffer dams. A conceptual drawing of this variable weir dam is presented as Figures 3.8 and 3.9.

Due to the proximity of the proposed dam to the bridge and low clearance beneath the bridge, the bridge will be used as the work staging area. If it is necessary to divert traffic during construction of the dam, traffic will be rerouted to the Wood Street, I-195 or Route 6 bridges. Because this aspect of construction is expected to require less than four weeks, impact on traffic is expected to be minimal.

Prior to the installation of the adjustable weir dam, a soil boring program will be performed to determine the subsurface soil conditions along the centerline of the proposed dam. Once the subsurface soil conditions are clearly understood, an engineering study addressing pile driveability, imposed shear and bending stress, and anticipated settlement will be performed. It is anticipated these studies will take three to four months to complete.

Upon completion of design of the adjustable weir dam, construction specifications will be drafted and the project let out to bid.

As stated above, the proposed dam would aid in construction by establishing a constant water level which would not be subject to tidal variations. To achieve a constant high water level, the dam weirs would be open on an incoming tide.

When the high tide water level occurs, the weirs would be closed and high tide conditions maintained on the upstream side of the dam. It is estimated that by use of this variable weir, approximately 3 to 4 feet of water could be added to the low tide level. Similarly, water levels below MSL could also be maintained if some tasks, such as rip rap placement, could be more efficiently conducted in dry or shallow water conditions.

Opening of the weirs would be performed at predetermined intervals to minimize stagnation and detrimental changes in the salinity of Upper Estuary water. The dam weirs have been designed to allow a full range of tidal hydraulic control in the Upper Estuary. With all three dam gates removed, a flow regime comparable to existing conditions would exist; with a reduced net cross-sectional flow area on the order of 110 square feet, flow would be reduced approximately 65 percent (ASA, 1988). In addition to adjusting the weirs to limit the potential for surface water stagnation, it may be advantageous to open the dam to facilitate accelerated consolidation of the cap in areas where the cap will be exposed at low tide. By exposing the cap to the atmosphere, the effects of buoyancy are reduced, and effective bearing pressure on the sediments underlying the exposed section of the cap would be increased, resulting in more rapid consolidation of these sediments.

In addition to allowing control over the Upper Estuary surface water elevation, the dam would also safeguard against one potential PCB transport mechanism during cap construction. Should sediment become resuspended during construction activity, additional time would be provided for settling of the resuspended sediment prior to potential transport into the harbor.

A permanent adjustable weir dam could also be beneficial during the occurrence of storm events. Prior to a storm event, the weirs in the dam could be adjusted to best accommodate storm conditions. This benefit would be realized both during and after construction. Additionally, in the unlikely event that the cap would require repair or maintenance at some time in the future, the surface water elevation could once again be controlled with little effort.

The variable weir dam would be operated to minimize adverse effects on the existing saltmarsh. A discussion of this operational parameter is provided in Section 5.5 of this report.

3.3.2.2 Upstream Controls

To moderate flow of the Acushnet River into the Upper Estuary, the New Bedford Reservoir dam, Hamlin Street dam and the Acushnet Saw Mill dam could be utilized. The New Bedford Reservoir dam, Hamlin Street dam and the Acushnet Saw Mill dam are located approximately 3 1/2, 1 1/4 and 1/2 miles north of the Wood Street bridge, respectively. The location of these dams is shown in Attachment E. At this time, the New Bedford Reservoir dam and Hamlin Street dam are operating with their adjustable weirs nearly open. The Acushnet Saw Mill dam, on the other hand, is operating with its adjustable weir nearly closed. Modification of the operation of these dams could result in significant reductions of potential peak flows from the Acushnet River into the Upper Estuary.

Assessment and activation of upstream hydraulic controls can be conducted during the design and construction of the adjustable weir dam. Initially, the dams located at the Acushnet Saw Mill, Hamlin Street and the New Bedford Reservoir will be assessed to determine their functional ability. It is unclear at this time if these dams are adjusted on a regular basis. Personal observations have indicated that these dams have not been adjusted for some time.

In addition to a functional assessment, arrangements will be made with the parties responsible for the operation of these dams to ensure that the water flow can be regulated.

3.4 MULTIMEDIA CAP

The design and construction of a multimedia cap involves technologies which have been independently used for years. As proposed, the multimedia cap would entail the placement of a woven geotextile over Upper Estuary sediments containing PCB concentrations in excess of 50 ppm. A typical cross-section of this cap is presented as Figure 3.10. A minimum of 15 cm of armored cap (stone and geofabric, with geoweb in some areas) will be constructed over 30 cm of sandy cap sediment in areas where peak storm flows may erode the cap sediment. In addition, armored cap will be installed over five acres of sediment with the highest reported PCB concentrations to increase the physical integrity of this portion of the cap and to make human breaching of this portion of the cap more difficult. A typical cross-section of the armored cap is presented as Figure 3.11. It is anticipated that a total of approximately 22 acres of the 140 acre cap will involve placement of armored erosion protection. Figure 3.12 depicts the approximate location of areas requiring erosion protection. A more detailed discussion of the analysis performed to determine the extent of erosion protection armored cap is contained in Section 3.4.5. Saltmarsh grass will be planted on the approximately 19 acres of intertidal cap which will exist between MSL and MHW.

3.4.1 Sediment Bed Response

Subsurface sediment conditions in the Upper Estuary consist mostly of fine grain organic silts and/ or clays underlain by predominantly fine to coarse sands. Studies by Woodward-Clyde Consultants (WCC) (1987) indicate the thickness of the organic silt and clay stratum varies from approximately 0 to 14 feet. Typically, the thickest deposits of fine grain soils were observed along the southern and western portions of the Upper Estuary. These observations appear to be in agreement with data presented by the USACE (1986). The variability in the thickness of the fine grained soil layer is due to the tidal variations, sediment depositional rate, and water velocity variation throughout the Upper Estuary.

To date, limited data are available describing engineering properties of these marine sediments. A study conducted by Geotechnical Engineers, Inc. (GEI) (1987) addresses some engineering properties of the marine sediments; however, this study was confined to the USACE Confined Disposal Facility (CDF) located along the western shore line in the southern portion of the Upper Estuary. In this study, which indicated the presence of silt/clay layers of up to 17 feet, selected undisturbed soil samples were tested for index properties, consolidation characteristics and shear strength determination. Results of index tests showed that fine grained soils were composed of organic clay containing approximately 20 to 30 percent fine to medium sand with occasional shells and organic matter. These soils were highly plastic, and generally had natural moisture contents at or above the soils liquid limit (LL). Liquid limits for the samples tested typically ranged from 83 to 122, while the plasticity index (PI) varied from 58 to 87. (The liquid limit of a soil is the moisture content which, when exceeded, will cause the soil to behave in a liquid state. The plasticity index is the magnitude of the water content range over which the soil remains plastic.) Natural moisture contents for these samples range from 92 percent to 128 percent. These data are slightly above the results reported by WCC due to changes in the soil type. WCC's data showed liquid limits to range from 43 to 77, plastic limits to range from 26 to 37, and natural moisture contents to range from 89 to 91 for the samples being discussed. The values of index properties reported above are considered typical for the soils encountered in the Upper Estuary. These values are also consistent with data for sediments within the active harbor area (EBASCO, 1988).

Using liquid limit data and Koppula's equation (Koppula, 1986), it is possible to estimate a value of the coefficient of consolidation which can be used in predicting settlement of the cap.

$$Cc = 0.009\ w + 0.005\ LL$$

where: Cc = Coefficient of consolidation,
w = Water content, and
LL = Liquid limit.

Based on the above referenced data and Koppula's equation, Cc was calculated and found to range from 1.01 to 1.76, with an average value being 1.30.

Olko Engineering Inc. (Olko) used the results of these index and consolidation tests to predict settlement in the organic silt/clay layer following cap placement (Olko, 1989). Settlements were calculated by:

$$H\ pri = \frac{Cc\ H}{(1+e_o)} \log \frac{[Po + P]}{Po}$$

where: H pri = Primary settlement,
Cc = Coefficient of consolidation,
H = Thickness of compressible soil layer,
Po = Effective overburden pressure,
P = Average increase in pressure
e_o = Void ratio at sample depth

It should be noted that the magnitude of settlement is a function of the thickness of the compressible soil layer (i.e., the organic silt and/or clay layer). The study by GEI reported the thickness of the organic silt/clay layer to range from 0 to 17 feet. Using a soil layer thickness of 17 feet, predicted primary settlement, which is expected to be on the order of 90% of total settlement, is approximately 0.9 feet. This primary settlement is expected to occur within six to twelve months after the sand cap has been placed.

The time required for the sediments to achieve primary consolidation was calculated using the following equation and a consolidation time factor for 90 percent consolidation equal to 0.848 (Terzaghi and Frolich, 1936).

$$t_{90} = T_{90} \frac{(H/2)^2}{C_v}$$

where:

where:	t_{90}	=	Time for sediments to undergo 90% consolidation
	T_{90}	=	Time factor (0.848)
	H	=	Compressible layer thickness
	C_v	=	Coefficient of consolidation

The value of C_v was chosen as 2.0×10^{-6} based on results of two incremental consolidation tests conducted as part o the GEI study.

In addition to primary settlement, the compressible soils will undergo secondary settlement. For the soil conditions discussed above, Olko (1989) predicted approximately 0.2 feet of secondary settlement which would occur during a subsequent 10 year period.

As previously stated, the magnitude of the settlement can be expected to vary as the thickness of the compressible layer varies. Since the thickness of the fine grained soil layer varies from 0 to 17 feet throughout the Upper Estuary, differential settlements can be expected. Olko (1989) predicted total settlement of approximately 0.7 feet based on a 4-foot-thick layer of organic silt/clay as compared to 1.1 feet of settlement based on a 17-foot-thick layer of the same soil.

Consolidation of the sediment cap material is expected to occur rapidly during the time of cap placement and, thus, should be monitored easily during placement to ensure installation of a minimum of 45 cm of cap material.

Figure 3.13 shows Upper Estuary habitat following cap placement, sediment primary consolidation, and saltmarsh establishment.

3.4.2 Geotextile

The potential for resuspension of contaminated sediments during the cap placement has been identified as an area of concern. Due to the soft nature of Upper Estuary fine grain sediments, placement of capping materials directly on the sediments could result in mixing of the cap material with the underlying sediments. To alleviate this condition, the use of a geotextile has been proposed for all areas designated to be capped.

3.4.2.1 Selection Criteria

Selection of the geotextile should focus primarily on the tensile strength and porosity of the fabric. It is anticipated that the greatest tensile stresses experienced by the geotextile will occur during deployment. Woven fabrics tend to have roughly twice the tensile strength as non-woven fabrics. In addition, non-woven fabrics undergo a reduction in tensile strength when they become inundated (Moraino, 1989).

Porosity is another important factor to consider in selecting the geotextile. Due to the large quantities of fabric this project will require, manufacturers have indicated that they can adjust their looms and custom weave a fabric for this project. Accordingly, as part of the final remedial design, a geofabric porosity will be specified which will effectively contain Upper Estuary sediments.

It should be noted that the greatest potential for sediment resuspension relative to the geotextile will occur around the periphery during deployment. However, it is believed that the potential for resuspension when using a woven geotextile will be negligible. Lastly, one additional benefit of using a woven geotextile in a marine environment is that it is easier to place under water since it has a lower capacity to absorb water. Typically, the fiber matrix of a non-woven geotextile absorbs water, thus increasing the working weight. By increasing fabric weight, it becomes more difficult to position the fabric in place. For these reasons, a woven geotextile appears most appropriate for use as the sediment cap underliner.

3.4.2.2 Anchoring

As previously stated, the limits of the cap would extend to areas where sediment PCB concentrations are less than 50 ppm. It is expected that the conditions encountered at the edge of the cap will vary. Along portions of the western shoreline, the cap will abut sheet pile bulkheads. In these areas, it may be possible to anchor the filter fabric by slowly depositing sandy soils from the shore on top of the fabric. Along the eastern shoreline, and in the remaining portions of the western shoreline, the filter fabric can be anchored using sand bags or sand socks. Sand socks are fabricated from remnants of geotextile and are filled with sand to form a cylindrical tube or elongated sand bag which is attached to the nearshore edge of the geotextile just prior to deployment.

3.4.2.3 Geotextile Deployment

Deployment of geotextiles in marine environments is not a unique concept. According to Moraino (1989), geotextiles have been used for containment of marine sediments in the United States for years. At the Suburu site in Boston, Massachusetts, cables and winches were used to position barges during the deployment of approximately 3,000 square yards of geotextile in a marine environment (Moraino, 1989). This program provided information regarding operational aspects of geofabric installation over submerged sediments.

One advantage of the New Bedford Harbor site as compared to many other sites is that due to the proposed use of hydraulic controls, i.e., the Coggeshall Street dam, there will be little effect from currents and tides during the positioning of barges. Thus, the key factor in geotextile placement in the Upper Estuary will be maneuvering barges and overcoming wind forces without disturbing the soft marine sediments. To limit the potential for disturbing sediment during deployment, a system of cables and winches can be employed to position barges. Actual deployment of the geotextile could be accomplished in a number of ways depending on the specific site conditions encountered in the vicinity of the area to be covered. It is anticipated that the geotextile will be deployed by either pulling and floating large sheets of fabric from the shore, or by unrolling the fabric from barges located in the Upper Estuary. Figures 3.14 and 3.15 depict conceptual deployment operations. Other modified methods of geofabric placement, such as deployment of folded piles of fabric from a barge, may also be utilized. The length and width of geofabric sheets and rolls will be determined for manageability in each application. Due to the large lateral extent of coverage, overlapping of sheets of fabric will be required. As the sheets of geotextile are placed, an overlap of approximately 5 feet would be made to limit the potential for underlying sediments to migrate during hydraulic placement of the sand cap. A more detailed discussion of how geofabric will be deployed is presented in Section 3.4.4 of this document.

3.4.3 Cap Sediment Selection

In place containment of contaminated sediments will include placing a clean sediment cap over the contaminated materials. This process has been shown to be an operationally feasible, cost-effective and environmentally sound method for contaminated dredge spoil disposal and contaminated bottom sediment containment in the marine environment. Previous studies have shown both sand and silt to be effective capping materials. However, it is recommended that sandy material be utilized as the capping material for the Upper Estuary based upon its:

- Physical Integrity,
- In Place Density,

- Ease of Placement,
- Rate of Consolidation,
- Ability to Support Rapid Recolonization,
- Ability to Reduce Contaminant Transport, and
- Cost-Effectiveness.

A study by the USACE using Stamford-New Haven Harbor, Connecticut sediment (SAIC, 1980) was performed to evaluate the effectiveness of sand and silt as capping material. Like the Acushnet River Upper Estuary, these sites contained elevated levels of PCBs and heavy metals. The results of this study indicated that both sand and silt could effectively cap and contain contaminated sediments.

The USACE study (SAIC, 1980) indicated that silt, if placed by hoppers, generally produces a thick, unconsolidated cohesive cap with rough microtopography. The cohesive nature of silt precludes extensive areal spreading of the cap and results in a rugged microtopography. Conversely, sand, which is more easily spread, produces caps which are dense and form an essentially smooth continuous layer over contaminated sediments. At the Central Long Island Site (SAIC, 1980), Hurricane David was found to have significantly reduced the thickness of a silt cap whereas a nearby sand cap was largely unaffected. This suggests sand can be a more stable capping agent than silt. The interaction of storm waves and rough microtopography of the silt could lead to large scale erosion and sediment transport if the silt cap is not smoothed and/or consolidated prior to the commencement of significant hydraulic activity.

As compared to silts and clays, sand as a capping material is also easier to handle during the placement. Sand would cover contaminated sediments with a clear demarcation, and because of its rapid consolidation properties, would not experience significant secondary settlement. A principal advantage of using sands as the cap material is the depositional nature of the sands. Sands in an hydraulic slurry will deposit in close proximity to their point of discharge without a tendency to drift. Also, through settlement, sands have a tendency to densify or consolidate more quickly. As such, it would be possible for workers to walk on the sand cap and move the pipeline in shallow portions of the Upper Estuary without clogging the pipeline with the fill it dispenses (Olko, 1989). Conversely, dispersing silt fill with a discharge pipeline presents a variety of problems because discharged silt tends to be resuspended more easily and is too soft to walk on.

In summary, sand is preferable over silt as a capping material because it will: be inherently more stable, particularly with regard to hydraulic erosion; be easier to place during capping operations; consolidate rapidly after placement; provide an effective barrier to contaminant migration; and result in a more cost-effective and rapid remedial program.

3.4.4 Construction Elements and Means

3.4.4.1 Staging Areas

It is anticipated that the sediment cap materials described above can be located from an onshore source. Studies by Garbisch (1988) indicate that terrestrial soils can be used as capping material with little adverse effect on the subsequent establishment of wetland vegetation. From discussions with local suppliers, it appears that sufficient quantities of capping materials exist within a 5 mile radius of New Bedford Harbor. Capping soils can be transported via truck to at least two staging areas on the shores of the Upper Estuary. Staging areas are proposed for both the eastern and western shores of the Upper Estuary. Final locations of these areas have yet to be determined; however, it appears that an eastern staging area could be located in the vicinity of the New Bedford Gas and Edison Light Company easement, and the western staging area could be located in the southwest portion of the estuary adjacent to the

USACE Pilot Dredging CDF. The New Bedford Gas and Edison Light Company easement located on the eastern shore of the Upper Estuary is desirable as staging area because it can adequately support capping operations in the northern portion of the Upper Estuary. Additionally, it is believed that operations conducted in this area provide little disruption to residential neighborhoods, and that traffic congestion would be minimized. The use of the New Bedford Gas and Edison Light Company easement would preclude the need to access individually-owned land.

A second potential staging area is located on the southwestern shoreline in the vicinity of the USACE pilot CDF. This location has been suggested due to its proximity to the Coggeshall Street bridge. From this location, truck traffic associated with the transport of capping materials could cross the Coggeshall Street bridge, and could access the staging area through a parking lot located to the north of Coggeshall Street. Arrangements would be made with the owner of the parking lot relative to passage and maintenance of the pavement. In addition to limiting traffic congestion, location of a staging area in the southwestern portion of the Upper Estuary would adequately support capping operations for the entire southern portion of the proposed cap.

Staging areas would be designed to include a sand slurry pit where sand transported from suppliers would be mixed with estuarine water to form a pumpable slurry. The sump pit would be constructed out of materials such that estuarine water could be pumped into the sump to completely hydrate the sand deposited by truck.

Dredge pumps would be incorporated into the design scheme to apply the driving force required to pump the slurry through floating pipes and hoses to the ultimate destination at the discharge diffuser head. Figure 3.16 conceptually depicts a proposed staging area.

Prior to the construction of the staging areas, arrangements would have to be made with property owners. Once access has been granted, engineering and design of the areas would begin. Preliminary engineering would include a geotechnical analysis based on soil borings conducted at the proposed locations. During the geotechnical engineering design phase, preliminary structural and pump design would be underway.

3.4.4.2 Discharge Lines

Prior to institution of cap placement, arrangements should be made for the sealing, rerouting, or extension of permitted discharge lines in the portion of the Upper Estuary to be capped. Of the five permitted combined sewer overflow (CSO) discharge lines in the Upper Estuary area, only three are located in the vicinity of the area to be capped. The location of these CSOs are shown on Figure 3.17. Currently, a study is being conducted by Camp, Dresser & McKee (CDM) relative to the redesign of the storm drainage system; CDM states they expect their recommendations to be available in the Fall of 1989. It is difficult at this time to determine what specific action should be taken relative to the CSO discharge lines; however, the fate of these CSO discharge lines should be resolved prior to the construction of the multimedia cap if possible. It is recommended that active communications be opened with the parties responsible for the design and repair of the storm drain and sewer system, requesting priority be given to the lines located north of the Coggeshall Street Bridge. Based on conversations with representatives of the City of New Bedford, it appears that the Belleville Avenue interceptor, which is adjacent to the Upper Estuary, contains a large amount of grit which currently restricts flow in the line. As one possible solution, if this grit were removed from the interceptor, the capacity of the line might be increased sufficiently to allow sealing of some or all of the Upper Estuary CSOs, thus resolving this issue and providing a rapid improvement of estuary water quality. Other alternatives could also be pursued including extending or rerouting the CSOs.

In addition to the permitted CSO discharges, there appear to be a number of non-permitted discharges into the Upper Estuary. It will be necessary for owners of these non-permitted discharges to relocate these lines, or the lines will be capped prior to placement of the cap. An inventory and assessment of all discharge lines entering the Upper Estuary, including non-permitted discharges, is recommended if this information is not readily available.

3.4.4.3 Vertical and Horizontal Controls

The establishment of vertical and horizontal controls will also be required prior to commencement of the capping operation. These controls will be in the form of benchmarks and targets located along the shoreline. The vertical control points will be used in assessing the cap thickness and sediment consolidation both during and after the placement of cap materials. Horizontal control points will be used in defining the limits of the cap, as well as in positioning support vessels.

3.4.4.4 Geotextile Placement

The placement of geotextiles is expected to be accomplished using two general methods. The "Near Shore" technique consists of stacking long strips of fabric oriented parallel to the shore line and seaming them in a fanfold fashion to produce a large single sheet. When pulled from the top, the fabric will systematically unfold. Folded fabric may be deployed from either a barge or the shoreline. Deployment of the fabric is expected to occur after hydraulic controls are adjusted to retain high water and support vessels have been moved into position. Figure 3.14 depicts unfolding a seamed sheet from the shoreline by pulling with a barge. The fabric will be pulled over or placed on the water surface by a support vessel stationed in the Upper Estuary. Since the proposed fabric will have a fiber density close to that of sea water, the fabric will not readily sink, but as the fabric is positioned into place, it can be sunk by placing reinforcing steel rods or sand bags over the fabric. The reinforcing steel would be placed in a systematic fashion such that air trapped under the fabric would be directed to the edge of the fabric. In some instances, it may be necessary to use sand bags to sink the fabric.

The second method of geotextile deployment which will be used is an "Off-Shore Technique." As shown in Figure 3.15, full rolls of geotextile will be mounted on shallow draft barges. The mounting devices containing the rolls of fabric will be equipped with a winch motor capable of unrolling the fabric. By using winches to unroll the fabric, stress exerted during deployment will be reduced. When the end of a roll is reached, subsequent rolls can be attached by field seaming, or roll ends will be overlapped. As with the "Near Shore" technique, the geotextile can be submerged by attaching reinforcing steel to the fabric or by placing sand bags over the fabric.

Details describing geotextile anchoring at the edges of the cap have been presented in Section 3.2.

3.4.4.5 Sediment Placement

Hydraulic placement of the sand cap will be accomplished by mixing sand and estuarine water to create a pumpable slurry, then hydraulically transporting the slurry to the point of deposition. As proposed, dump trucks will deposit terrestrial sand into the hydration pit at the staging area. The hydration pits will be constructed out of a material which will allow estuarine water to be contained within the pit. The pit will be equipped with dredge pumps capable of transporting a 10% sand slurry through hydraulic lines floating on the water surface. Intermittent booster pumps may have to be incorporated into the lines if necessary. Based on evaluations performed to date, it appears that between 30 and 100 cubic yards of sand can be placed per hour by each pumping unit. Once the slurry reaches the discharge point, a hydraulic diffuser will be used to disperse the sand at or above the water surface. Through controlling the rate of deposition, the slurry exit velocity and pressure, and the distance between the diffuser head and the geotextile, controlled placement of cap material can be accomplished to avoid formation of mud waves.

3.4.4.6 Construction Sequence and Placement of Armored Cap

Upon completion of support facilities and prerequisite tasks, construction of the multimedia cap can begin. It is anticipated that construction activities will start in the northern portion of the Upper Estuary and proceed in a southerly direction. As shown conceptually in Figures 3.14 and 3.15, a woven geotextile will be deployed by placing large, pre-seamed sheets of fabric over the area to be capped. As deployment of the geotextile proceeds, application of the sand cap over geotextile will follow closely to provide more complete anchoring of the geotextile. During times when the sand cap is being placed, continuous monitoring of the sand cap thickness will be performed. As placement of the geofabric and 30-cm-thick sand cap proceeds southward over areas where erosion protection cap armor is to be installed, as well as over five acres of Upper Estuary sediment with the highest reported PCB concentrations, the placement of a second layer of geofabric over the sand cap will begin. This second layer of geotextile will be overlain with erosion resistant materials consisting of stone, and in other areas, geoweb filled with stone. Construction operations would be planned so that the deployment of the geotextile can proceed in one area while the sand cap and erosion protection are being placed in another. Erosion protection would typically consist of crushed stone ranging in size from 1 inch to 1 1/2 inches. In the center of the channel where the highest water velocities are expected, as well as at the "Hot Spot," geoweb filled with stone will be installed over the sand cap to improve the physical integrity of the cap. (Geoweb is a high density polyethylene grid which is used to hold erosion stone in place.) The cells in the geoweb will be backfilled with 1 1/2 inch crushed stone. It is expected that the erosion protection will be deposited using a clamshell bucket. Specific attention will be paid to the placement of the erosion stone such that the underlying sand cap is not disturbed.

When the placement of the lower layer of geotextile has proceeded to the limits of the area requiring erosion protection, the thickness of the sand cap will then be increased to 45 cm. From this point southward, the cap will be constructed using one layer of geotextile overlain by 45 cm of sand.

At the same time construction of the cap is taking place in the northern portion of the Upper Estuary, deployment of geotextile and the 45-cm-thick sand cap can be underway in the southern portion of the Upper Estuary. The deployment of geotextile can begin along the western shore at the southern edge of the cap. Anchoring of the geofabric along the western shore line will be monitored closely in view of the reported presence of soft sediments adjacent to portions of the bulkheads along the shore. The placement of the sand cap would proceed eastward and northward until encountering the southern edge of the cap being placed from the north, or until the limits of the cap are reached. Once the limits of the cap are reached, geofabric deployment will be terminated. In areas where the cap terminates in open water, the hydraulic placement of the sand would continue approximately 10 feet past the edge of the geotextile. During the deposition of sand in areas not underlain by geotextile, close attention will be paid to the depositional rate used to distribute the sand. In order to minimize mixing of cap materials with underlying sediments, the depositional discharge velocity and pressure will be reduced.

During hydraulic placement of capping materials, special attention will be given to avoid the creation of mud waves under the geotextile. Mud waves tend to occur when large point loads of soil are placed on a geofabric which is underlain by very soft sediments. This process was observed during construction of the USACE pilot CDF. As previously discussed in Section 2.3.4 and as demonstrated at other sites, creation of mud waves can be avoided by using a diffuser head to disperse discharged sediments and reduce flow velocities, moving the discharge point to prevent large accumulations of cap material, properly regulating the depositional rate of the hydraulic diffuser, and maintaining sufficient distance between the diffuser and the geotextile.

Placement of sediment in this manner avoids the creation of point loads from placed sediment.

3.4.4.7 Cap Construction Rate

Based on the application of a minimum 45 cm thickness of sand to portions of the Upper Estuary where PCB sediment concentrations are greater than 50 ppm, 340,000 cubic yards of sand would be required for cap construction. Based on discussions with pump manufacturers, between 30 and 100 cubic yards of sand per pumping unit could be placed per hour depending on the diameter of the pipe used to transport sand slurry. As such, it is anticipated that approximately 500 to 1,600 cubic yards of sand will be delivered and placed per day. It should be noted that the limiting factor with respect to cap depositional rate will be the rate at which the geotextile is deployed.

3.4.5 Cap Stability

In order to assess cap stability, the potential for erosion (entrainment of sediment particles into the overlying water column) of non-cohesive particles composing the cap was considered. As used herein, "entrainment" is defined as the collective processes that initiate movement of non-cohesive particles from one location to another. Therefore, entrainment is a function of the erosive power of flow for a given set of hydraulic conditions. Assessing the potential for entrainment of the cap material involves estimating the critical diameter of the largest particle that could be eroded from the cap under given hydraulic conditions. The entrainment of this critical diameter particle occurs at some threshold velocity for a given grain size and set of hydraulic conditions.

Several studies have been conducted to quantify or develop methods for estimating threshold velocities for sediments in riverine and marine environments. The differences between marine and riverine flows result primarily from the presence or absence of wave-current interactions. In marine flows, wave-current interactions which complicate specification of boundary roughness and friction characteristics which, in turn, affect velocity due to variations in skin friction and form drag are common.

The HEC-1 predicted 50-year storm discharge hydrography and corresponding flow velocities predicted by the DAMBRK model (ASA 1989) were used as a basis for estimating erosion of the cap material which was assumed to be composed of non-cohesive particles. It was assumed that the flow regime during this type of storm event would clearly dominate any surface waves or oscillatory flow from tidal or wave-generated origins. Based on the assumption of the absence of significant wave-current interactions and maintenance of a planer bed, it was assumed that boundary frictional characteristics are primarily a function of the small scale roughness of the sediment-water interface. In order to provide a conservative (worst-case) estimate of the critical particle diameters for the cap in the Upper Estuary area, flow velocities estimated to occur during the HEC-1 predicted 50-year storm discharge during MLW conditions were utilized; velocities modeled by DAMBRK assuming a tidal stage higher than MLW were lower than those predicted at MLW. Estimated velocities and output data from the DAMBRK model (ASA, 1989) were used and a critical particle diameter was estimated for each of the seven cross-sections of the Upper Estuary referenced in the (ASA, 1989) report.

Some of the most common and widely accepted methods for estimating sediment threshold are those of Shields (1936), Yalin (1972), and Lane (1955). These are primarily semi-empirical techniques developed from flume studies. Several other studies have produced site-specific predictive methods for estimating threshold velocities for specific particle sizes; however, these studies usually have been based on some empirical regression technique and have shown considerable scatter in predicting critical particle diameters in areas other than those for which they were developed. Accordingly, the methods of the three investigators cited above were used herein.

The Shields method was used as described in Dingman (1984). This approach assumes a logarithmic velocity profile and that flow is turbulent. Consistent with model output from the DAMBRK simulation (ASA, 1989), it was assumed that the depth of flow in the Upper Estuary during the 50-year storm event at MLW would not exceed one meter, and that this flow depth was a good approximation of the hydraulic radius.

The Yalin (1972) method is a modified version of the Shields approach and is easier to apply. This technique was used as described in Miller et al. (1977). It was assumed that the water temperature during the HEC-1 predicted 50-year discharge event would be approximately 10°C and that cap particles had a density of 2.65 grams per cubic centimeter. These assumptions affect the fluid density and kinematic viscosity used in determining the threshold velocity for a given particle diameter.

The Lane (1955) method was developed using quartz density material in water at 20°C. This approach was implemented as described in Miller et al. (1977).

The Yalin and Lane methods required an estimate of the friction or shear velocity to determine the critical particle diameter. For these cases, friction velocity was established using the maximum (worst-case) estimated average flow velocities contained in the ASA (1989) DAMBRK model output. Friction velocities were estimated at 0.25 cm above the bed surface using the Prandtl-von Karman velocity distribution function.

Table 3.1 summarizes the critical diameter of the particles for each of the seven cross-sections discussed above using these three methods, and the critical particle diameters used herein based on these method estimates including a safety factor of 1.15. This table also includes the maximum estimated average flow velocity at each cross-section. Review of the results indicates the critical particle diameters predicted by each method are fairly consistent, with those diameters obtained using the method shown by Dingman (1984) being slightly lower than the others. The three methods provide estimates of the largest particle diameters that the corresponding velocities would be capable of eroding under the assumed hydraulic conditions. These estimates assume uniform grain size and that the particles in the cap material are closely packed.

Figure 3.18 illustrates the approximate locations of the seven cross-sections simulated by the DAMBRK model (ASA, 1989). The selected critical particle diameters shown on Table 3.1 were used in conjunction with predicted ebb tide circulation patterns for the Upper Estuary (ASA, 1986) to differentiate cap material requirements in the Upper Estuary based on required critical particle diameters for the 50-year storm event. Since the maximum estimated average flow velocities used were based on predictions by the DAMBRK model at specific cross-sections, flow velocities between cross-sections were not available. Therefore, as a conservative (worst-case) estimate, specific critical particle diameters shown on Figure 3.18 were generally extended between two cross-sections such that the critical particle diameter was based on the higher predicted flow velocity at the two cross-sections considered. This method thus provided an additional safety factor (values up to 2.1) in the designation of the size of capping material.

The particle size of the anticipated cap material that was 50 percent or finer by weight (D_{50}) based on grain size analyses was used to identify areas of the cap that would be capable of withstanding erosive forces during the 50-year storm event. The D_{50} for the cap material was selected as approximately 5 mm which would have a conservative erosion threshold velocity of approximately 90 cm/sec based on the three methods used above. Figure 3.18 illustrates areas recommended for the installation of cap armor where peak storm flow velocities could result in erosion of this cap material. This cap armor was also extended over areas of elevated sediment PCB contamination. Similarly, areas of the cap where cap armor is not recommended were considered unlikely to be eroded by the 50-year peak storm flow velocities.

As can be seen from Figure 3.18 and Table 3.1, armored cap is required only between the Wood Street bridge (cross-section 1) and cross-section 3 assuming a D_{50} of 5 centimeters for cap material. Data output from inlet-basin model runs were then reviewed in combination with ideal velocity profiles to better understand velocity profile trends along Upper Estuary cross-sections. On this basis, the armored cap was extended further downstream from cross-section 3 to provide added containment protection for "hot spot" sediment. On this basis, 22 acres of the Upper Estuary will be covered with an armored cap.

Based upon a comparison between the critical particle diameters predicted above and laboratory sediment erosion studies performed with Upper Estuary sediment (ASA, 1987), it appears that the theoretical predictive methods yield very conservative (very high safety factor) results. Thus, as part of final remedial design, flume studies would be performed to provide a firmer basis for the sizing of cap sediment material.

3.4.6 Saltmarsh Establishment

Approximately 19 acres of newly capped areas which are brought above MSL by the addition of the 45 cm cap would be vegetated by seeding and/or transplantation of nursery-propagated seedlings of the cord grass, Spartina alterniflora. This process will be aided by natural seeding and propagation from surrounding stands of endemic saltmarsh species. Because surface elevation is the most critical variable in determining the location of the additional saltmarsh, establishment of saltmarsh grass will not proceed until primary consolidation of underlying estuary sediments has occurred. Following this consolidation period, saltmarsh will be established in cap areas with an elevation between MSL and MHW. In addition, the time of saltmarsh planting will also be scheduled to correspond with the optimal season for this activity. For these reasons, it is likely that saltmarsh establishment will begin from 3 to 12 months after placement of the sand cap. Once established, new saltmarsh will be managed and monitored to ensure that development of a mature, functional cord grass saltmarsh as similar as possible to currently existing stands in the area occurs.

3.4.6.1 Feasibility of Saltmarsh Establishment in Acushnet River Upper Estuary

While the success of saltmarsh establishment, as well as the rate of growth and the degree to which the new marsh duplicates the functions of a naturally occurring marsh are dependent upon a number of factors, past attempts in a variety of estuarine locations have been successful (Broome, et al, 1974; Garbisch, 1975; Seneca, et al, 1976; Earhart, et al 1983; DeLaune, et al, 1984).

Several factors contribute to the expectation that the feasibility of establishing a saltmarsh on the newly capped areas is high. The Upper Estuary is a shallow, relatively low energy environment facilitating placement, control and management of the capped area that will become the substrate for the saltmarsh. Washing away of cord grass seeds or young plants, as well as erosion of the newly created saltmarsh substrate, should be minimized in this environment. Capping material properties, including grain size, organic content and nutrient availability, can be chosen to optimize success. The proximity of a contiguous healthy saltmarsh should provide an ample source of seeds both initially and in subsequent years to complement the seeding and plantings conducted as part of the remedial program.

The survival of seeds and transplants is dependent on several factors but generally transplants are more successful than seed over a greater portion of the intertidal range and under more rigorous environmental conditions (Seneca, et al. 1976). The elevation range over which seeds can be expected to survive is generally in the upper half of the range of naturally occurring plants in the area (Broome, et al. 1974; Seneca, et al. 1976). Transplants of nursery propagated stock will therefore be used in the lower half of the naturally occurring range.

Other factors such as duration-of-inundation, salinity levels, and plant species composition of natural marshes in the area are generally important determinants of success (Seneca, et al, 1985). A visit to the Upper Estuary by Garbisch (personal communication) indicated that those factors most important to success at this site would likely be slope and ensuring sufficient circulation through the developing saltmarsh. Garbisch believed that the environmental factors on the site over which control was not practical (i.e. energy regime, inundation, etc.) were favorable for establishment of an expanded saltmarsh.

The rate of propagation of the new saltmarsh is dependent upon the specific characteristics of the substrate and the environment but in most instances is relatively rapid. Broome, et al. (1974) reported that complete cover can be achieved during the first growing season and that the above-ground standing crop produced from seed in one growing season may approach that of established marshes. Seneca, et al. (1985) studied the development of man-initiated marshes in North Carolina and found that usually 16 to 18 months were required to stabilize the substrate and develop vegetative cover similar to that of a natural marsh. By the twelfth season the Spartina alterniflora had spread approximately 30 meters beyond the original planting (Seneca et al., 1985).

Broome, et al. (1983) found that in areas where nutrients are limiting factors, application of nitrogen and phosphorus fertilizers were important in optimizing growth response of S. alterniflora and in maintenance of vigorous stands.

3.4.6.2 Procedures Utilized to Establish Saltmarsh

Final design for saltmarsh establishment will address selection of substrate, methods of containment (where necessary), fertilization nature and rate, methods of achieving specified final grade, anticipated consolidation time and degree, irrigation (if necessary), landscaping detail, and construction and management timetable.

3.5 EXISTING SALTMARSH REMEDIATION

As discussed in Section 1.2 and shown on Figure 1.4, approximately 50 acres of established saltmarsh wetlands exist along the eastern shore of the Acushnet River Upper Estuary in Fairhaven and Acushnet. Numerous studies (IEP, 1988; Sanford Ecological Services, 1987) have been performed by EPA and the USACE to map these areas, describe the physical and ecological characteristics of these areas, describe the ecological health and viability of these areas, and to determine PCB concentrations in wetland sediments. The results of these studies indicate that these wetlands are healthy and ecologically valuable. Accordingly, it was concluded that minimum disturbance of these saltmarsh wetlands should occur during remedial actions undertaken for the New Bedford Harbor site.

Existing PCB sediment quality data were reviewed to characterize these wetland sediments (Balsam, 1989 (Attachment I)). In performing this assessment, four variables were identified as the principal elements affecting PCB concentrations in these sediments. Two of these variables related to areal location, one variable related to sediment depth, and one variable related to sediment surface elevation. A summary of these four variables and how they relate to PCB distribution within the saltmarsh wetlands is presented below.

In general, a declining PCB concentration trend was observed from north to south in sediment samples collected from the eastern shore saltmarsh wetlands. This trend is consistent with the PCB sediment quality trends observed in Upper Estuary marine sediments. Additionally, a declining PCB concentration trend was also observed from west to east through the wetlands. This trend is believed to relate to proximity to the estuary water edge and thus, to the frequency of inundation from estuary water.

The third variable related to PCB contaminant trends was sample depth. PCB concentrations in samples collected at stations where samples were analyzed at varying depth intervals were typically seen to sharply decline with depth. At locations where samples were collected in 6 inch intervals, the majority of PCBs observed present were found in the first 6-inch-deep sample. At intervals where samples were collected at 12 inch intervals, the vast majority of PCBs were found to exist in the uppermost sediments sampled.

The fourth variable which related to PCB sediment concentrations was the physiographic nature of the sampling location. Samples collected from within a tidal creek or mosquito drainage ditch which was tidally inundated were found to have substantially higher PCB concentrations than samples collected from adjacent areas above the tidal creek or drainage ditch. This observation is consistent with the west to east PCB concentration trend in that it relates directly to the frequency of inundation from estuary waters. A more detailed discussion of this wetland sediments evaluation is included as Attachment I.

Some of the higher levels of PCBs in wetland sediments were found in the northern half of the wetlands and the largest tidal creeks and drainage ditches in the wetlands existing in the northern portions of the wetlands. These will be remediated in a manner similar to the remedial approach for marine sediments by capping these areas with clean soil. Soil used in this capping process will be obtained from an excavation made adjacent to the area to be remediated. In this way, a replacement tidal creek or drainage ditch will be created for each remediated area to mitigate for the loss of this area.

Remediation in the balance of the wetland tidal creeks and drainage ditches will depend on subsequent sediment sampling and a comparison of these sampling data to the PCB action level for the Upper Estuary. Creeks and channels found to contain sediment in excess of 50 ppm PCB will also be remediated by in place containment through capping. Cap source material for these remedial activities will be obtained from an area adjacent to the creek or ditch to be capped in a manner consistent with the remedial process described above.

At the conclusion of wetlands remedial capping efforts, disturbed areas will be seeded to reestablish either S. alterniflora or S. patens, depending upon the elevation of the capped area. Reestablishment of the disturbed areas with these marsh grasses is expected to occur quickly.

3.6 POST-CAPPING ACTIVITIES

Following completion of cap construction, a series of activities will be undertaken to demobilize site construction forces, including removal of the two proposed staging areas. A discussion of these activities is presented below.

3.6.1 Post-Remedial Survey

As previously discussed, construction monitoring will be initiated during cap placement to insure that the cap covers sediment above the specified action level, and that the cap thickness is a minimum of 45 centimeters. This monitoring will be performed to allow placement of additional cap material while the hydraulic discharge line is in close proximity to areas requiring additional fill placement.

Before demobilization of project equipment and staging areas, a more comprehensive post-remedial survey will be performed to assure adequate installation of the containment cap. A horizontal survey of the Upper Estuary will be performed to record the extent of the cap and assure that the lateral extent of the cap is sufficient. In addition, an extensive series of non-destructive sediment probes will be conducted to assure adequate cap thickness. Because geotextile will underlay the sediment cap, probes can be inserted into the cap until encountering the geotextile to determine the thickness of the cap at that location. These thin diameter probes will either be physically or hydraulically inserted through the sandy cap material until encountering the geofabric. Measurement of the depth of probe penetration will provide an actual measurement of the thickness of the cap. If areas of insufficient cap thickness (less than 45 centimeters) are encountered during this monitoring, additional sand will be placed in these areas. Following satisfactory completion of this survey, the two staging areas will be removed.

3.6.2 Adjustment of Hydraulic Controls

Following completion of construction of the cap, a review of the role of hydraulic controls will be performed to determine their future use at the project site. Discussions will be held with the owners and operators of the New Bedford Reservoir, Hamlin Street and Acushnet Saw Mill Dams to understand their needs and intentions for future operations of these structures.

As to the variable weir dam installed at the Coggeshall Street bridge, it is proposed that flow restriction panels of this dam be removed in stages to allow monitoring of the stability of the cap. Although the cap has been designed to withstand hydrodynamic forces, phased removal of dam weir panels will allow monitoring of the cap during gradual reintroduction of the full range of tidal and hydrodynamic forces. During the first year following cap construction completion, the dam weir panels can gradually be removed until all panels have been withdrawn from the dam. Following this time, it is recommended that the dam, without weir panels, be left in place for some period of time to allow for hydraulic control in the Upper Estuary at a future time should this control be needed.

3.6.3 Initiation of Inspection and Monitoring Programs

After completion of containment cap construction, an inspection and monitoring program will be initiated. This program will be developed to address demonstration of the physical integrity of the cap as well as the performance of the cap in containing underlying contaminants. To address these aspects, the inspection and monitoring program will include the following:

3.6.3.1 Physical Survey of Cap and Saltmarsh

On a monthly basis, a physical survey will be performed to determine the thickness of the cap throughout the Upper Estuary. This survey will include monitoring of the cap in both submerged and intertidal areas. If areas of the cap are identified with a less than 45-centimeter-thick layer of clean material, additional clean material will be placed over these areas. In addition, established and reestablished saltmarsh areas will be inspected to assure the viability of these areas. If establishment or reestablishment of the saltmarsh is not satisfactory, additional saltmarsh grass planting or seeding will be performed.

3.6.3.2 Surface Water Sampling

Surface water sampling will be performed at the Coggeshall Street Bridge on a quarterly basis. Samples will be collected on both the flood and ebb tides and compared to past water quality data collected at this location to measure the effectiveness of the cap.

3.6.3.3 Collection of Cap Sediment Core Samples

Cap sediment core samples will be collected on a quarterly basis and analyzed for PCBs. These samples will provide another means to determine the effectiveness of the cap to contain underlying contaminants.

3.6.3.4 Collection of Biota Samples

Biota samples will be collected from the Upper Estuary on a quarterly basis. This biota monitoring program will be initiated soon after recolonization of the Upper Estuary. The species to be included in the monitoring program will be determined based on a survey of the Upper Estuary following recolonization. Species samples selected for inclusion in this monitoring program will be collected on a quarterly basis and analyzed for PCB body burden. These data will also provide a means of evaluating the performance of the containment cap.

The frequency and intensity of this inspection and monitoring program have been selected to provide a comprehensive means of assuring the physical integrity of the containment cap, as well as the performance of the cap. Based on the results of the first years of this monitoring program, the nature and frequency of monitoring activities may be modified. These modifications would be made with the involvement and approval of EPA and the Massachusetts Department of Environmental Protection (MA DEP).

3.6.3.5 Institutional Controls

As previously discussed, it is anticipated that the current fishery ban imposed in the Upper Estuary will be maintained until sewage discharges to the estuary cease, and the Upper Estuary is fully recolonized. As part of the monthly cap survey, signs posting the prohibition of fishing (and swimming) in the Upper Estuary will be inspected. Damaged or missing signs will be repaired or replaced, respectively.

4.0 REMEDIAL ALTERNATIVE CONSTRUCTION SEQUENCE AND SCHEDULE

As previously discussed, implementation of the in place containment alternative will require mobilization and construction of support facilities prior to the installation of the multimedia cap. The establishment of hydraulic controls, construction of staging areas, and management of CSOs will be the most intensive mobilization activities. Following these initial activities, construction of the multimedia cap will occur in a phased and integrated fashion. At the completion of cap construction, a post-remedial survey will be performed, hydraulic control activities will be modified or altered, and a regular inspection and monitoring program will be initiated. A flow chart showing this sequence is presented as Figure 4.1.

Establishment of hydraulic controls will include construction of an adjustable weir dam just north of the Coggeshall Street Bridge. It is anticipated that three to six months will be required for the selection of a contractor. Field construction of the dam is expected to take less than two months, although construction activities which may affect traffic flow are expected to require less than four weeks. In addition, hydraulic controls will be utilized upstream of the Upper Estuary. It is anticipated that six months to one year will be required to establish these controls.

To facilitate the implementation of the remedial alternative, at least two staging areas will be constructed. Since construction of the staging areas is independent of hydraulic controls construction, these activities can proceed concurrently. Approximately six to twelve months should be allocated for obtaining property access and design of the staging areas. An additional nine to twelve months should be allowed for selection of a contractor and construction of the facilities. If activities such as access and engineering design can be conducted concurrently, the total time required for the establishment of staging areas would be approximately one to one and one half years. During this same time, it should also be possible to address existing discharge lines to the Upper Estuary, establish adequate horizontal and vertical controls for construction oversight purposes, and to obtain temporary access to properties which front the Upper Estuary to permit support of construction activities.

Following these preliminary activities, cap placement will begin. A full discussion of the methodology of cap construction has been presented in Section 3.4.4. It is anticipated that approximately 1,000 to 3,000 square yards (0.2 to 0.6 acres) of cap can be placed per day, depending on the type of cap being installed and the number of slurry pumps operating. Taking this production rate into account, as well as time devoted to maintenance, breakdowns and weather, it is anticipated that one and one-half to two years will be required to complete this aspect of capping Upper Estuary sediments.

As previously stated, some tidal creeks and mosquito trenches located along the eastern shore reported to contain concentrations of PCBs in excess of 50 ppm will be remediated. As proposed, the trenches and creeks would be mechanically capped with soils obtained from areas adjacent to the trenches. Since the capping operations in this portion of the site will be performed mechanically and are independent of remedial activities associated with capping operations in other areas of the site, they can be conducted concurrently with cap construction. It is anticipated that two to four months will be needed for completion of this phase of the remedial program.

As previously discussed, approximately 19 additional acres of saltmarsh will be created as part of this remedial program. It is anticipated that up to 6 months will be required to prepare and plant the 19 acres of new saltmarsh following cap placement and primary consolidation.

Upon successful completion of the capping operations, staging areas will be removed. Since these facilities will be designed and constructed as temporary structures, demobilization should proceed rapidly. At this same time, hydraulic

controls will be adjusted or removed as decided by involved parties. It is anticipated that two to three months will be required to demobilize staging area equipment and structures and to adjust the hydraulic control structures.

5.0 APPLICATION OF DETAILED ANALYSIS CRITERIA

After initial screening of potential remedial alternatives to determine their suitability for Superfund site cleanup, remedial alternatives are then subjected to a detailed analysis utilizing nine criteria. These nine criteria are: 1) overall protection of human health and the environment, 2) compliance with ARARs, 3) long-term effectiveness and permanence, 4) reduction of toxicity, mobility or volume, 5) short-term effectiveness, 6) implementability, 7) cost, 8) state acceptance, and 9) community acceptance. Because this document presents only one remedial alternative, it was not possible to perform comparative analyses utilizing these nine criteria. Nevertheless, the proposed in place capping alternative was evaluated utilizing each of these nine criteria to allow assessment of whether this remedial alternative would provide an acceptable and effective means for remediating PCB contamination within New Bedford Harbor. This analysis provides the basis for decision makers to more fully understand and evaluate this alternative.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The fundamental purpose of Superfund site remedial action is to reduce potential threats which may be posed by the site to human health and the environment. A discussion of how the in place containment remedial alternative satisfies this criterion is presented below.

5.1.1 Human Health Risks

One of the principal objectives of any remedial action program for the New Bedford Harbor site is to reduce risks posed to public health from contaminants present in harbor sediments through the reduction of exposure to site contaminants or elimination of complete exposure pathways between public receptors and site contaminants.

As a means to quantify actual PCB exposure to residents of the Greater New Bedford area, a comprehensive epidemiological survey was performed by the U. S. Centers for Disease Control (CDC), the Massachusetts Department of Public Health (MDPH), and the Massachusetts Health Research Institute (MHRI) in coordination with the EPA. Municipalities involved in "The Greater New Bedford PCB Health Effects Study, 1984-1987" (GNBHES, 1987) included Dartmouth, New Bedford, Acushnet and Fairhaven. The protocol for this epidemiological study was to randomly select a statistically significant number of people from the Greater New Bedford area between the ages of 10 and 64, determine PCB concentrations in blood serum samples from these individuals, prepare comprehensive profiles of their PCB exposure history, and, if significant PCB exposures were noted from the blood serum sample analyses, study observed health effects on the study subjects with elevated PCB blood serum levels. The objective of the first phase of the epidemiological study was to identify 150 area residents with PCB blood serum concentrations of over 30 parts per billion (ppb); however, after review of blood serum analytical data, only eleven such individuals were identified. Based upon these results, CDC and MDPH concluded that a sufficient number of individuals would not be identified with elevated PCB blood serum levels to allow study of PCB related adverse health effects. Rather, it was concluded that residents of the Greater New Bedford area had PCB blood serum levels comparable to blood serum levels of persons throughout the United States (GNBHES, 1987).

Although significant PCB exposure was not indicated by these data, CDC and MDPH elected to perform an additional study, an "enrichment" study, in an attempt to identify and evaluate Greater New Bedford area residents expected to have high exposure to PCBs due to ingestion of high amounts of locally caught seafood or due to occupational PCB exposure. This subsequent evaluation of Greater New Bedford area residents resulted in the identification of, and blood serum sample collection and analyses from, 110 additional individuals (GNBHES, 1987).

The results of the enrichment study indicated that even individuals expected to have well above-average exposure to PCBs through industrial work experience or consumption of locally caught seafood did not have exceptionally high PCB blood serum levels. Of the 110 individuals involved in the enrichment study, only seven had PCB blood serum levels above 30 ppb. On this basis, CDC and MDPH concluded, "that the prevalence of elevated serum PCB exposure among residents of Greater New Bedford is low...." and " even the residents at higher risk of PCB exposure from locally caught seafood consumption, for the most part, had levels within the typical range of the U. S. population." (GNBHES, 1987).

Although this epidemiological study concluded that Greater New Bedford area residents do not have significant environmental exposure from PCBs, EPA undertook a baseline risk assessment (Ebasco, 1989) which involved the use of theoretical exposure and toxicological models. Assumptions and methods utilized by EPA in performing this baseline risk assessment indicated that the results of the assessment are expected to be conservative in nature (i.e., the results will tend to overestimate risk) (Terra, 1989). Even with conservative assumptions, the authors of the baseline risk assessment concluded that "direct contact with and/or incidental ingestion of surface water does not result in significant contaminant (PCB) exposure." These conclusions appear consistent with site data and the Greater New Bedford PCB Health Effects Study.

Additionally, the EPA baseline risk assessment concluded that over 99 percent of all PCB exposure within the New Bedford Harbor area was attributable to ingestion of aquatic biota (fish and lobster), direct contact with sediments, ingestion of sediments, and to a much lesser extent, inhalation of airborne PCBs. The percent contribution of PCB lifetime exposure from these four pathways was 1.4%, 84%, 14.7%, and 0.025%, respectively (Ebasco, 1989). Although this exposure analysis appeared to be inconsistent with data generated through the Greater New Bedford Health Effects Study because the study concluded that Greater New Bedford area residents, including those who eat locally caught fish, do not have elevated levels of PCBs, EPA's theoretical modeling of PCB exposure to Greater New Bedford area residents indicated potentially significant PCB exposure through three of these four pathways; inhalation of airborne PCBs by area residents was not considered significant.

The critical first step in the risk assessment process is a hazard evaluation which summarizes available toxicological data for the chemicals of interest at the site. As previously stated, PCBs have been identified by EPA as the principal contaminant of concern at the New Bedford Harbor Superfund site. For this reason an extensive review and analysis of PCB toxicological data was performed by Terra, Inc. (Terra), a specialist in toxicological evaluation and risk assessment, for AVX Corporation. Based on this review and analysis, Terra prepared a toxicant profile for PCBs; this toxicant profile has been included as Attachment J. The toxicant profile contains a complete presentation of the properties of PCBs and the health effects (toxicology) of PCBs in animals and humans. Using this extensive database, Terra performed a toxicological evaluation of the PCBs present in New Bedford Harbor sediments, which include Aroclors 1016, 1242, and 1254. The results of this PCB toxicological hazard evaluation are included as Attachment K. In summary, the Terra evaluation concludes that there is no evidence of carcinogenicity of 42% chlorine PCB mixtures (Aroclor 1016, Aroclor 1242) in animals or humans. The report further concludes that animal evidence for the carcinogenicity of 54% chlorine PCB mixtures (Aroclor 1254) is equivocal and of questionable relevance to man. Although the report concludes that there is evidence for the carcinogenicity of 60% chlorine PCB mixtures (Aroclor 1260) in animals, several aspects of the animal bioassay results indicate that these studies also have limited relevance to humans. The Terra report concludes that there is inadequate evidence to show an association between PCB exposure and cancer in humans (Terra, 1989).

Based on the results of the PCB hazard evaluation as well as existing site data, Terra performed a PCB exposure assessment and risk assessment for the New Bedford Harbor site, included as Attachments L and M, respectively. The focus of the exposure assessment and risk assessment was to address concerns about PCB exposure through direct contact and ingestion of sediments, as well as consumption of biota.

PCB exposures were calculated for adults and children potentially involved in beachcombing or shellfishing activities in the Upper Estuary. These exposures conservatively assumed direct contact with sediments at frequencies up to 18 times per year for 30 years. Doses of PCBs calculated to occur for each exposure event were well below the 1 microgram per kilogram of body weight per day (ug/kg/day) acceptable daily intake (ADI) calculated by Terra for 54% and 42% chlorine PCB mixtures. As discussed in the New Bedford Harbor Hazard Evaluation, it is scientifically unsupportable to assess risks for these mixtures in the same manner as 60% chlorine PCB mixtures (Terra, 1989). In addition, the cancer potency factor derived by the EPA for 60% chlorine PCB mixtures is based on an animal study of questionable experimental design (Norback and Weltman, 1985). Terra derived a more appropriate and accurate cancer potency factor which was used to calculate risks. Applying Terra's cancer potency factor to 42% and 54% chlorine PCB mixture exposures due to direct contact with Upper Estuary sediments, the calculated risks ranged from 4.6 x 10^{-7} to 1.80 x 10^{-8}. Without conceding that it is either correct or appropriate, EPA's cancer potency factor was applied in this and other calculations by Terra for comparative purposes. The range of risks calculated to result from these same exposures was 1.97 x 10^{-5} to 7.68 x $10.^{-7}$. Both calculations are considered acceptable in light of the range of risk considered acceptable by EPA (Terra, 1989).

Risk associated with PCB intake from consumption of seafood from areas closed to fishing were also assessed. Daily doses of PCBs from seafood consumption were less than 0.2 ug/kg/day for adult, older child, and young child receptors. Thus, all doses calculated were below the 1 ug/kg/day ADI. When calculated using the Terra cancer potency factor, risks associated with average PCB consumption in seafood were 7.75 x 10^{-6} or lower. At the highest seafood consumption rate, risks calculated using the EPA cancer potency factor were 3.31 x 10^{-4} or lower. This risk is only marginally above the 1 x 10^{-4} upper bound for risks considered acceptable by the EPA (Terra, 1989).

Capping sediments containing concentrations of PCBs in excess of 50 ppm was calculated to decrease PCB doses in the Upper Estuary area by 83%. The highest dose of PCBs calculated to result from exposure to sediments after capping was 0.0451 ug/kg/day. This dose is well below the 1 ug/kg/day ADI developed by Terra. Regardless of the cancer potency factor used, all post-remedial risks due to direct contact with sediment were calculated to be below the 1 x 10^{-5} risk level (Terra, 1989).

The degree of reduction in PCB biota concentrations which would result from capping have not been quantified for all areas of New Bedford Harbor. However, as set forth below, post-remedial concentrations of PCBs in biota in the Upper Estuary have been estimated. Although a fisherman is unlikely to limit fishing activities to the Acushnet River Upper Estuary, estimates of PCB ingestion resulting from consumption of seafood taken only from this location were estimated. The highest daily intake of PCBs from seafood consumption was calculated to be 0.0395 ug/kg/day, level well below the ADI calculated by Terra. Cancer risks associated with consumption of seafood from this area were 1.87×10^{-6} to 1.66×10^{-8} when calculated using the Terra cancer potency factor. These risks are below 1×10^{-5} and well within the range of risks considered acceptable to regulatory officials. Risks calculated using the EPA cancer potency factor were 7.98×10^{-5} to 7.09×10^{-7}. These risks are within the range of risks considered acceptable by EPA (Terra, 1989).

As previously discussed, the in place containment remedial alternative will effectively prevent human exposure to sediments containing a PCB concentration of 50 ppm or greater. Furthermore, much of the uncapped sediment in the Upper Estuary and the vast majority of sediment in the Middle Harbor, Lower Harbor and Outer Harbor Area exists in deeper water where direct contact or ingestion of harbor sediments is highly unlikely. The results of the Terra risk assessment for beachcombing and shellfishing, human activities associated with direct contact and ingestion of sediments, indicate that post-capping PCB exposure under both typical and reasonable worst case scenarios would be well below acceptable levels (Terra, 1989). Accordingly, this remedial alternative effectively addresses concerns related to these exposure pathways and potential incremental health risks posed by direct contact to or ingestion of New Bedford Harbor PCB contaminated sediments.

With respect to concern about consumption of PCBs in biota, RI/FS data describing edible fish PCB body burden were reviewed. Apparently inconsistent data complicated the ability to reach definitive conclusions regarding PCB concentrations in New Bedford area fish. In particular, data reported by EPA for New Bedford Harbor (Battelle, 1987) and data presented during a Greater New Bedford Environmental Community Work Group (CWG) meeting do not appear consistent with comparable data released in the "Draft Final Baseline

Public Health Risk Assessment; New Bedford Harbor Feasibility Study," dated August 1989. Selected PCB data from this Battelle study for lobster and winter flounder were reported by Battelle in 1987 (Hillman, 1987). Other PCB data gathered by Battelle for hardshell clams, crabs, mussels and polychaetes were reviewed in raw form; however, these PCB data represented concentrations in sample extracts only and were not normalized for the mass of the specimens. Accordingly, it was not possible to calculate PCB body burdens for these additional data. PCB data for aquatic species presented by Hydroqual, Inc. (Hydroqual) during the July 11, 1988 CWG meeting were also reviewed. However, because these data were not formally provided in written form during or after the meeting, they could not be used to resolve PCB body burden concentrations.

In addition to PCB body burden data generated as part of the Battelle studies, historic PCB body burden data for various species collected in the New Bedford Harbor area were also evaluated. Because the sampling methodology and information regarding sample handling and analytical methodology were not available, these data were judged to be less reliable than the Battelle data.

Nevertheless, review of the available Battelle PCB body burden data did allow identification of general PCB body burden characteristics. The Battelle data sets indicated that the average lobster muscle, winter flounder flesh and clam tissue PCB concentrations throughout the New Bedford Harbor study area (see Figure 5-1) were less than 1 ppm. As such, these data indicate that winter flounder and clams caught from throughout the New Bedford Harbor area, including areas currently closed to fishing due to sewage pollution, contain average PCB concentrations in edible tissue at levels below the United States Food and Drug Administration (USFDA) permissible PCB seafood consumption level of 2.0 ppm in edible tissue (see also Section 5.2.1).

Analyses of lobster tomalley (liver) reported higher PCB concentrations than in lobster muscle. If lobster tomalley were not considered edible, lobster caught from throughout the New Bedford Harbor area would also contain less PCB than the USFDA permissible level. If lobster tomalley is considered edible, only lobster from areas one and two, as shown on Figure 5-1, would exceed USFDA PCB levels (Ebasco, 1989).

Although these species caught from much of the study area were shown to be acceptable for human consumption under the USFDA PCB standard for seafood, consideration was given to the effect of the in place capping remedial alternative on PCB body burdens of these and other edible aquatic species. A significant reduction of biota PCB exposure from direct contact with highly PCB-contaminated sediment will be achieved through capping of large portions of the Upper Estuary. Furthermore, a significant reduction of the current level of PCB flux from the Upper Estuary will also occur following capping of designated areas of Upper Estuary sediment.

In order to assess PCB body burden reduction in New Bedford species following remediation, site specific data in combination with food chain modeling were used. As part of EPA's RI/FS, Hydroqual has developed a food chain model which was the subject of a 1988 "preview" paper published in the "Wetlands/Waterways and Their Remediation" conference report. Information about the Hydroqual food chain model is quite limited and is drawn from the referenced article. Further review of Hydroqual's model must await EPA's release of additional information about its work in New Bedford Harbor. The model was developed from a variety of data found in the literature (e.g., consumption rates, assimilation efficiencies, etc.), and calibrated with site specific field data collected in New Bedford Harbor and Buzzards Bay by Battelle in 1985 and 1986 (Connolly and St. John, 1988). The basic form of the model has been used by Thomann, Connolly, St. John and others in the past (Thomann and Connolly, 1984).

Review of the data in this and other papers (CDR Environmental Specialists, 1989) (CDR) that examined age and size-dependent PCB bioconcentration factors

(BCFs) indicates BCFs of 1,000 to 100,000. The BCFs calculated by the New Bedford Harbor food chain model (Connolly and St. John, 1988) listed in Table 2 of that paper are consistent with most related PCB literature from other locations and can therefore be used at this site with some degree of confidence, although further review of the Hydroqual work will be undertaken when additional data are made available.

Since BCFs are an expression of the ratio of PCB concentration in an organism to the PCB concentration in the water column, an estimate of how capping will affect water column PCB concentration was needed. ASA used a simple box model to provide a first order estimate of PCB water column concentrations after capping (ASA, 1989). ASA's calculations show that under the proposed containment alternative, water column PCB concentrations would be reduced by a factor of 100 to approximately 17 to 25 (average of 21) nanograms per liter or parts per trillion (ng/l) in the Upper Estuary, and would be reduced by a factor of about 10 to approximately 23 to 31 (average of 27) ng/l in the Middle and Lower Harbor. These box model estimates are discussed in more detail in Section 5.1.2.4, and are presented as Attachment N.

If one assumes that body burden varies linearly with water column concentration directly by the BCF, body burdens of endemic marine organisms should likewise be decreased by factors of 100 and 10 in the Upper Estuary and Middle/Lower Harbors, respectively after cap construction.

Using the "total" PCB BCFs from Table 2 of Connolly and St. John (1988), and assuming that these BCFs are for total PCB body burden, estimates of the body burdens that would result from a reduction in the Upper Estuary PCB water column concentration to the levels reported by ASA (1989) are as follows:

Species	Total Body BCF	Resulting Body Burden
Lobster	14,200	0.24 - 0.36 ppm
Winter Flounder	32,000	0.54 - 0.81 ppm
Crab	14,200	0.24 - 0.36 ppm
Hard Clam	5,300	0.090 - 0.13 ppm
Mussel	16,000	0.27 - 0.40 ppm
Polychaete	46,700	0.79 - 1.2 ppm

These first order approximations of resulting PCB body burdens indicate that after capping, whole body PCB concentrations would be significantly reduced from current reported levels, and would be below the current USFDA standard. Furthermore, these calculations estimate whole body PCB burden, not just edible body portions; PCB concentrations in edible portions of these species (excluding non-edible polychaetes) would probably be lower yet. Estimates of the resulting risk from consuming locally caught seafood with body burdens at these levels following remediation (Terra, 1989) were well within the 1 microgram/kilogram/day acceptable daily intake (ADI) developed by Terra, and below the 1×10^{-5} risk when risk was calculated using the Terra derived cancer potency factor (CPF).

Consideration also was given to potential short-term public health impacts associated with remedial action activities. A second important objective in the selection of a remedial action is to choose an alternative that does not create additional short-term risk as it is implemented. Examples of additional short-term risks which could be posed to public receptors through implementation of remedial action include increasing the volatile loss of PCBs from harbor sediments, increasing the airborne concentration of particulate-bound contaminants, resuspending and enhancing migration of contaminated sediments in the water column, and the discharge of PCB treatment by-products to the ambient air or water column (EPA; 1986, 1988). As discussed in Section 5.5, because the in place containment remedial alternative will not result in significant sediment disturbance and will not remove any sediment from the estuary, little to no incremental PCB release is expected from implementation of this remedial alternative. Therefore, the implementation of the in place containment remedial alternative is not expected to create significant short-term human health risks.

5.1.2 Environmental Impact From Remedial Program

5.1.2.1 Upper Estuary Habitat

The upper section of the Acushnet River estuary, from Coggeshall Street north to Wood Street, encompasses approximately 239 acres which include subtidal mudflats and channels, intertidal mudflats and beach, and saltmarsh. Table 5.1 quantifies the present areal extent of these habitats, as well as predicted post-remedial habitat. New Bedford's history as a mill town is reflected in the present appearance of the west bank. The western bank of the river has been altered to such an extent that it bears little resemblance to its original condition. Most of the original bank has been altered by human use so that the shoreline now consists mainly of steel or timber bulkhead, riprap, or fill. The only area along the west side of the river that has not been significantly impacted by construction is in the cove to the north of the Coggeshall Street bridge, although it now is partially filled with the EPA CDF.

The eastern bank of the Upper Estuary lies in Fairhaven and Acushnet and has an entirely different character than the west bank. Most of the area is undeveloped saltmarsh. The town of Fairhaven owns a portion of this saltmarsh as conservation land. Behind the undeveloped areas along the bank, the land has been developed for residential use. The only industrialized sections on this bank lie immediately north of the Coggeshall Street bridge and immediately south of the Wood Street bridge.

The estuary itself, as well as its shoreline, reflects a history of manufacturing and population growth. Since the early 1900's, the estuary and harbor have repeatedly been closed to shell fishing due to contamination by raw sewage. Today, the harbor remains closed to recreational and commercial fishing in compliance with a 1979 order by the MDPH after PCBs were identified in several species of bottom fish and shellfish.

Recreational uses for the Upper Estuary are currently minimal. Most potential areas of access in the Upper Estuary are fenced off, and warning signs are posted indicating contamination of finfish and shellfish.

Several studies have been conducted that have focused on the wetlands in the Upper Estuary (SES, 1987, 1988; IEP Inc., 1988; Bellmer, 1989). While these reports have not been comprehensive nor quantitatively rigorous, they do provide a description of the habitats and some insight as to the functional values of the wetlands in the Upper Estuary.

The subtidal benthos in the Upper Estuary was sampled in September 1986 (SES, 1987) as part of an estuary-wide benthic study. Results of the Upper Estuary sampling indicate low species diversity and a polychaete-dominated benthic community with the most numerous species, Streblospio benedicti, Capitella capitata and Podarke obscura, being small tubiculous or burrowing, opportunistic species. These characteristics are indicative of a "stressed" environment (Rhoads and Germano, 1986).

The finfish community has not been quantitatively studied with the exception of some beach seine and minnow trap sampling conducted during the summer of 1987 (Bellmer, 1989). This collection effort yielded large numbers of the Atlantic silversides, Menidia menidia (approximately 77% of the seine catch) as well as killifish, Fundulus spp.; F. heteroclitus made up 99% of the minnow trap catch in the Upper Estuary. Other species were caught too infrequently to be of use in describing the finfish community. Jason Cortell and Associates (1982) list a number of species that may be expected to be found in the Acushnet River estuary; that list is reproduced as Table 5.2. Two species of anadromous fish, Alosa aestivalis and Alosa pseudoharengus, that are listed may be expected to pass through the estuary on their way to the Acushnet River for spawning. Little is known about the current viability of the Upper Estuary as a nursery area, although "snapper" bluefish, Pomatomus saltatrix, have been observed feeding.

The intertidal areas are dominated by the same spionid and capitellid species that dominate the subtidal mudflats (IEP, 1988). Tubiculous amphipods, e.g., Corophium insidiosum, the soft-shell clam, Mya arenaria, the ribbed mussel, Geukensia demissa, the mud snail, Ilyanassa obsoleta, as well as various polychaete species were also found in large numbers depending on the substrate composition. Sea lettuce, Ulva lactuca and Entermorpha sp. (probably E. intestinalis), covered large areas of parts of the intertidal zone.

The intertidal saltmarsh in the Upper Estuary comprises approximately 50 acres, the majority of which is on the east bank of the estuary. This marsh is dominated by Spartina alterniflora in the low marsh and S. patens and Distichlis spicata in the high marsh (SES, 1987). Phragmites australis is locally abundant in disturbed areas. Bellmer (1989) discussed the relatively high productivity of the Fairhaven and Acushnet marshes.

Several small mammal species were trapped and attracted to scent posts in the saltmarsh area. These included mice and rats as well as occasional larger species such as eastern cottontail rabbit and fox. Incidental observation of squirrel, muskrat and raccoon signs were also made (IEP, 1988; Bellmer, 1989).

A number of bird species were observed in both the open water and the saltmarsh in the Upper Estuary in a quantitative study conducted by IEP (1988). The Upper Estuary is utilized, at times heavily, by several species of dabbling or wading birds. The Mute Swan and Mallard are often seen in large numbers while the Snowy and Great Egret and Black-crowned Night Heron are often seen. Gulls and terns are abundant. A number of bird species were observed in the saltmarsh. Most numerous was the Red-Winged Blackbird, Song Sparrow, Sharp-tailed Sparrow and Tree Swallow (IEP, 1988).

5.1.2.2 Potential Impacts of Capping Alternative

Capping will result in both short-term impacts during construction as well as permanent long-term changes. Quantification of effects resulting from the trade-off between subtidal mudflats, intertidal mudflats and saltmarsh habitat is problematic. The relative values of various estuarine habitats have been the subject of many studies by estuarine scientists over at least the last 20 years. Not only are substantial basic research questions yet to be addressed, but broad underlying axioms relating to the various estuarine functional values are elusive since many attributes of estuarine dynamics are fairly site specific.

What has been widely accepted is the importance of wetlands. Estuarine scientists have developed a number of criteria to categorize the functional values of these wetlands. This understanding of functional values, which may include water quality, habitat, sediment or geomorphological values, aquifer recharge, food chain production and nutrient exchange, and flood control and storm damage prevention, have evolved to become the basis for regulations that have been developed to protect these wetlands. A number of papers have discussed and described a variety of functional values for estuarine wetlands, including Nixon (1980, 1982), Pomeroy and Wiegert (1981), Odum, et al. (1984) and Tiner (1987).

The evaluation of impacts in this instance is perhaps best organized using the EPA CWA Section 404(b)(1) Guidelines Interim Regulations on Discharge of Dredged or Fill Material into Navigable Waters, Subparts C, D, E, and F (40 CFR Part 230). This evaluation includes an analysis of short-term impacts;

additional issues relevant to the construction and implementation of the capping alternative are also contained within Section 5.5. Since Sanford Ecological Services (SES, 1988) also used the Section 404 framework to evaluate the "hydraulic control" and the "in harbor containment" alternatives, use of this regulatory framework will permit comparison of the capping alternative discussed in this report with other alternatives that are being considered by EPA.

5.1.2.2.1 Potential Impacts on Physical and Chemical Characteristics of Substrate

As discussed previously, approximately 340,000 cubic yards of fill will be placed over approximately 140 acres of the Upper Estuary where contaminant levels of PCBs in sediment are greater than 50 ppm. It will be placed over a period of approximately 1 1/2 to 2 years while the hydrologic regime of the Upper Estuary is being controlled with various dams and weirs.

Capping will result in the permanent modification of a portion of subtidal and intertidal habitat in the Upper Estuary. As described in Table 5.1, approximately 19 acres of intertidal mudflat habitat will be converted to saltmarsh, and 17 acres of subtidal mudflat habitat will become intertidal mudflat. In all, 36 acres of subtidal mudflat will be transformed. About 22 acres of current subtidal and intertidal habitat will become an erosion armored cap, 11 acres being intertidal and approximately 11 acres being subtidal. In addition, the character of the substrate in the Upper Estuary will change from the present highly organic silt to that of the fill which is sandy, except for the area in the erosion channel. This area would be armored with gravel or cobble-sized stone. As discussed in Section 3.4.1, it is expected that this new substrate should consolidate approximately 20 to 25 cm over a period of approximately a year. In addition, it is expected that should continued sedimentation take place, the sediment surface will gain more silts and clays as these finer particles settle out in the relatively quiescent environment of the Upper Estuary.

Impacts from Suspended Particulates/Turbidity

During construction, movement of barges and placement of geofabric will result in some localized resuspension of the sediment surface with attendant turbidity. However, due to the use of specialized barge and boat movement methods developed for specific Upper Estuary conditions, significant resuspension of contaminated sediment is not expected. Furthermore, since construction activities will occur in a controlled environment (i.e., controlled hydraulics through use of the weir dam and upstream controls), it is expected that the resuspension and turbidity will be minimized, and effects therefore negligible.

In the long term, the modified hydraulic regime should result in lower levels of suspended solids than exist at present.

Impacts on Water Quality Associated with Cap Placement

During construction, it is expected that there will be some increase in suspended solid levels and concomitant resuspension of particle-related contaminants. In addition, there will be the potential for localized, short-term mobilization of metals and PCBs through dissolution. As discussed above, these impacts are not expected to be significant.

In the long term, although a reduced tidal volume will exist in the Upper Estuary, somewhat lower biochemical oxygen demand (BOD) levels are expected. This reduction is attributed to capping approximately 140 acres of organic-rich bottom sediment which exert a BOD load on the overlying water column. The placement of clean cap material over these sediments will significantly reduce this BOD load. The somewhat reduced depth of the Upper Estuary will also allow more oxygenation and mixing of estuary water. Furthermore, the added saltmarsh is expected to increase sediment trapping and the potential for binding nutrients and contaminants in the marsh, thus further acting to improve water quality.

Impacts on Current Patterns and Water Circulation

During construction, the hydraulic controls used will significantly modify current patterns, tidal prism and tidal amplitude. As discussed in Section 3.3, the objective of hydraulic control operations will be to control the tidal regime in the Upper Estuary in order to facilitate the movement of barges and installation of the cap, as well as to minimize impacts from resuspended sediment. This will temporarily reduce or eliminate tidal exchange and significantly depress the normal tidal amplitude when the weir is closed.

After the cap is placed and consolidation takes place, tidal currents should be reduced since there will be less tidal exchange within the Upper Estuary. In addition, it is expected that with a somewhat decreased surface area of water in the Upper Estuary, there would be less potential for localized wind-driven circulation. During high precipitation events, it is expected that, because of the shallower conditions, storm runoff would cause higher currents than are presently experienced.

Impacts on Normal Water Fluctuation

During construction, there will be a substantial effect on water fluctuation. In the long term, however, there will probably be little change in tidal amplitude because tidal driving forces at the Coggeshall Street bridge will be the same as before remediation.

Impacts on Salinity Gradients

Hydraulic control during construction will result in short-term changes of salinity within the Upper Estuary. Because the dam weirs will be removed on a frequent basis to allow water exchange between the Upper Estuary and the harbor as discussed in Sections 3.3 and 5.5.3, these changes are not expected to be significant.

In the long term, because the tidal exchange will be reduced, it is expected that the salinity gradient would be moved downriver from where it presently exists. Because the Upper Estuary is well mixed, and because base flow of the Acushnet River is low (10 to 30 cfs), this movement is not expected to be large.

5.1.2.2.2 Potential Impacts on Biological Characteristics

Impacts on Threatened and Endangered Species

The Massachusetts Natural Heritage Program has reported that there are no known threatened or endangered species or ecologically significant natural communities within the project area (SES, 1988). Two species of "special concern", the Sharp-shinned Hawk and the Least Tern have been observed on occasion in the Acushnet estuary (SES, 1988). It is not expected, however, that the small changes in habitats due to this project will negatively affect those species. In fact it may be argued that to the degree these species utilize the Upper Estuary, the long term affects of the project will be beneficial.

Impacts on Fish, Crustaceans, Molluscs and Other Aquatic Organisms in Food Web

In the short term, construction will result in the burial of sessile and slow moving benthic organisms in the capped area. As discussed above, it is also expected that some increased localized turbidity levels will occur. These increased suspended solids levels may also have an effect on nearby downstream benthic communities by localized burial and limited short-term exposure to mobilized contaminants. Mobile fish and epifauna will be able to avoid the capping material as it is placed and escape from the area. It is expected that during construction, migratory fish species which normally utilize the estuary will be deterred by the hydraulic controls or will be stimulated to leave the area by construction activities.

In the long term, it is expected that recolonization will proceed quickly. Whitlatch (1989) has discussed this potential and, while it is difficult to project the character of the species composition with certainty, it is likely that species dominant south of the Upper Estuary will strongly influence the structure of the benthic community in the Upper Estuary. Attachment C (Whitlatch, 1989) contains a comprehensive discussion of expected post-remedial recolonization in the Upper Estuary. This recolonization will occur relatively rapidly depending upon the seasonality of the construction; the rates and nature of recolonization in this region have been well documented in the literature (McCall, 1977, 1978; Simon and Dauer, 1977; Rhoads et al., 1978).

The overall modification of the Upper Estuary habitats as discussed above will result in increased saltmarsh, increased intertidal mudflat and decreased subtidal mudflat, as well as the addition of approximately 22 acres of riprap channel in the intertidal and subtidal zones. These modifications will result in a concomitant decrease or increase in species and communities associated with each of those habitats. In addition to habitat modification, it is also expected that large-scale reduction of contamination in the area will enhance the potential for an increase in abundance of various species, as well as diversity of species within the communities. For instance, although the subtidal community may experience a reduction due to the decreased habitat available, it may also be that the increased carrying capacity of the habitat resulting from placement of clean sediment will compensate partially or completely for the reduction in area of habitat. Should this be the case, then the increase in carrying capacity would mitigate for the removal of habitat, and the effect on the food chain would be minimal. It is also expected that there may be some slight shift in distribution of species with stenohaline characteristics due to the modification of the salinity regime. Species sensitive to salinity include some crustaceans as well as echinoderms.

Impacts on Other Wildlife

During construction, it is expected that wildlife using the Upper Estuary (e.g., avifauna, as well as some mammal species utilizing the marsh) would be disturbed and displaced. However, it is expected that after construction, the increased saltmarsh area would provide additional habitat for saltmarsh species. It is also likely, as Whitlatch (1989) discusses, that the shallowness of the capped area would provide additional feeding habitat for some species of ducks, geese and swans.

5.1.2.2.3 Impacts on Special Aquatic Sites

Impacts on Existing Wetlands

The change in various habitat areas would result in some modification of the subtidal, intertidal and saltmarsh communities. It is also assumed that the increased "quality" of the capping material would result in increased abundances of those species recolonizing the area. The increased area of saltmarsh should enhance sediment trapping and water purification functions of the wetlands through increased uptake of sediment nutrients and sediments associated with adsorbed contaminants.

Impacts on Mudflats and Beach

Placement of the cap will bury areas of the subtidal and intertidal mudflats and species currently living there. However, as discussed above, it is expected that recolonization will rapidly occur and that the increase in intertidal area will increase the overall potential intertidal species. In addition, it is expected that the overall reduction of contamination in the Upper Estuary will be environmentally beneficial and should result in increased carrying capacity for those species living in or utilizing the Upper Estuary.

The expected decreased dynamics of the hydrologic regime (e.g., shallower depths and lower tidal velocities) in the Upper Estuary should decrease the potential for wave or current-induced erosion. Certainly there would be less potential for this than under a dredging alternative where the creation of banks along the dredged area would significantly increase the potential for erosion and slumping.

5.1.2.2.4 Effects on Human Use Environmental Characteristics

Effects on Recreational and Commercial Fisheries –

As noted, in the short term, construction will bury some of the shellfish species currently living in the Upper Estuary and associated intertidal areas, causing their temporary elimination. It is also expected that fish species which use the Upper Estuary as a nursery area or which migrate up the Acushnet River to spawn will be restricted from doing so during construction, although timing of construction activities could minimize this potential.

In the long term, migration up the Acushnet River by migratory fish species (e.g., river herring) will be restricted during some tidal stages. Through the placement of fish passage devices, this tidal restriction could be eliminated. The decreased open water area in the Upper Estuary could also have the effect of lowering the carrying capacity and, if the increased "health" of the habitat does not compensate for the decreased open water area, it would put some pressure on those benthic species that provide a food source for fish species who use the Upper Estuary as a nursery/feeding area. The capping alternative should result, however, in the reduction of high body burdens found in some of the locally caught fish species. Once the cap material has consolidated, there should be potential for a revived recreational fishery in the Upper Estuary following cessation of sewage discharge to the estuary and harbor.

5.1.2.2.5 Evaluation and Testing of Dredged or Fill Material

Since the cap material will be brought from an off-site borrow area, it will be tested thoroughly for potential chemical contaminants to minimize potential adverse effects from the chemical nature of the cap material.

5.1.2.3 Mitigation

5.1.2.3.1 Saltmarsh

As previously discussed, all new habitat above MSL will be planted with cord grass (Spartina alterniflora) seeds or seedlings. These will be managed to enhance the carrying capacity of the new as well as the existing saltmarsh. Section 3.4.6 discusses the success of saltmarsh establishment at other sites, and the potential for success in the Upper Estuary.

5.1.2.3.2 Fish Passage Device

Since the proposed erosion protection cap will be placed across northern portions of the Upper Estuary, the potential exists for partial blockage to free finfish travel between the Acushnet River and the Upper Estuary during some tidal stages. The potential for partial blockage is a direct function of the cap thickness and the amount of settlement the underlying sediment will undergo. It is anticipated that construction of the cap will begin in the northern portions of the Upper Estuary and will progress in a southerly direction. Thus, it will be possible to observe the extent of the settlement and determine if fish passage devices will be needed.

At this time, estimates of sediment consolidation in the northern portion of the Upper Estuary range from 20 to 25 cm. These estimates indicate that shallow water would exist over the cap in this portion of the Upper Estuary at MLW.

5.1.2.4 Reduction of PCB Exposure

Under the planned containment alternative, 140 acres of the Upper Estuary would be capped with clean sediment. As a result, 74 percent of the Upper Estuary will have clean sediment on the bottom. For the remainder of the Upper Estuary and for parts of the Middle and Lower Harbor, the PCB concentration for the upper layers of the sediment would range between <1 and approximately 50 ppm. Table 5.3 illustrates the areal distribution of PCB concentration regimes after capping.

In general, it is obvious that capping would substantially reduce exposure and therefore risk of adverse effects to aquatic organisms. The water column PCB concentration resulting after capping has been estimated by ASA (1989) using a simple box model to provide a first order approximation. As noted, ASA calculated that under the proposed in place containment alternative, water column PCB concentrations would be reduced by a factor of 100, to approximately 21 ng/l in the Upper Estuary, and would be reduced by a factor of about 10, to approximately 27 ng/l in the Middle and Lower Harbor. Those species living in the water column, plankton and fish, should experience an estimated hundred-fold reduction in PCB water column concentration in the Upper Estuary and a 10-fold reduction in the Middle and Lower Harbor. After capping the maximum sediment concentration that benthic species should be exposed to is approximately 50 ppm.

The post-capping water column PCB concentration predicted by ASA (1989) ranges from about 17 to 31 ng/l under a variety of assumed tidal exchange and sediment flux scenarios. These levels are below or only slightly above the Federal Ambient Water Quality Criteria (AWQC) for PCB in salt water of

30 ng/l for chronic exposure, and substantially below the acute criteria of 10 ppb (EPA, 1980) (See Section 5.2.2 below). Since plankton and fish are either actively or passively mobile, the acute criterion or some hitherto uncalculated time-varying criterion would be a more appropriate criterion to apply in New Bedford Harbor. Due to tidal exchange in New Bedford Harbor, there is rapid dilution of estuarine waters by relatively clean water from Buzzards Bay in each tidal cycle. The effect of this tidal circulation is continual variation in water column PCB concentration. Given this, it would seem logical that a more appropriate site specific criterion would therefore lie somewhere between the chronic AWQC of 30 ng/l and the acute AWQC of 10 ppb. Since it appears, however, that the resulting water column concentration after capping will be less than the EPA chronic AWQC, sufficient protection to plantonic and nektonic species should be afforded.

Additional information relevant to consideration of the effect of predicted water column PCB concentrations is offered by CDR Environmental Specialists (CDR) (1989). In their review of relevant literature, they reported that worst case Maximum Acceptable Toxicant Concentration (MATCs) for maintenance of photosynthesis or cell division in phytoplankton, arguably the most sensitive of water column organisms, was approximately 3.2 ppb for a 6 hr exposure, approximately the time of one half tidal cycle. One can postulate that even under present conditions, passively drifting phytoplankton would, for the most part, be "carried" in and out of the Upper Estuary and only have the potential to be exposed for a portion of the tidal cycle to those areas where the water column PCB concentration would approach the MATC for 6 hour exposure. After capping, the substantial reduction in water column PCB concentration would be appreciably lower than the MATC for plankton. Additionally, the sublethal effects water column PCB concentration for most fish examined in the CDR (1989) literature review was greater than 10 ppb, far higher than predicted water column concentrations after capping.

For benthic species, particularly some deposit feeding infaunal species, the estimation of the degree to which exposure to PCB, and consequently the potential for adverse effects, would be reduced through the in place containment alternative is more complicated. It is first important to understand that in considering the effects of PCB in the sediment and in the water column on benthic species, one must first differentiate, at least in a gross way, between the variety of benthic species living in the New Bedford Harbor estuary. Epifaunal and infaunal species that are suspension feeders are probably more affected by PCBs taken in from their food in the overlying water column; infaunal deposit feeders, on the other hand, are probably more affected by the quantity of PCB they ingest while passing the sediment through their body. Deposit feeders, therefore, would seem to offer a worst case for evaluating exposure and risk of adverse effects from PCB.

For epifaunal and suspension feeding infaunal species, probably the best indicator of their exposure is a consideration of the body burden information presented in Section 5.1.1. Of those modeled by Connelley and St. John (1988), the lobster, flounder, crab and mussel are epifaunal species; the hard clam an infaunal suspension feeder. Post-capping PCB body burden analysis (See table on page 5-11) for these representative species is expected to show a substantial decrease in body burden. Although the relationship between body burden of PCB and other toxicological effects is not clear, one would logically expect there to be a direct reduction of risk to these species. The literature review of PCB effects (CDR, 1989) did not reveal any toxicological effects to benthic species exposed to PCB concentrations in the range of the predicted 17-31 ng/l in the water column.

With respect to infaunal deposit feeders or "soft-bodied" infaunal suspension feeders, CDR (1989) reviewed the literature relating to toxicological effects of PCB in sediment on these benthic species, many of which may now live or have the potential to live in New Bedford Harbor after it is capped. Review of tests using these species indicated that sublethal toxicological response could be expected at levels ranging from about 1 to 10 ppm of PCB in sediment; MATCs for survival ranged from 30 to about 90 ppm. While the CDR (1989) review did not critically analyze the laboratory toxicological studies reported upon, these MATC's are used in this report for discussion purposes only.

A study by Hansen et al. (1986) using New Bedford Harbor sediment suggested that a chronic MATC for sublethal effects of about 7 ppm would be appropriate for a benthic infaunal species, Ampelisca abdita. Review of the Hansen et al. study, concluded that the results of these toxicity experiments could have been confounded by a variety of factors relating to experimental design and laboratory controls. These factors include:

1. The PCB was introduced to the experiment in a "carrier", either polyethylene glycol or acetone, which has the effect of delivering higher levels of PCB to an organism than are possible in the natural habitat;

2. Failure appropriately to control for other contaminants, e.g., PAHs, which may have been present in the sediment;

3. Use of an inappropriate experimental design and statistical test to differentiate the effects of PCB as compared to metals;

4. Potential failure to control temperature and salinity during tests, and;

5. The methodology used to measure water concentrations of PCB raises a number of questions as to exactly what concentrations the test organisms were exposed to.

Nevertheless, if one accepts, for purposes of this discussion only, a MATC of 10 ppm as a predictor of sublethal effects, then one would conclude that there will be the potential for some limited portion of some sensitive species populations in New Bedford Harbor to experience PCB-related sublethal toxicological effects if they inhabit sediment in excess of approximately 10 ppm. This would be approximately 15% of the Upper Estuary and 26% of the total estuary north of the hurricane barrier after capping is completed. MATCs for survival of some benthic species of 30 ppm, the lower end of the MATC range for lethal effects presented by CDR (1989), would be exceeded after capping in approximately 7% of the Upper Estuary and 12% of the total estuary north of the hurricane barrier; using a mid-range MATC of 60 ppm, none of the Upper Estuary and only 4% of the total estuary north of the hurricane barrier would exceed this level after capping.

Extrapolation of these potential effects on some individuals of certain species to population and ecosystem impacts involves consideration of a number of factors. These factors include the degree to which sublethal effects moderate the ability of individual organisms to fulfill their ecological role, the numbers of affected individuals compared to total estuarine population, and the degree to which reproductive success of species populations within the affected species range is diminished by reproductive failure or death of a few individuals.

The majority of the potentially affected species in the Upper Estuary have a high reproductive capacity, depending on large numbers of sexual products to mitigate for high egg and larval mortality rates, and depend upon a planktonic larval stage to ensure broad geographic distribution. Since the dominant species currently living or likely to be living in New Bedford Harbor after capping are widely distributed along the northeast Atlantic coasts, there will be a continuous source for recruitment of species to New Bedford Harbor whether or not there are any localized lethal or sublethal effects to individual organisms. For these reasons it is unlikely that, in the event toxicological effects are experienced by some infaunal individuals in limited areas of New Bedford Harbor, these effects will result in a significant impact to the species population there or in nearby waters. Likewise, it is expected that there will be ample replacement of affected individuals so ecological roles they fill should not be significantly or permanently impacted.

There has also been some concern raised regarding whether PCB accumulated in the tissues of benthic organisms would be concentrated in higher levels of the food chain. Although there currently is a fair amount of controversy in the scientific community regarding whether or not biomagnification occurs (CDR, 1989), it is clear at least that higher levels of a food chain could accumulate some PCB from lower levels of the food chain. Data which currently lend some perspective to this subject is that reported by Battelle (1987). They found that two species, the lobster and the winter flounder, which occupy places at higher levels of the food chain have largely accumulated less than 2 ppm in their edible flesh under present conditions.

Based on these findings, it seems clear that after remediation, higher levels of the food chain should experience less PCB body burden and hence less potential for associated toxicological effects.

5.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This evaluation criterion is derived from Section 121(d) of CERCLA (as added by Section 121 of SARA) which provides, subject to certain defined exceptions ("waivers"), that the selected remedial action is to meet or attain those federal and state standards, requirements, criteria or limitations that have been identified as "legally applicable to the hazardous substance or pollutant or contaminant concerned" or as "relevant and appropriate under the circumstances of the release" (42 U.S.C. Section 9621(d)(2)(A)). Detailed analysis of a given remedial alternative thus includes an evaluation of whether the alternative is expected to attain all "legally applicable" or "relevant and appropriate" standards, requirements, criteria or limitations ("ARARs") and, if not, whether application of one of the "waivers" set out in Section 121(d)(4) of CERCLA (42 U.S.C. Section 9621(d)(4)) is justified (Proposed Revised NCP, Preamble at 108-109 (Proposed Rule 53 Fed. Reg. 51394; December 21, 1988). See also NCP Section 300.68(i)(5) (40 CFR 300.68(i)(5)).

The detailed analysis also will include consideration of available guidance materials that are not ARARs (e.g., advisories, health effects information, EPA guidances) where the lead agency has determined (within the bounds of its discretion) that reference to such materials is appropriate (EPA, 1988). If included, these guidance materials are not treated as furnishing fixed and invariable requirements, but rather are accorded "to be considered" status, so that remedy selection may be informed by their contents (Proposed Revised NCP, Preamble at 135 (Proposed Rule 53 Fed. Reg. 51394; December 21, 1988).

In the course of EPA's RI/FS for the New Bedford Harbor site, its contractors have conducted an assessment of the ARARs potentially implicated by the various remedial options currently under consideration for the site as a whole. The results of that assessment have been published in a document entitled "Regulation Assessment (Task 63) for New Bedford Harbor, Massachusetts"

(E. C. Jordan/Ebasco, March 1988). The regulation assessment identifies chemical and location-specific ARARs for New Bedford Harbor and action-specific ARARs for the remedial technologies under consideration. Potentially pertinent federal and state non-ARAR criteria, advisories and guidances also are canvassed.

In the recently released "Hot Spot Feasibility Study for New Bedford Harbor" (HSFS) (E. C. Jordan/Ebasco, July 1989) certain additional ARARs are identified (e.g., the Massachusetts Contingency Plan, 310 CMR 40.000) and each of the four alternatives retained for detailed analysis are evaluated for ARAR compliance. Since EPA views each of the "hot spot" alternatives as "interim" measures, however, none is designed or expected to attain chemical specific ARARs for surface water quality or biota tissue PCB concentration.

The evaluation of the containment alternative presented herein draws upon both the "Regulation Assessment" and the HSFS in identifying federal and state standards, requirements, criteria and limitations that may be deemed "applicable" or "relevant and appropriate." For present purposes, chemical and location-specific ARARs and guidance materials identified in the HSFS have been treated as potentially pertinent to the containment alternative. Table 5.4 compiles the appropriate regulatory references and provides commentary on attainment or compliance.

Table 5.5 lists potential action-specific ARARs implicated by the activities involved in the containment remedy. The references found in Table 5.5 have been selected with the aid of the "Regulation Assessment," but also reflect an independent analysis of the environmental and human health concerns unique to this alternative.

The contaminant containment alternative is expected to attain or comply with all standards, requirements, criteria or limitations that may be deemed to be ARARs, including those which the "hot spot" alternatives are not expected to attain. In order to make clear the analysis by which this conclusion has been reached, specific discussion of some of the more significant ARARs and guidance materials selected by EPA is provided below.

5.2.1 FDA Tolerances for PCB Residues in Fish and Shellfish

Pursuant to the Federal Food, Drug and Cosmetic Act (21 U.S.C. Sections 301 et seq.) the Food and Drug Administration of the Department of Health and Human Services (FDA) has promulgated regulations establishing "tolerances" for PCB residues in foods, including fish and shellfish (21 CFR 109.30). Under this provision, fish or shellfish tissue will be considered unsafe for consumption only if PCB concentrations in edible portions exceed 2 ppm (21 CFR 109.30(a)(7)). The edible portion of fish excludes the head, scales, viscera and inedible bones (id.).

Current and expected post-remedial concentration data for edible fish and shellfish PCB body burden in the New Bedford Harbor area are discussed in Section 5.1.1. These data indicate that, under the current regime, PCB concentrations exceed 2 ppm in only one of the edible fish and shellfish specifies tested -- lobsters -- and then only in the liver (or "tomalley") of lobsters. Even if lobster tomalley is included as part of the "edible portion" of lobster (contrary to the implication of the language of the regulation excluding fish "viscera") first order food chain modeling suggests that post-remedy PCB body burden in all fish and shellfish will be within the FDA tolerance (See Section 5.1).

5.2.2 Surface Water Quality Criteria

In connection with its authorities under the Massachusetts Clean Waters Act (M.G.L. Chapter 21 Sections 26 et seq.), the Division of Water Pollution Control of the Department of Environmental Protection (DWPC) has promulgated the Massachusetts Surface Water Quality Standards (SWQSs) (314 CMR 4.00). These standards are used by DWPC in regulating discharges of pollutants to surface waters. DWPC is charged with limiting or prohibiting such discharges "to insure that the water quality standards of the receiving waters will be maintained or attained" (314 CMR 4.02(1)). Specific water quality criteria for defined classes of surface waters are set out in 314 CMR 4.03(4).

Federal water quality criteria also have been published by EPA pursuant to Section 304(a) of the Clean Water Act (33 U.S.C. Section 1314(a)). Of particular relevance to the New Bedford Harbor site is EPA's "Ambient Water Quality Criteria for Polychlorinated Biphenyls" (EPA Doc. No. 440/5-80-068, October 1980). This document contains criteria for chronic and acute exposure of saltwater aquatic life to PCBs (0.030 ug/l and 10 ug/l, respectively). The AWQC for PCBs "is a scientific entity, based solely on data and scientific judgment;" it is not a water quality standard "and in itself has no regulatory effect" (EPA, 1980).

The DWPC Surface Water Quality Standards make specific reference to federal AWQCs. In Section 4.03(2) of those regulations, it is provided that DWPC "will use EPA criteria established pursuant to Section 304(a)(1) of [the Clean Water Act] in establishing case-by-case discharge limits for pollutants not specifically listed in these standards but included under the heading 'Other Constituents' in 314 CMR 4.03(4), for identifying bioassay application factors and for interpretations of narrative criteria." PCBs fall into the category of "other constituents" under these regulations, and thus, Federal AWQCs for PCBs are properly considered "as guidance" in the application of the SWQSs for establishing pollutant discharge limitations.

The HSFS erroneously has identified DWPC SWQSs as "applicable" to the remedy within the meaning of Section 121(d)(2)(A)(ii) of CERCLA (42 U.S.C. Section 9621(d)(2)(A)(ii)) and erroneously has stated that the DWPC regulations incorporate the Federal AWQC for PCBs as a regulatory "standard" for Massachusetts surface waters. These propositions together suggest the erroneous conclusion that a remedy which would result in deviation from

AWQCs, by however little, could not properly be selected absent invocation of one of the "waivers" referred to in Section 121(d)(4) of CERCLA (42 U.S.C. Section 121(d)(4)).

Massachusetts Surface Water Quality Standards are not legally "applicable" to the remedy since neither the remedial action contemplated nor the circumstances at the site "satisfy all of the jurisdictional prerequisites" of the regulatory requirements that incorporate the SWQSs, such as the discharge permit program of 314 CMR 3.10. See EPA Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements (July 1987) at 2. Compare Section 121(d)(2)(A) and (d)(2)(B)(i) of CERCLA (42 U.S.C. Section 121(d)(2)(A) AND (d)(2)(B)(i)) (referring to AWQCs as potentially "relevant and appropriate").

Further, to interpret the DWPC regulations as elevating AWQCs to the status of regulatory standards not only is inconsistent with the express language of the regulations referring to AWQCs "as guidance," but also with the mandate of the regulations that "[i]n interpreting and applying the minimum criteria in 314 CMR 4.03(4), [DWPC] shall consider local conditions including . . . temperature, weather, flow and physical and chemical characteristics . . ." (314 CMR 4.02(1)). Given the comprehensive studies of this site undertaken by EPA and potentially responsible party (PRP) consultants, analysis of the surface water quality impacts of any remedial scheme without reference to other site characteristics clearly would be imprudent.

While AWQCs thus are not properly considered fixed and invariable "ARARs" for this site, they have been considered in the development of the in place containment alternative, and it is expected that residual water column PCB concentrations will fall below 0.030 ppb (See Section 5.1.2.4, above). For these reasons, consideration of AWQCs does not raise questions concerning the overall protectiveness of the containment remedy.

5.2.3 TSCA PCB Storage and Disposal Regulations

EPA regulations issued under the Toxic Substances Control Act (TSCA) impose certain limitations on methods of disposal of PCB wastes (40 CFR 761.60). For example, waste PCBs at concentrations of 500 ppm or greater must be disposed of in an incinerator which complies with 40 CFR 761.70 (40 CFR 761.60(a)(1)). Mineral oil dielectric fluid from PCB-contaminated electrical equipment, and other materials containing PCBs at concentrations greater than 50 ppm but less than 500 ppm, must be disposed of by certain specified methods (40 CFR 761.60(a)(2) - (5)).

The TSCA disposal regulations are neither "applicable" nor "relevant and appropriate" to the containment alternative. The containment alternative does not involve removal and subsequent disposal of PCB-contaminated sediments; "disposal" regulation therefore are inapposite. Even if these provisions were deemed "relevant and appropriate" in determining the propriety of a remedy leaving in place PCBs at concentrations exceeding 50 ppm, the regulations themselves contain an exception appropriate for invocation in the circumstances here presented.

The nearest analogy to the present situation is that referred to in 40 CFR 761.60(a)(5), which deals with disposal of dredged materials and municipal sewage treatment sludges. That provision contains a procedure, however, whereby the EPA Regional Administrator for the Region in which the PCBs are located may approve alternative disposal methods that assure adequate protection of the environment (40 CFR 761.60(a)(5)(iii)). For all of the reasons discussed elsewhere in this report -- and given the risks inherent in dredging and disposal alternatives -- alternative "disposal" by means of the containment alternative is appropriate and protective.

5.2.4 CWA Section 404 Permit Program

An evaluation of how the in place containment alternative would be considered under the Section 404 permit program has been presented in Section 5.1.2. However, because comparable remedial programs have not yet been developed for the Upper Estuary by EPA, it was not possible to perform a comprehensive comparative analysis with other feasible alternatives as required under Section 404. Nevertheless, some comparison has been made between this proposed remedial alternative and a generic remedial alternative involving dredging of estuary/harbor sediment. In many ways, previously discussed impacts associated with capping (e.g., elimination of current benthic community and modification of habitat) also occur as a result of dredging. However, in one particular area, resuspension and transport of contaminated sediment, the magnitude of adverse impact appears much greater for a dredging alternative. On this basis, and as previously discussed in Section 5.1.2, it appears that the proposed in place containment remedial alternative would comply with Section 404 requirements.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

For a remedial action program to be judged feasible, technically adequate and protective of human health and the environment, it must be deemed effective for the long-term. Long-term effectiveness is defined in terms of magnitude of residual risk and adequacy and reliability of controls (EPA, 1988). The magnitude of expected residual risk is discussed in detail in Section 5.1, above. The second aspect of this criterion, adequacy and reliability of controls, is discussed in this section.

Specific to the New Bedford Harbor Superfund site and the in place containment remedial action program, three primary long-term effectiveness criteria have been identified. These three criteria are:

1) The capability of the containment system to effectively preclude migration of PCBs through the cap,

2) The capability of the cap to withstand recurrent hydrodynamic forces in the Upper Estuary, including tidal and wind-driven currents as well as infrequent, high-intensity surface water run-off events, and

3) The capability of the cap to withstand intrusive human activities without allowing significant contaminant migration.

As discussed below, the in place containment alternative satisfies these criteria and is believed to be a permanent and effective method for remediation of contaminated sediments in the Upper Estuary.

5.3.1 Chemical Containment Effectiveness

The capability of the capping system to effectively contain PCBs present in Acushnet River Upper Estuary sediments for extremely long periods of time has previously been discussed in Section 3.1 of this report. In summary, laboratory studies performed by the USACE (1988) to determine the effectiveness of capping New Bedford Harbor PCB contaminated sediments were reviewed to provide an initial assessment of the feasibility of an in place containment remedial program. The results of this study indicated that capping is an effective means of limiting the migration of PCBs from New Bedford Harbor sediments.

In order to expand on the results of the USACE laboratory bench scale testing, analytical modeling of capping effectiveness was performed by Thibodeaux (Attachment B). The purpose of this assessment was to provide additional data to evaluate the effectiveness of a sediment cap in containing PCBs present in New Bedford Harbor sediment, to provide a means of estimating the period of time required for PCBs to migrate through the cap (breakthrough time), and to estimate the mass of PCBs which would be expected to migrate through the cap following achievement of steady state conditions. A range of cap material organic content concentrations and PCB Aroclor solubilities were considered in evaluating PCB cap breakthrough time. Assuming the placement of a 45 centimeter thick sediment cap over Upper Estuary sediments, with only 25 centimeters of sediment being designed to act as a chemical barrier, PCB breakthrough times were estimated to be nearly or in excess of a thousand years; at the time of PCB breakthrough and/or steady state PCB flux conditions, assuming no further sedimentation occurs in the Upper Estuary, the total PCB concentration in sediment pore water at a bed depth of 10 cm will be approximately 30 ng/l. Following breakthrough and occurrence of steady state PCB flux conditions, it was estimated that the steady state PCB flux rate through the 140 acre cap would be approximately 200 to 270 grams per year (approximately 1/2 pound per year) (Thibodeaux, 1989).

In estimating the amount of post-breakthrough (worst-case) PCB flux through the cap and the long-term effectiveness of the cap, consideration was given to the potential effect of sediment PCB concentration on cap performance. Above a concentration of 300 ppm, sediment PCB concentration was not found to affect the performance of the cap (Thibodeaux, 1989). The cap should be equally effective in containing sediment with 300 ppm of PCB as sediment with 50,000 ppm of PCB. The effectiveness of the cap in containing PCBs regardless of concentrations is due to the very low solubility of PCBs, and the belief that molecular diffusion is the limiting process for contaminant transport once particle transport processes, like bioturbation, are precluded from estuary sediment by placement of the cap. Sediment with a PCB concentration of 300 ppm or above will saturate pore water with PCB. However, once PCBs in pore water are at the saturation concentration (88 ppb for Aroclor 1242 and 12 ppb for Aroclor 1254), no more PCB can enter the pore water until some of the existing PCB is removed from the water. This removal process occurs through transport of the PCB molecules to other pore water or sediment particles by molecular diffusion, which is a very slow process. Because this process is so slow (recalling cap breakthrough times for thousands of years), sediment with 50,000 ppm of PCB can place no more PCB into solution for transport than sediment with 300 ppm of PCB. It is for this reason that the cap has been judged to be effective in immobilizing low-level PCB contaminated sediments as well as "hot spot" sediments.

In performing this analytical modeling of capping effectiveness, several conservative assumptions were employed. Perhaps the most significant assumption made in modeling capping effectiveness was that no additional sediment will be deposited in the Upper Estuary following completion of the remedial program. Any additional accretion of sediments occurring in the Upper Estuary will serve to further preclude the migration of PCBs from existing estuary sediment to the overlying water column.

In summary, laboratory bench scale studies and independent analytical modeling have been performed to assess the ability of an in place remedial containment alternative to effectively preclude the migration of PCBs from Upper Estuary sediments to the environment. It was concluded that the proposed remedial alternative should be effective for a period approaching or exceeding 1,000 years. After that time, PCB flux through the cap has been estimated to be less than 300 grams per year.

5.3.2 Hydrodynamic Physical Integrity

Numerous studies have been performed to describe the hydrodynamic circulation system in the New Bedford Harbor site area. These studies have indicated that relatively low wind-driven and tidally driven currents exist throughout the vast majority of the study area. With the exception of the area immediately north of the Coggeshall Street bridge, tidal currents within the Acushnet River Upper Estuary typically are less than 10 centimeters per second, with maximum tidally induced currents near the bridge typically being less than 99 centimeters per second (ASA, 1988). Areas where significant tidal currents may exist in the Upper Estuary (e.g., the portion of the estuary due north and adjacent to the Coggeshall Street bridge) are not proposed to be capped as part of this remedial program due to the relatively low concentration of PCBs present in sediments in this area. Erosive forces due to wind and tide driven currents therefore are not expected to significantly impact the long-term physical stability of the containment cap.

Protection from storm surges is provided by the hurricane barrier at the entrance to New Bedford Harbor. According to USACE operational guidelines, the barrier is to be closed if the sea surface elevation is greater than five feet above MSL (USACE, 1982). Storm surges which may enter the harbor when the barrier is open will be dampened by the Route 6, I-195 and Coggeshall Street bridges prior to reaching the Upper Estuary. Storm surges therefore are not expected to affect the integrity of the cap.

In addition to tidal and wind-driven forces, consideration was given to erosive forces produced in the Upper Estuary during periods of high surface water run-off and associated peak discharge from the Acushnet River to the Upper

Estuary. As previously discussed in Sections 3.3 and 3.4.5, detailed analysis of routing of peak storm events from the Acushnet River through the Upper Estuary has indicated that elevated flow currents could exist in the northernmost portion of the estuary. For this reason, additional sediment erosion protection measures have been taken to protect the sediment cap. These measures include the placement of stone riprap over a 22 acre portion of the northern extent of the cap and the use of geoweb to supplement the erosive resistance of this riprap in selected high velocity zone portions of the Upper Estuary as well as over sediments with the highest reported concentrations of PCBs. Included in this design were safety factors to account for localized increased scour velocity zones and turbulent forces expected to exist during an extremely high discharge event.

In summary, the proposed containment cap has been designed for protection from tidal, wind-driven and surface water discharge erosive forces. This analysis has included the conduct of hydrodynamic tidal circulation and transport modeling, surface water routing and transport modeling, and sediment erosion analytical modeling. Following the application of applicable safety factors to these modeling outputs, the containment cap was designed to effectively resist environmental erosive forces. The proposed remedial alternative therefore should be effective in maintaining its physical integrity through an extremely wide range of meteorological and hydrologic conditions.

5.3.3 Resistance to Human Breaching of Cap

The third long-term effectiveness site specific variable identified for the New Bedford Harbor site was the possibility of breaching of the protective cap through human activities. To identify possible human activities which could result in partial or complete breaching of the cap, literature describing marine shore human activities as well as site specific demographic and risk assessment documents were reviewed and a site reconnaissance was performed (EPA, 1986; EPA, 1989; MDPH, 1987). Based on a review of this information, three principal public activities were identified which could result in disturbance to the sediment containment cap. These three activities are:

1) Beach walking or beachcombing,

2) Shellfishing, and

3) Recreational boating.

Beachcombing and walking are likely to be the most frequent activities occurring on the sediment containment cap. Due to the physical nature of the sandy materials proposed for construction of the sediment cap, as well as the use of a geotextile as an initial component of the containment cap, surficial human traffic is not expected to impact the physical stability or integrity of the cap. The sandy material selected for construction of the cap is expected to consolidate in a relatively short period of time (i.e., one to three months) and provide a relatively dense layer which should support human traffic without significant disturbance to the cap. The use of a geotextile underlying the sandy cap material will also serve to increase the load bearing strength of the cap, further decreasing the likelihood of physical disturbance to the cap from human traffic over the cap. As discussed in Section 3.4.1 of this report, estuary sediments are also expected to consolidate following placement of the containment cap due to the increased load on these sediments from placement of the sandy cap. The majority of this settlement is expected to occur in a relatively brief period, and will result in increasing the load bearing capacity of these underlying, presently soft, sediments. The increased load bearing capacity of the underlying existing sediments should serve to further increase the physical stability of the containment cap from surficial traffic.

Shellfishing activity conducted in the intertidal portion of the sediment containment cap is the human activity most likely to affect the containment cap. However, as previously discussed, due to the discharge of sewage to the estuary and harbor, a complete fishing ban has been imposed in the Upper Estuary. This ban would be maintained at least until these sewage discharges cease and the benthic community of the estuary is fully recolonized. On this basis, shellfishing in the Upper Estuary may be banned for some time in the future. Nevertheless, an assessment of the impacts shellfishing may have on cap permanence was performed and is presented below.

In many ways, clamming activities in the Upper Estuary are comparable to bioturbation of the cap by benthic organisms; clamming activities would have much larger localized impact on sediment, but would have a substantially lower density and frequency of occurrence than benthic bioturbation activity. Shellfishing could potentially occur in portions of the intertidal zone following recolonization of the Upper Estuary. Shellfishing activities would likely involve the use of shovels or rakes to remove clams from estuary sediment. Normally, clamming activities would not be expected to fully breach the 45 cm sediment cap. However, in instances where individuals who are clamming dig or rake to a depth of 45 centimeters, they will encounter a geofabric underlying the sediment cap. Due to the puncture strength of this geofabric, it is highly unlikely that this fabric will be breached. Although an individual may advance a clam rake or shovel to a depth of 45 centimeters through the sediment containment cap on an infrequent basis, it is unlikely that the individual will be capable of effectively penetrating the underlying geofabric layer to allow exposure to or the release of contaminated estuary sediments.

Certain intertidal portions of the containment cap would not be subject to clamming activities. These areas include the portions of the containment cap overlayed with a stone and/or geoweb riprap component. Shellfish would not be expected to burrow into this riprap layer and thus, shellfishing would not likely occur in these areas. Furthermore, due to the difficulty in digging in these areas as compared to adjacent sandy areas, clamming activities in riprap-protected portions of the containment cap would be even less likely.

Clamming activities are likely to result in the creation of shallow depressions in the sediment cap. However, due to the relatively noncohesive nature of the proposed cap material, and the hydrodynamic forces associated with twice daily tidal cycles, the depressions created are expected to be self-repairing, being refilled with clean sediment through a combination of hydrodynamic forces and pore water seepage. Tidal hydrodynamic forces, in concert with wave energy, have a tendency to heal depressions and dissipate mounds in sandy areas. These forces will have a tendency to smooth irregularities occurring in the cap, filling depressions and leveling mounds.

Lateral pore water seepage into sediment cap depressions also is expected to aid in the cap healing process. Clamming activities typically occur during low tide periods, which also coincides with a period of localized ground water depression. As the flood tide cycle proceeds, intertidal portions of the Upper Estuary are gradually inundated. During this period of inundation, localized ground water levels also rise. This localized ground water elevation increase will cause estuary pore water to flow into any newly created depressions. Due to the noncohesive nature of the cap material, this water flow into the depressions will serve to transport sediment from the depression walls into the depression, thus filling it in a manner similar to that associated with hydrodynamic tidal and wave action.

In summary, although clamming activities may result in localized disturbance of the cap, full breaching of the cap is not expected as a result of these activities. Areas which are disturbed by clamming activities are expected to be repaired during the process of incoming flood tides and as such, will be self-healing.

Following the completion of remedial program implementation, recreational boating activity is expected to increase in the Upper Estuary due to improved environmental conditions in the Upper Estuary. Some of this boating activity may involve the use of vessels with motors; these vessels may disturb sediments in shallow water depths due to propeller (prop) wash disturbance. However, due to the sandy nature of the cap material, prop wash impacts on the sediment cap are expected to be of little significance. Prop wash is not expected to transport sediment material significant distances due to the proposed cap sediment grain size and specific gravity, and are not expected to result in deep scouring of the cap. Because the sandy cap material will consolidate relatively quickly after placement, props which come in direct contact with the sediment cap would likely be damaged or cause motor failure before substantially affecting the cap. Depressions created by prop wash or anchoring should be self healing by the same mechanisms described previously.

5.4 REDUCTION OF TOXICITY, MOBILITY OR VOLUME

Section 121 of CERCLA (as added by Section 121 of SARA) provides, among other things, that the remedial action selected for a Superfund site be one that "utilizes permanent solutions . . . to the maximum extent practicable" (42 U.S.C. Section 9621(b)(1)). Under Section 121, EPA must "conduct an assessment of permanent solutions . . . that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility or volume of the hazardous substance, pollutant or contaminant" (id.).

Consistent with this movement towards the adoption of "permanent solutions," CERCLA now expresses a general preference for remedial actions "in which treatment which permanently and significantly reduces the volume, toxicity or mobility of the hazardous substances, pollutants, and contaminants is a principal element" over remedial alternatives "not involving such treatment" (42 U.S.C. Section 9621(b)(1)). EPA has recognized, however, that "[w]hile the CERCLA amendments strongly encourage the use of treatment technologies in CERCLA remedial actions, they allow for discretion in dealing with site circumstances and technological, economic, and implementation constraints that place practical limitations on the use of treatment technologies." Proposed Revised NCP, Preamble at 92 (Proposed Rule 53 Fed. Reg. 51394; December 21, 1988).

The in place contaminant containment alternative is a "permanent solution" that will result in a "significant decrease in the toxicity, mobility or volume" of PCB-contaminated sediments in the Acushnet River Estuary. Capping serves effectively to immobilize PCBs present in estuary sediments by isolating contaminated material and thereby suppressing the mechanisms principally responsible for PCB release and migration. Sediment contaminant migration modeling results indicate that current PCB flux from the Upper Estuary will be reduced by 99 percent (Thibodeaux, 1989). Further, because the Upper Estuary has a depositional regime, it is expected that additional capping would occur naturally through sediment deposition in the Upper Estuary, further reducing

PCB flux from capped as well as uncapped sediments (Balsam, 1989). In summary, the in place containment alternative is expected to practically immobilize the great majority of PCBs present in New Bedford Harbor sediments. A comprehensive discussion of the immobilization of PCBs through implementation of the in place containment alternative is presented in Attachment B to this report.

The reduction of PCB mobility to be achieved by the containment cap is expected to be "permanent" in that neither hydrodynamic effects nor public activities are likely to result in significant or lasting breaches of cap integrity. The impacts of tidal forces and extreme surface water run-off events have been studied and have not been found to pose significant threats to the permanence of the cap. Similarly, public activities such as beachcombing, shellfishing and recreational boating are deemed unlikely to result in permanent breaches of the cap, given the self-healing nature of the sediments selected for cap construction. A more detailed discussion of the long-term effectiveness and permanence of the in place containment alternative is presented in Section 5.3.

While the immobilization of PCBs to be achieved by the in place containment alternative is sufficient, standing alone, to satisfy the criterion of "reduction of toxicity, mobility or volume," the containment alternative also will preserve anaerobic conditions which are supporting extensive microbial dechlorination of PCBs in Upper Estuary sediments, a natural process that results in reduction of PCB toxicity. This anaerobic PCB biodegradation process involves the successive removal of chlorine atoms from PCB molecules. Through this dechlorination process, the chlorine content of individual PCB molecules and, consequently, the toxicity of PCBs, is reduced (Kimbrough and Jensen, 1988; Goldstein and Safe, 1989). An extensive body of evidence has been developed which demonstrates that anaerobic biodegradation of PCBs by indigenous microorganisms is taking place over a wide area of the estuary and over a wide range of PCB concentrations, and is presented as Attachment O.

Work has been performed by Dr. John Brown demonstrating biodegradation of PCBs in New Bedford Harbor sediments by indigenous microbes (Brown, 1984; Brown, 1987). Additional and independent work has been undertaken by Dr. Anna Yoakum to evaluate PCB biodegradation in Upper Estuary and harbor sediments, which is presented within Attachment O as Appendices II through VII. Her findings to date have been generally consistent with those of Dr. Brown and indicate that extensive degradation of PCBs is occurring in these areas through anaerobic microbial processes.

To perform her evaluation, Dr. Yoakum has reviewed a substantial amount of data generated by EPA, as well as supplemental data collected by Balsam. Dr. Yoakum has reviewed PCB sediment quality data from the USACE Upper Estuary sediment sampling program which were generated by the USACE NED Water Quality Laboratory, Cambridge Analytical Associates and Laucks Testing Laboratories, and sediment quality data for samples from the Middle Harbor, Lower Harbor and Outer Harbor Area collected in the course of the GZAD program and analyzed by York Laboratories Division of YWC; S-Cubed Division of Maxwell Laboratories, Inc; ERCO Division of ENSCO, Inc.; and PEI Associates, Inc. In summary, Upper Estuary samples collected from a 0 to 12 inch depth interval generally showed moderate to advanced degradation of PCB Aroclor 1254 and moderate degradation of PCB Aroclors 1016/1242. In samples collected from depths greater than 12 inches, PCB biotransformation for both Aroclor 1254 and Aroclors 1016/1242 was even more extensive. Ninety-seven percent of the aquatic Upper Estuary sediment samples evaluated by Dr. Yoakum exhibited PCB biotransformation.

The in place containment alternative does not contemplate the use of "treatment" in the sense of human intervention by means of the application of technologies to contaminated media. As noted, however, the use of such treatment is not mandated by CERCLA where factors such as site circumstances and implementation constraints indicate that alternative remedial schemes will be more protective or will permit less overall risk to human health and the environment. In the present context, site circumstances are such that application of treatment technologies would interrupt a natural form of "treatment" (i.e., anaerobic biodegradation) that is effectively diminishing the toxicity of PCBs in New Bedford Harbor sediments. Further, as discussed more fully in AVX's comments on EPA's Hot Spot Feasibility Study, the implementation of a treatment effort which would require dredging and removal of PCB-contaminated sediments threatens to engender serious short-term risk due to release and migration of presently immobile contaminants. In such circumstances, it is consistent with CERCLA, and with the policies expressed in the proposed revised NCP, to select a remedial action involving the immobilization of PCBs and natural "treatment" of contaminated sediments by means of anaerobic biodegradation.

5.5 SHORT-TERM IMPACTS AND EFFECTIVENESS

In order for a remedial alternative to be appropriate for selection, it must be demonstrated that it will not result in the creation of significant short-term impacts to the community (including the construction work force) or the environment during construction and implementation. Typical short-term impacts are related to the release of contaminants from the site associated with excavation, handling, transport, or treatment of contaminated media. Additionally, economic or community use impacts may also arise from implementation of a remedial program. An evaluation of the in place containment remedial alternative in terms of these criteria is presented below.

5.5.1 Effects on Community

This remedial alternative has been developed to result in minimal short-term impacts to the community, work force and environment. Because contaminated sediment are not being moved as part of the remedy, most of the associated adverse impacts have been avoided. Remedial construction activities have been planned to limit impacts to the community by placing staging areas away from residential areas and by conducting work in a manner which should result in minimal releases, emissions and impacts.

5.5.1.1 Community Health Risks

Because the in place containment remedial alternative does not involve disturbance of contaminated site media, increased short-term health risks to the community are not expected to result from implementation. Due to the potential for adverse impacts from contaminant loss through volatilization, airborne transport of contaminated dusts, and resuspension with subsequent transport of contaminants in the water column, activities which would result in these types of contaminant release were minimized. Specialized construction techniques have been developed to move construction vessels and deploy cap material to limit resuspension of contaminated bottom sediment. Additionally, placement of a geofabric over bottom sediment prior to clean cap fill material should result in little to no resuspension of contaminated material during subsequent cap construction. These aspects of short-term impacts have been discussed in detail previously in Section 3.4.2.3 and 3.4.4.

5.5.1.2 Community Impacts

Several short-term impacts to community activities were identified which would occur with implementation of this remedial alternative. Many of these impacts would be realized, regardless of the nature of any remedial alternative, with the exception of a no action alternative. Nevertheless, a discussion of these short-term adverse impacts has been prepared.

5.5.1.2.1 Construction Operations

Operations within the cap construction staging areas will result in the generation of some additional dust and noise. However, because the primary activity occurring within these staging areas will be the hydration of cap material, dust generation should not be significant. Due to the close proximity of staging areas to the estuary shoreline, estuary water could be used to keep stockpiled capping material moist to reduce the generation of fugitive dust.

The use of heavy equipment to transport cap materials within construction staging areas will generate some noise. However, proposed staging area locations have been selected to create minimal noise impacts to residential areas. Furthermore, because construction activities will be limited to normal work hours, noise impacts frequently associated with continuous operations will be avoided.

5.5.1.2.2 Impacts of Combined Sewer Overflows on Water Quality

The New Bedford Harbor area currently has combined sewer overflows (CSOs) in 39 authorized locations. Five of these CSOs (OF 22-26) are located within the Upper Estuary as shown on Figure 3.17. Through the installation and operation of a weir at the Coggeshall Street bridge, adverse short-term impacts from CSO discharges may arise. For this reason, an assessment of water quality effects from CSOs was performed.

All of the 39 CSOs, together with the New Bedford Municipal Treatment Facility are authorized to discharge effluent under the National Pollutant Discharge Elimination System (NPDES) in compliance with the provisions of the Clean Water Act (CWA) and the Massachusetts Clean Waters Act (MCWA). A single NPDES permit issued jointly by the EPA and the DWPC sets forth standards for effluent limitations, monitoring requirements and other conditions for these 39 CSOs and the municipal waste water treatment facility. At the present time, an additional number of unpermitted discharges also exist into New Bedford Harbor (CDM, 1989).

The CSOs are permitted to discharge waste water/storm water during rainfall events only. However, EPA has determined that the City of New Bedford is not in compliance with its NPDES permit as it relates to discharges from the New Bedford Municipal Treatment Facility and its CSOs, and has entered into a consent order with the City of New Bedford to remedy this problem. Removal of grit and sediment from sewer interceptors associated with CSOs discharging to the Upper Estuary to increase the carrying capacity of the interceptors, as well as treatment of CSO effluent, is provided for in this order.

CSO loading during rainfall events, coupled with partial closure of the Upper Estuary following construction of a weir dam, could potentially adversely impact water quality, including an increase of BOD and a corresponding decrease in dissolved oxygen. CDM is currently evaluating a number of remedial alternatives to decrease CSO loading to the Upper Estuary for the City of New Bedford. Mercer (personal communication, 1989) indicates that the municipal sewage lines are carrying both septage and storm water/waste water to the treatment plant. Mercer further states that there is considerable variability in how or which individual CSOs handle storm events; some CSOs will discharge effluent during storm events while others are largely unaffected.

The significance of this water quality impact on the environment from CSOs during site remediation should be minimal due to the level and nature of site disturbance which will be occurring. Because capping in the Upper Estuary will result in the elimination of most current benthic biota, and because rapid recolonization of the Upper Estuary is expected following cap construction, short-term impacts on these communities from CSO discharges should not be significant. Additionally, due to the shallow nature of the Upper Estuary, and the common occurrence of seabreezes over the estuary, natural aeration and subsequent oxidation of CSO discharges should occur during low and moderate CSO flow periods. Upper Estuary BOD loads from CSOs in a range of 11,000 to 22,000 pounds per day may be possible without significantly impacting water quality (Metcalf & Eddy, 1972). During periods of elevated CSO discharge, overtopping of the dam weir may occur releasing some of this pollutant (e.g., BOD) discharge. Additionally, the weirs of the dam will be opened on a periodic basis to allow circulation between the estuary and harbor, thus releasing and diluting CSO discharges.

At the present time, the City of New Bedford is investigating various means of remedying CSO discharges. Accordingly, depending on the timing of the identification of a CSO discharge solution and initiation of remedial activities, impacts from CSOs to the Upper Estuary may not exist.

5.5.1.2.3 Boat Traffic

Through the installation of a weir dam to allow hydraulic control in the Upper Estuary, recreational boat traffic in the Upper Estuary will be significantly reduced. Although the weirs of the dam will be removed on a regular basis to allow circulation of estuary and harbor water, recreational boating activities would still be constrained. However, little recreational boating presently appears to occur in the Upper Estuary. Therefore, this impact was not judged to be significant.

5.5.1.2.4 Truck Traffic

The transportation of capping materials from an off-site borrow source to staging areas will result in some increased truck traffic. However, the location of staging areas has been selected to minimize this adverse impact. Haul routes previously discussed in Section 3.4.4 have been identified to utilize major existing highways, or, to the extent possible, roads that do not abut residential areas. Accordingly, the short haul distance from the borrow area to the construction staging areas, and the location of the staging areas adjacent to the Upper Estuary, should serve to minimize potential adverse traffic impacts.

5.5.1.2.5 Ground Water Wells

A preliminary assessment of the potential impact operation of the Coggeshall Street weir dam may have on ground water wells in close proximity to the Upper Estuary was performed. Although the local hydrogeology around the New Bedford Harbor site has not been extensively studied, a hydrogeologic investigation was performed on the Aerovox facility by GHR Engineering, Corp (GHR). (GHR, 1983), and a survey was performed by the United States Geological Survey (USGS) to identify wells, borings and municipal water systems in the site area. The GHR hydrogeologic investigation concluded that, in the vicinity of the Aerovox plant, only surficial saturated zones were tidally affected.

The USGS survey identified six water wells in close proximity to the Upper Estuary. A listing and description of these wells is presented in Table 5.6. Of the six identified wells, only two were found to be operating, and were used for industrial purposes. Both of these wells were advanced into bedrock, indicating the likely source of water withdrawn from these wells is deep consolidated deposits. On this basis, it is unlikely that these wells would be affected by short-term increases in ground water salinity immediately adjacent to the Upper Estuary resulting from operation of the weir dam.

5.5.1.2.6 Flood Routing

Routing of storm water discharges through the Upper Estuary will be impeded if all weirs of the weir dam are in place. However, since the weir dam will allow water overtopping at an elevation slightly greater than MHW, most surface water discharge to the Upper Estuary could flow over the weir dam without creating significant impacts. Should an extreme precipitation event occur during the remedial program, some increased water elevation could be expected in the Upper Estuary if all dam weirs were in place. Operation of the dam weir would be coordinated to accommodate such precipitation events.

5.5.2 Impact on Workers

Because the in place containment remedial alternative does not involve disturbing contaminated site media, and because combustion or high pressure treatment technologies will not be utilized as part of this remedial program, significant risks are not expected to be posed to workers involved in cap construction activities. Normal construction safety procedures will be utilized to protect workers from risks associated with typical heavy construction activities.

5.5.3 Environmental Impacts

A discussion of short and long-term environmental impacts associated with implementation of the in place containment remedial alternative has been presented in Section 5.1.2. In summary, this analysis indicated that the environmental use and value of the Upper Estuary will be impacted during construction activities. However, rapid recolonization and restored use of the Upper Estuary is expected following completion of remedial activities. These impacts are not expected to be different in nature from impacts that would be caused by other alternatives EPA has considered.

In addition to the environmental impacts discussed in Section 5.1.2, an analysis was performed to assess the salinity effects associated with operation of the weir dam. A hydrodynamic numerical model developed by the USACE (Seelig et al., 1977) was used by ASA (1987) to determine the effects of dam closure on the circulation, tidal range and salinity regimes in the Upper Estuary. Figure 5.2 shows the model prediction of the tidal range and flow rates through the channel and the salinity for the low (1/2 x mean), mean (30 cfs) and high (2 x mean) Acushnet River flow rates assuming the cross sectional area of the Coggeshall Street bridge channel is 147 m^2 (1582 ft^2) with a salinity of 26 parts per thousand (ppt) under mean river flow and a tidal flux (upper half cycle) of 9.2×10^5 m^3 (3.24×10^7 ft^3) (ASA, 1988).

According to model results, reducing the cross sectional flow area at the Coggeshall Street bridge by 52 percent to (750 ft^2 or 70 m^2) will have little effect on the tidal range, integrated tidal flow volume or salinity in the Upper Estuary, although localized velocities will increase proportionally. On this basis, the dam weir will be designed with an available cross-section flow area of 750 ft^2 to allow for unaltered hydraulic salinity and water quality conditions throughout most of the estuary. Reduction of the dam flow area to 110 ft^2 (10 m^2) would result in a slight reduction of estuary water salinity (22 ppt), assuming average flows from the Acushnet River.

Figure 5.3 depicts changes in the salinity regime of the Upper Estuary as a function of time after dam closure. The slow decline in salinity results from the low rate of fresh water input into the Upper Estuary (ASA, 1988).

Since damming the Upper Estuary with a weir dam may potentially alter the salinity regime in the estuary, the impact of an altered salinity regime of estuarine saltmarsh must be considered. Garbisch (1988) reports that soil salinities in excess of 50 ppt are toxic to most saltmarsh plant species. Consequently, in order to maintain the existing saltmarsh during the cap placement operation, soil salinities must be maintained below the toxic 50 ppt level, particularly during the growing season.

Based on past experience, Garbisch has observed toxic responses to saltmarsh grasses during periods of saltmarsh dewatering which were attributed to salt buildup in soils. This process occurs as saline soil pore water evaporates/evapotranspirates which results in the concentration of salts in soils. Because marine waters typically contain salinity levels in excess of 25 ppt, buildup of salt concentrations close to the toxic 50 ppt levels can occur within a matter of days following cessation of cyclic tidal inundation. However, elevated soil salinity levels have not been observed to effect saltmarsh grass viability during the dormant season as plant metabolic functions are greatly reduced at this time.

Conversely, inundation (wet capping) of saltmarsh grasses has not been observed to result in significant adverse short-term impacts associated with salt toxicity. Rather, prolonged flooding of these grasses can result in the elimination of the transfer of oxygen to the plant root system which in turn can result in a toxic response by the grasses. Accordingly, periodic (weekly or bi-weekly) draining of saltmarsh soils was recommended (Garbisch, 1988).

To maintain acceptable salinity levels for wetland plant species, Garbisch (1988) advocates conduct of dry capping/construction activities during only the dormant season (November-March), whereas wet capping/construction activities can proceed throughout the year. Dry capping/construction activities therefore will be limited to dormant saltmarsh times of the year, whereas wet construction activities can proceed year-round. During the conduct of wet construction activities, the dam weirs will be opened for several days on a weekly or at least bi-weekly schedule to allow unrestricted tidal water circulation throughout the estuary and to drain surficial saltmarsh soils to maintain the health of the existing saltmarsh. Proper operation of the weir dam therefore should not result in the creation of significant adverse short-term impacts associated with salinity changes in the Upper Estuary.

5.5.4 Time for Project Completion

A discussion of the project schedule has been included in Section 4.0 of this report. In summary, following fulfillment of all administrative requirements, cap construction could be completed within a 2 to 3 year period. Because cap construction will be initiated in the northernmost part of the Upper Estuary where the highest concentrations of PCBs in sediments have been reported, benefit from program implementation will be achieved soon after construction activities begin. Due to the straightforward nature of the remedial program, it is expected that this program can be completed in a relatively short period of time, as compared to alternatives which may involve the removal, handling and treatment of estuary sediments.

5.6 IMPLEMENTABILITY

A thorough discussion of how the in place containment remedial alternative could be implemented has previously been presented in Sections 3.4 and 3.5. As discussed therein, this remedial alternative utilizes a number of existing and proven engineering technologies and environmental restoration methods in an innovative fashion. The construction of sheetpile walls to contain or control hydraulics has been successfully performed for decades. Similarly, geotextiles and geoweb have an established track record performing the functions for which they are to be used for this remedial program. The hydraulic placement of sediment in subaqueous environments has been conducted for years, and in some instances, as discussed in Section 2.3.4, has been performed to isolate contaminated dredge spoils or sediment from the overlying water column.

Sections 3.4 and 3.5 also discuss the availability of the services, equipment and methodologies necessary to conduct this remedial alternative. Identified project needs can be met utilizing existing material sources and labor pools without endangering the project schedule.

5.7 COST ESTIMATES

5.7.1 CONSTRUCTION COSTS

Cost estimates for the containment alternative have been divided into 10 categories discussed below, and presented in Table 5.7. The costs discussed are based on preliminary design data and include a 30 percent contingency to account for possible changes during full-scale design. As the design phase for this remedial program progresses, it will be possible to estimate the cost of remediation in greater detail. At the present time, project costs are estimated to range from $17,000,000 to $19,000,000. At this time, the costs discussed below are considered reasonable and should be used for comparison in the economic evaluation of remedial alternatives.

5.7.1.1 Establish Hydraulic Control

Costs associated with the establishment of hydraulic controls are focused on two areas, the construction of an adjustable weir dam at the Coggeshall Street bridge and the mobilization of equipment for the activation of the Acushnet Saw Mill, Hamlin Street, and the New Bedford Reservoir dams. Costs for the construction of the Coggeshall Street dam were estimated to be approximately $700,000 to $800,000. These costs are based on the construction of a permanent, adjustable-weir sheet pile dam. Included in the estimate are costs for performing geotechnical engineering analyses, completion of structural designs, and the construction of the facility.

Costs associated with the activation of upstream hydraulic controls located at the Acushnet Saw Mill, Hamlin Street and the New Bedford Reservoir dams were estimated to range from $10,000 to $50,000. These costs include funds for equipment and labor, assuming that minor components such as stop logs and weir panels may require maintenance or limited replacement. This cost estimate does not include funds for major refurbishment.

5.7.1.2 Construction of Staging Areas

Costs associated with the construction of two staging areas and purchase of equipment for subsequent hydraulic placement of sand capping materials have been estimated to range from $3,500,000 to $4,500,000. This estimate includes costs for the construction of two staging areas and the ancillary equipment required to transport the capping material hydraulically to the point of deposition in the Upper Estuary. Key components of the staging areas include: construction of hydration pits, installation of suction/dredge pumps, installation of booster pumps, the purchase of 1.5 miles of floating hydraulic pipe line, and the leasing of six 24 cubic yard dump trucks and two 4.5 cubic yard front end loaders. This estimate also includes $500,000 for temporary staging area land use requirements.

5.7.1.3 Management of Permitted CSO Discharges

The costs associated with the management of permitted CSO discharges located north of the Coggeshall Street bridge which may be affected by the containment cap are not easily defined at this time. The City of New Bedford has retained CDM to address remedial alternatives regarding the CSOs existing in the Upper Estuary. Engineers from CDM have indicated that the extension, cleaning, enlargement or rerouting of these permitted discharges and/or interceptors would be consistent with the overall objective of the proposed remedial program. Because the means of addressing these CSOs is unclear, a range of costs up to $300,000 has been estimated for this work.

5.7.1.4 Establishment of Vertical and Horizontal Control

Costs associated with the establishment of vertical and horizontal control throughout the Upper Estuary are estimated to range from $20,000 to $30,000. This estimate includes costs for a first order leveling survey and a second order horizontal distance survey. It is anticipated that monuments will be set along the western shore, and temporary pins will be set along the eastern shore where access is more difficult. All work will be performed under the direct supervision of a Registered Land Surveyor with marine surveying experience.

5.7.1.5 Cap Construction

Costs associated with the construction of the proposed 45 cm multimedia cap are estimated to range from $11,000,000 to $12,000,000. These costs are based on capping sediments containing greater than 50 ppm of total PCBs and some estuary eastern shoreline (an approximate 140 acre area), and include the placement of approximately 330,000 cubic yards of sand and approximately 20,000 cubic yards of crushed stone. As proposed, approximately $2,000,000 of the total would be allocated for construction of portions of the cap requiring erosion protection, approximately 22 acres. The remaining $9,000,000 to $10,000,000 would be used to construct the sand cap. This estimate includes costs for materials (sand, stone, geofabric), labor and equipment required to complete the cap construction.

5.7.1.6 Existing Saltmarsh Remediation

Costs associated with remediation of tidal creeks and mosquito trenches within wetlands located along the eastern shore of the Upper Estuary are estimated to range from $50,000 to $70,000. These costs include personnel, equipment and materials required to cap existing trenches and excavate new trenches. In addition, wetland vegetation will be established in the newly capped areas.

5.7.1.7 Demobilization of Staging Areas

Upon completion of the capping operations, staging areas will be removed. An estimate of $180,000 to $ 200,000 has been allocated for the removal of equipment and structures from two staging areas. The major portion of the expense in demobilization of the staging areas involves the removal of sheet pile. In general, costs associated with the removal of sheet piling are dependent on the difficulty encountered in withdrawing the piling, and can be as high as one half the installation costs. One consideration for reducing the cost of demobilization would be to allow the sheet piling to remain in place and to backfill the sump pits. This could result in a cost savings of approximately $120,000. The cost estimates for demobilization do not include any salvage or resale value of the sheet piling, pumps, or trucks and heavy equipment.

5.7.1.8 Post-Remedial Bathymetry Survey

A post-remedial survey will be performed upon completion of capping operations and prior to planting and seeding of wetland vegetation. This survey will be conducted using a 50 foot grid and electronic distance measuring (EDM) devices provided that reflection and refraction of light over the surface waters of the Upper Estuary do not impede data acquisition. It is anticipated that the post-remedial survey will take approximately two to three weeks to complete and will cost between $15,000 to $20,000.

5.7.1.9 Establishment of Additional Saltmarsh

Approximately 19 acres of additional saltmarsh will be established in the intertidal zone between MHW and MSL. It is anticipated that half of the additional saltmarsh will be established by planting nursery propagated plants, and the remainder will be established by seeding. The cost for establishment of additional wetlands has been estimated to range from $300,000 to $350,000. This cost includes labor, equipment, and materials required to establish the saltmarsh.

5.7.1.10 Adjustment of Hydraulic Controls for Long-Term Use

Adjustment or decommissioning of hydraulic controls for long-term use or abandonment will be performed upon completion of the remedial alternative. It is estimated that $10,000 to $20,000 will be required for equipment and labor necessary to adjust stop logs and adjustable weirs for the three upstream hydraulic controls, i.e., Acushnet Saw Mill, Hamlin St. and New Bedford Reservoir Dams, and the weir dam.

5.7.2 Long-Term Monitoring

Long-term monitoring of total PCB concentrations in the cap sediment, estuary surface water, and biota will be conducted on a quarterly basis until results of analyses indicate that monitoring is no longer required or the frequency of monitoring can be reduced. Visual inspections of the cap for erosion and indications of stressed vegetation will be conducted on a monthly basis for the first year and on a quarterly basis thereafter. Currently, it is anticipated that 10 surface water, 10 sediment and 20 biota samples will be collected during quarterly monitoring. The annual cost for monitoring of PCBs in cap sediment, surface water, and biota has been estimated to range from $60,000 to $80,000.

For purposes of more fully estimating costs for long-term monitoring, some assumptions have been made regarding future monitoring. These assumptions are: 1) monitoring will occur over a 20 year period; 2) a monitoring program as described above will occur over the first five years; and 3) a reduced (60%) monitoring program will occur from the sixth to the twentieth years. These assumptions are based on the results of long-term monitoring programs conducted for other similar sites, principally the James River site.

Based on these assumptions, a present value analysis of monitoring costs was performed. This analysis indicated such a monitoring program would have a present value of $850,000.

5.8 STATE ACCEPTANCE

Section 121(f) of CERCLA (as added by Section 121 of SARA) provides for state participation "in initiation, development and selection of remedial actions to be undertaken in that State" (42 U.S.C. Section 9621(f)(1)). To afford states an adequate opportunity for such participation, EPA is required, among other things, to give "[n]otice to the State and an opportunity to comment o[n] the ... proposed plan for remedial action as well as on alternative plans under consideration" (42 U.S.C. Section 9621(f)(1)(G)).

The "state acceptance" detailed analysis criterion is, in part at least, a response to Section 121(f). Typically, the state acceptance criterion is not addressed in the RI/FS or proposed plan, but rather in the Record of Decision (ROD) after comments on the RI/FS report and proposed plan are received (Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final, EPA, October 1988, Section 6.2.3.8 at 6-13). In the present context, however, it may be useful to address the potential for state acceptance of the containment alternative at this juncture, since no containment remedy was retained for detailed analysis in EPA's HSFS.

Based on comments made by representatives of the state at the August 22, 1989 public hearing on the capping proposal, it is anticipated that the willingness of the Commonwealth of Massachusetts to accept that proposal will hinge upon whether it is properly viewed as a "permanent solution" within the meaning of M.G.L. Chapter 21E, Section 3A and the MCP (310 CMR 40.000).

Section 3A of M.G.L. Chapter 21E defines "permanent solution" as "a measure or combination of measures that, at a minimum, will ensure the attainment of a level of control of each identified substance of concern at disposal site [sic] or in the surrounding environment such that no such substance of concern will present a significant or otherwise unacceptable risk of damage to health, safety, public welfare, or the environment during any foreseeable period of time"

(M.G.L. Chapter 21E, Section 3A(g)). Section 3A further provides that, "[w]here feasible, permanent remedial action shall include measures designed to reduce to the extent possible the level of oil or hazardous materials in the environment to the level that would exist in the absence of the disposal site of concern" (id.) See MCP, Section 40.546(4) (310 CMR 40.546(4)).

The concerns of the Commonwealth all relate to these concepts of "permanent solution," and can be summarized as raising four issues: (1) whether the cap can eliminate, or virtually eliminate PCB flux from sediments into the water column; (2) whether adequate safeguards against breaches of the cap can be provided; (3) whether mixing of cap material and contaminated sediments during construction will increase the volume of contaminated media, and (4) whether the rate of biodegradation of "Hot Spot" PCBs is sufficient to assure detoxification of sediments in these areas within a reasonable period of time.

This report has been prepared with a view toward addressing each of these issues. Specifically, concerns regarding PCB from sediment flux to the water column are addressed in Section 5.1.2.5 and Attachment N. Concerns related to potential breaching of the cap are addressed in Section 3.4.5 and 5.3. Questions as to whether mixing of contaminated sediment will occur with clean capping sediment during cap construction have been answered in Section 3.4.2. Finally, concerns related to extensiveness of PCB biodegradation in New Bedford Harbor sediment have been addressed in Attachment O. Accordingly, it is submitted that all legitimate concerns raised by the Commonwealth have been addressed.

5.9 COMMUNITY ACCEPTANCE

Like the state acceptance criterion, consideration of the "community acceptance" criterion is generally deferred until after filing of public comments on the RI/FS and proposed plan. It is appropriate now, however, to describe the issues that appear to be community concerns and how the in place containment alternative satisfies those concerns.

EPA initiated a public participation program with the New Bedford Environmental Community Work Group (CWG) representing citizens of the New Bedford area approximately two years ago. Monthly meetings have been held during which the progress and future direction of the project have been discussed. During this time, EPA's RI/FS process has focused on investigation of remedial action utilizing dredging. These studies have been the major topic for presentations and discussions at CWG meetings.

On July 10, 1989, representatives of AVX Corporation (AVX) presented to the CWG an in place containment alternative to be considered for remedial action in the Upper Estuary. The presentation included an analysis of the alternative and a discussion of the action that could serve as a permanent solution for PCB contamination in the Upper Estuary. The questions posed by the CWG members demonstrated their understanding of the issues related to the site and remedial action in the estuary. It is anticipated that the CWG will file comments on the Hot Spot Feasibility Study and EPA's proposed plan.

The specific concerns that have been cited by the CWG at their monthly meetings have included the following:

- o environmental quality,
- o effectiveness of the selected technology,
- o fishing potential after implementation,
- o environmental impacts of implementation,

- o cost of implementation,
- o funding of implementation,
- o financial responsibility of the City,
- o financial condition of the City,
- o impacts on jobs in the New Bedford area,
- o economic health of local employers, and
- o image of the community.

Environmental quality concerns within the estuary have primarily been voiced in terms of the potential for fishing within the estuary. The CWG members have on occasion discussed reopening the estuary to shellfishing. They have recognized, however, that the estuary was closed to shellfishing prior to 1900, well prior to the use of PCBs. Superfund remedial actions being considered for the harbor will not eliminate sewage and other waste discharges to the harbor which originally led to closing of the harbor to fishing and continue to be a source of contamination to the harbor. Members of the CWG understand this. It is clear that members of the CWG understand that implementation of a remedial action is a very expensive process and that unlimited funding, either by the government or potentially responsible parties (PRPs) is unlikely.

The implementation of the in place containment alternative should satisfy many of the concerns that have been voiced by CWG members. Implementation of the in place containment alternate is advantageous to the Greater New Bedford community for the following reasons:

- o It will contain a significant PCB source (90±%) within the site and reduce the current PCB flux from the Upper Estuary by approximately 99%.
- o It should result in removal of PCB fishery closures.
- o It should significantly reduce potential threats to human health posed by PCB contaminated sediment.
- o It is cost-effective and affordable.

- It should have significantly less financial impact on the City of New Bedford as compared to other contemplated comprehensive remedial plans.
- It will have significantly less financial impact on the local employers, thus minimizing impact on local jobs.
- It can be completed in a relatively short period of time.
- It provides a comprehensive solution to site PCB contamination.

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TABLE 3.1

CRITICAL PARTICLE DIAMETERS

Cross-Section (from ASA, 1989)	Maximum Estimated Average Velocity (cm/sec) (from ASA, 1989)	Critical Particle Diameters (mm)			Calculated Critical Particle Diameter (mm)*
		Dingham (1984)	Yalin (1972) (from Miller et al. (1977)	Lane (1955) (from Miller et al. (1977)	
1	106.7	3.5	7.0	7.3	8.4
2	130.8	6.2	9.0	9.5	10.9
3	80.2	1.7	4.6	4.3	5.3
4	59.1	1.0	2.7	2.5	3.1
5	47.2	0.4	1.9	1.9	2.2
6	58.8	1.0	2.7	2.5	3.1
7	22.6	<.075	0.3	0.4	0.5

NOTE

* = Criticle particle diameter values calculated by selection of largest (most conservative) estimated critical particle size and increasing size by safety factors of 1.15.

TABLE 5.1

ACUSHNET RIVER UPPER ESTUARY HABITAT DISTRIBUTION

Habitat	Depth Zone	Existing Habitat (acres)	Post-Remedial Habitat (acres)
Salt Marsh	MSHW-MSL	50	69
Intertidal Beach/Mud Flats	MSL-MSLW	14	22
Intertidal Armored Cap	MSL-MSLW	0	9
Subtidal Estuary	MSLW-to-15 MSL	175	139
Total		239	239

NOTES

MSHW: mean spring high water.

MSL: mears mean sea level.

MSLW: means mean spring low water.

TABLE 5.2

POSSIBLE ACUSHNET RIVER ESTUARY FINFISH

Scientific Name	Common Name
Alosa pseudoharengus	Alewife
Alosa aestivallis	Blueback
Poronatus triacanthus	Butterfish
Tautagolabrus adspersus	Cunner
Paralichthys dentatus	Summer Flounder
Brevortia tyrannus	Menhaden
Opsanus tau	Toadfish
Stenatomus chysops	Scup
Myoxocephalus sp.	Sculpin
Clupea harengus	Sea Herring
Prionotus sp.	Sea Robin
Morone saxatilis	Striped Bass
Tautoga onitis	Tautog
Pseudopleuronetes americanus	Winter Flounder
Scophtahalmus acquosus	Windowpane Flounder
Anquilla rostrata	Eel

NOTE: Finfish which may be expected to be found (at least occasionally) in the Upper Acushnet River estuary (after J. Cortell and Associates, 1982).

TABLE 5.3

POST-REMEDIAL SEDIMENT PCB CONCENTRATIONS

Location	PCB Concentration (ppm)	Area (acres)
Upper Estuary	Clean Cap	140
	0-10	21
	10-50	28
Middle Harbor	0-5	70
	5-10	31
	10-25	70
	25-50	61
	>50	45
Lower Harbor	0-5	333
	5-10	109
	10-25	37
	25-50	1
Outer Harbor Area	0-5	297
	5-10	65
	10-25	41
	25-50	26
	>50	2

TABLE 5.4

POTENTIAL CHEMICAL AND LOCATION-SPECIFIC ARARs AND GUIDANCE MATERIALS

Medium	Reference	Comment
Biota	Tolerances for PCB residues in foods under Federal Food, Drug and Cosmetic Act (21 CFR 109.30)	See discussion in Section 5.2.1.
Surface water	Mass. Surface Water Quality Standards (314 CMR 4.00)	See discussion in Section 5.2.2.
	Federal Ambient Water Quality Criteria for Polychlorinated Biphenyls (Guidance) (EPA Report No. 440/5-80-068)	See discussion in Section 5.2.2.
Air	National Ambient Air Quality Standards for Particulate Matter (40 CFR 50.6)	See discussion in Section 5.5.1.
	Massachusetts Ambient Air Quality Standards for Particulate Matter (310 CMR 6.04)	See discussion in Section 5.5.1.
	Federal Threshold Limit Values (TLVs)	See discussion in Section 5.5.1.
Wetlands/Flood Plains	Federal Clean Water Act Section 404 Dredged and Fill Material Discharge Permit Program (33 CFR Part 323; 40 CFR Part 230, 231)	See discussion in Sections 5.1.2 and 5.2.4
	Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00)	See discussion in Section 5.1.2.
	Federal Wetlands Executive Order (No. 11990) (Guidance)	See discussion in Section 5.1.2.
	Federal Flood Plains Executive Order (No. 11990) (Guidance)	See discussion in Sections 3.5.5 and 5.5.1.2.6.

TABLE 5.5

POTENTIAL ACTION-SPECIFIC ARARs AND GUIDANCE MATERIALS

Reference	Comment
RCRA Closure and Post-Closure Regulations (40 CFR 264.110-264.120)	To be used in developing long-term monitoring and maintenance plan for the site.
TSCA Storage and Disposal (40 CFR 761.60-761.79)	See discussion in Section 5.2.3.
OSHA General Industry Standards (29 CFR Part 1910)	Respiratory equipment will be worn if necessary. Workers performing remedial activities will be required to have completed specified training curriculum.
OSHA Recordkeeping, Reporting Regulations (29 CFR 1904)	Recordkeeping and reporting procedures to be followed by site contractors and subcontractors during all work.
Mass. Hazardous Waste Regulations (310 CMR 30.000)	Few applicable as no hazardous waste generation, treatment, storage or disposal involved. If applicable, utilize more stringent of federal or Massachusetts regulations.
Mass. Administration of Waterways Licenses (310 CMR 9.00)	See Note 1 below.
Mass. Contingency Plan (310 CMR 40.000)	See discussion in Section 5.8.
Mass. Department of Public Health - Right to Know (105 CMR 670.000)	All workers to be provided with hazardous substance information prior to and during remedial activities.

TABLE 5.5 (continued)

POTENTIAL ACTION-SPECIFIC ARARs AND GUIDANCE MATERIALS

Reference	Comment
Mass. Department of Environmental Protection - Employee and Community Right to Know (310 CMR 33.00)	Public to be provided with hazardous substance information prior to and during remedial activities.
Mass. Department of Labor - Right to Know (441 CMR 21.00)	Workers will be provided with hazardous substance information prior to and during remedial activities.
Mass. Environmental Policy Act (M.G.L. c.30, Sections 61-61H)	Will file an Environmental Notification Form pursuant to 301 CMR 11.00 and an Environmental Impact Report pursuant to 301 CMR 11.25.

NOTE

1) DEP regulations, to appear at 310 CMR 9.00, currently are in draft form. Remedial work would constitute a water-dependent use (Section 9.04 (3)(b)(o)) and would fall outside of categorical exclusions (see Section 9.05(3)(a)(4)). Construction of cap and hydraulic controls will comply with relevant provisions summarized in Section 9.05(i)(a)(i), if promulgated.

TABLE 5.6

WATER WELLS IN CLOSE PROXIMITY TO UPPER ESTUARY

USGS Well	Elevation (ft MSL)	Owner/User	Depth	Well Use	Water Use	Water Level (ft MSL)	Pump Yield (gpm)
Acushnet:							
W03	05	Acushnet Proc.	100	Water w/ drawal	Industrial	NM	120
New Bedford:							
W08	06	Manomet Mills	700	Water w/ drawal	Industrial	NM	70
W22	07	T. Hersom Corp.	060	Unused	Industrial	NM	5
W33	11	Aerovox	200	Unused	Industrial	+7	100
W34	05	Aerovox	200	Unused	Industrial	NM	NM
W38	08	Acushnet Proc.	200	Unused	Industrial	+1	110

Source - USGS, 1980 - Massachusetts Hydrologic - Data Report No. 20.

NOTES

NM: not measured.

MSL: mean sea level.

TABLE 5.7

REMEDIAL ALTERNATIVE CONSTRUCTION COST ESTIMATES

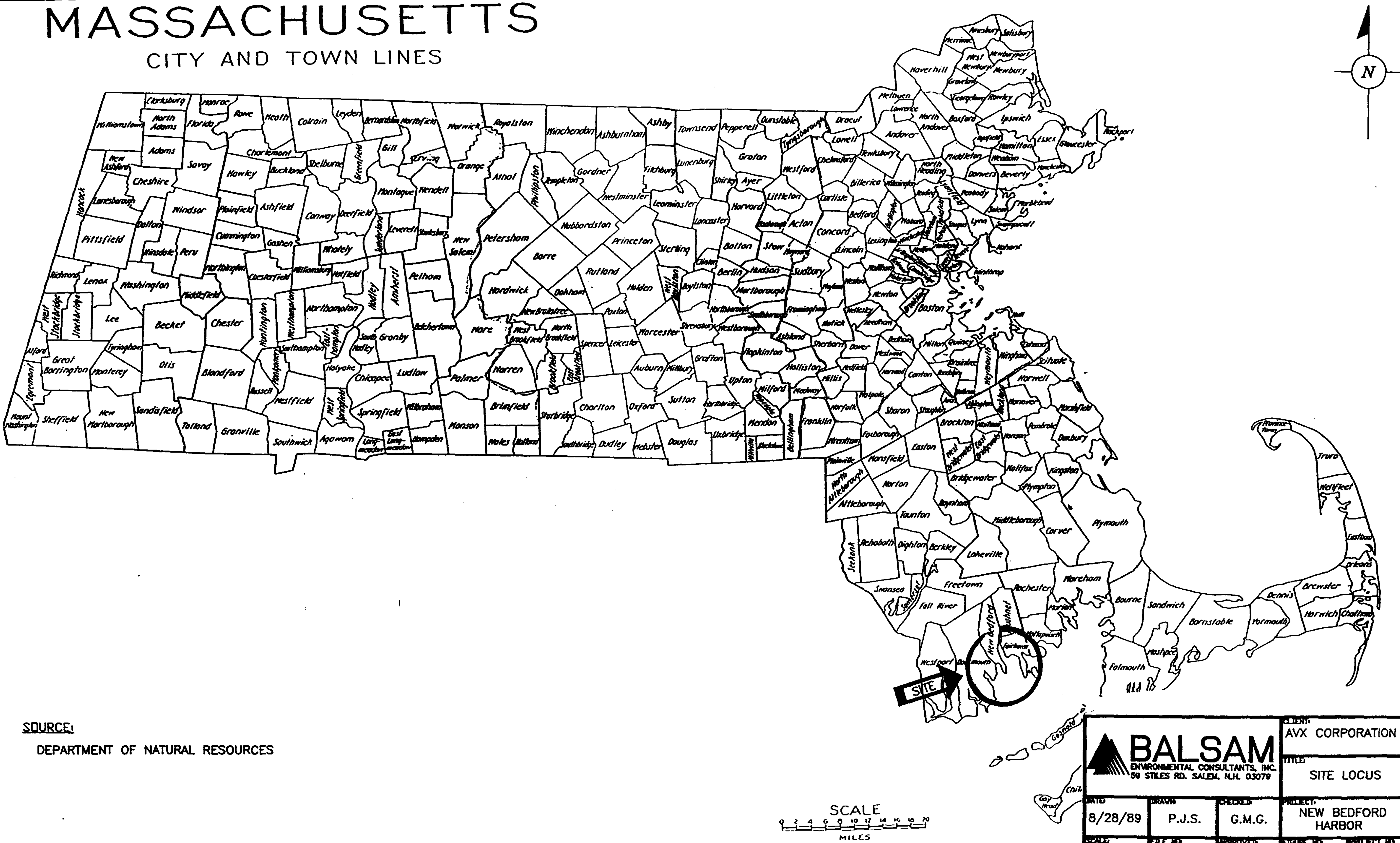
Task		Estimated Cost
1.	Establish Hydraulic Controls	$700,000 - 900,000
2.	Construction of Staging Areas	$3,500,000 - 4,500,000
3.	Management of CSO Discharges	$0 - 300,000
4.	Establish Vertical and Horizontal Control	$20,000 - 30,000
5.	Cap Construction	$11,000,000 - 12,000,000
6.	Existing Saltmarsh Remediation	$50,000 - 70,000
7.	Demobilization of Staging Areas	$180,000 - 200,000
8.	Post-Remedial Bathymetric Survey	$15,000 - 20,000
9.	Establishment of Additional Saltmarsh	$300,000 - 350,000
10.	Adjustment of Hydraulic Controls for Long Term Use	$10,000 - 20,000
	TOTAL	$15,775,000 - 18,390,000

NOTES

1) 30% contingency included in estimated costs.

MASSACHUSETTS

CITY AND TOWN LINES



SOURCE:

DEPARTMENT OF NATURAL RESOURCES

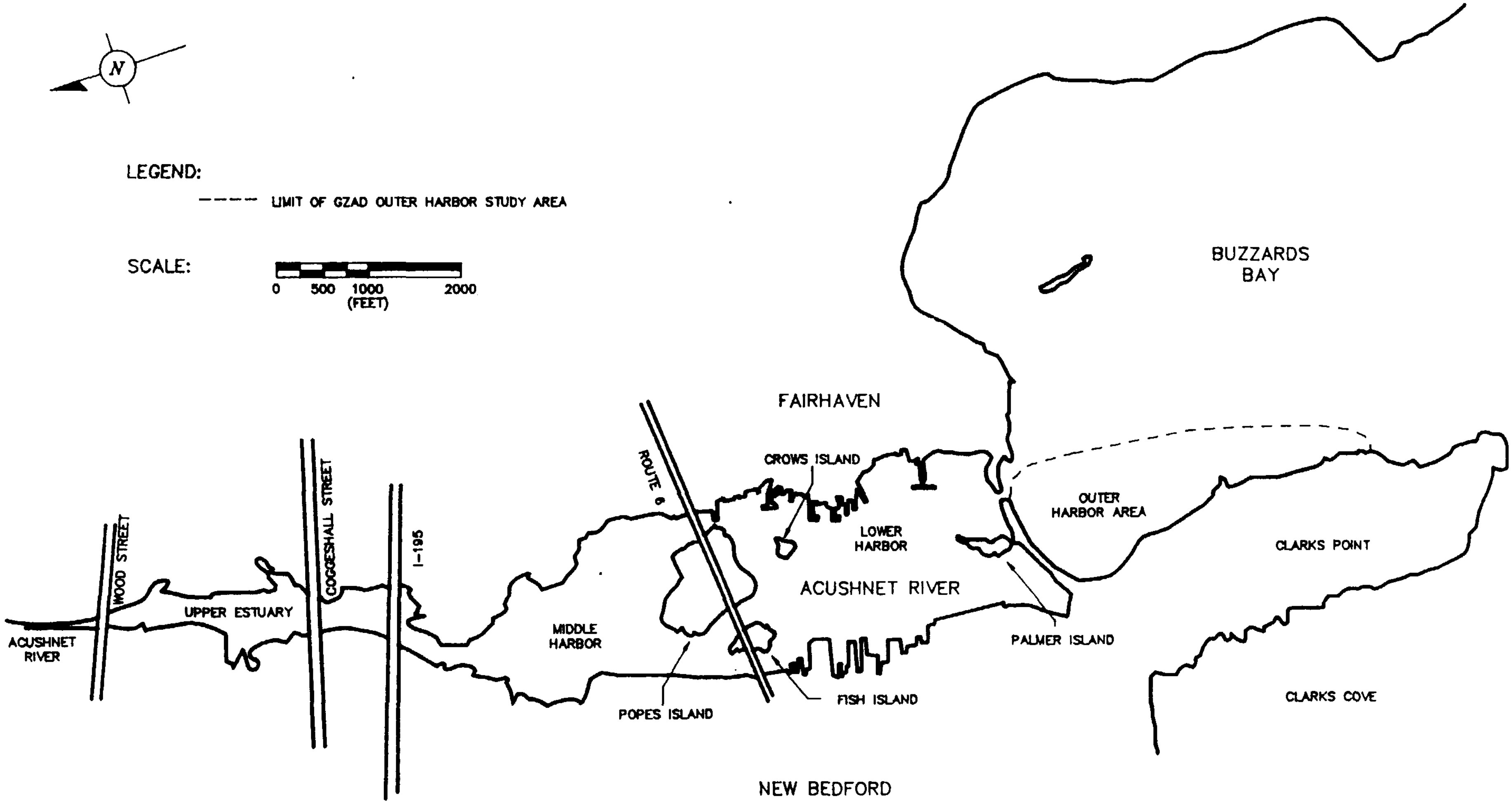
BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: SITE LOCUS	
DATE: 8/28/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: AS NOTED	FILE NO: 62925	APPROVED: L.C.S.	FIGURE NO: 1.1	PROJECT NO: 6292.05

N

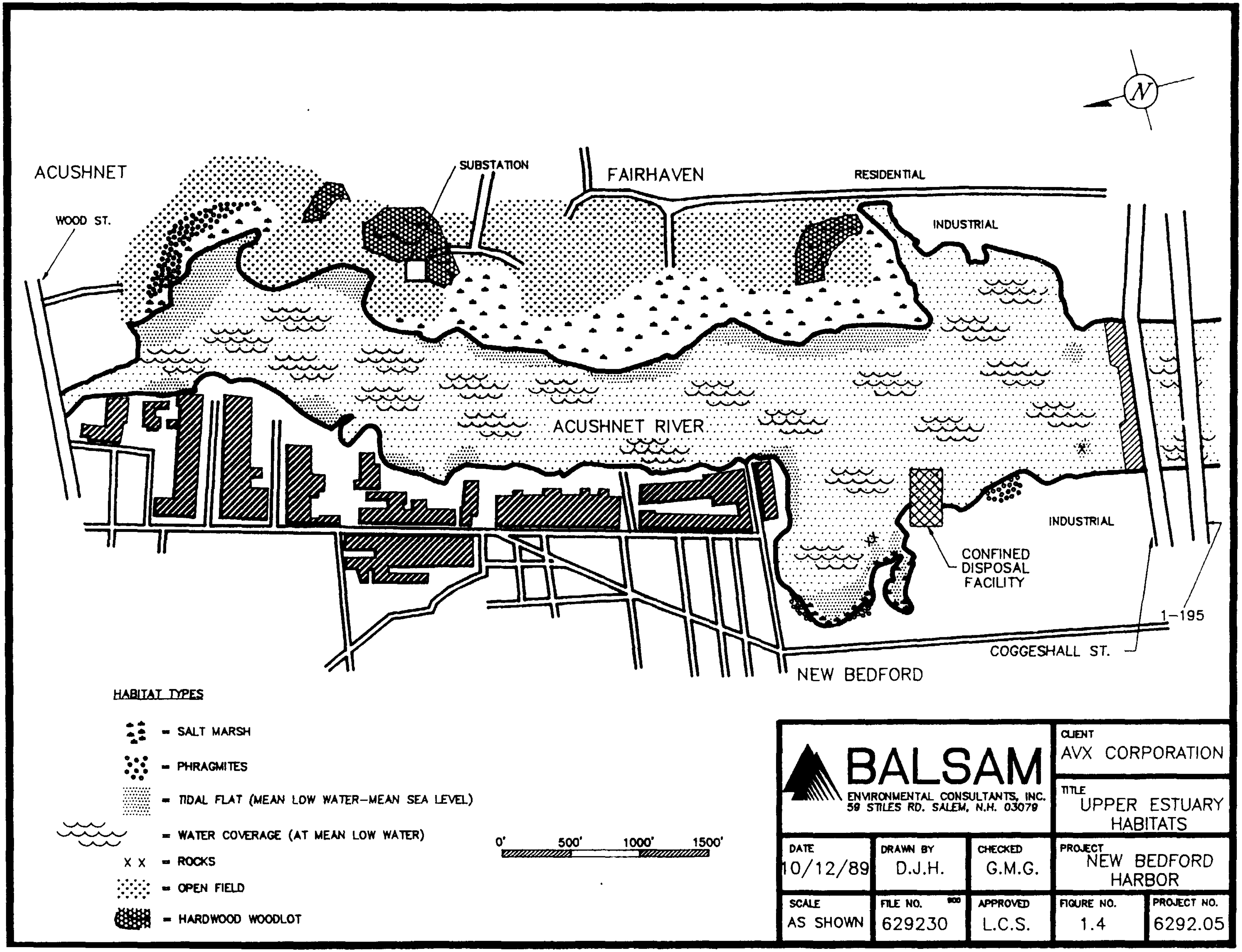
SOURCE:
NEW BEDFORD
NORTH QUADRANGLE
7.5 MINUTE SERIES
TOPOGRAPHIC
1979

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

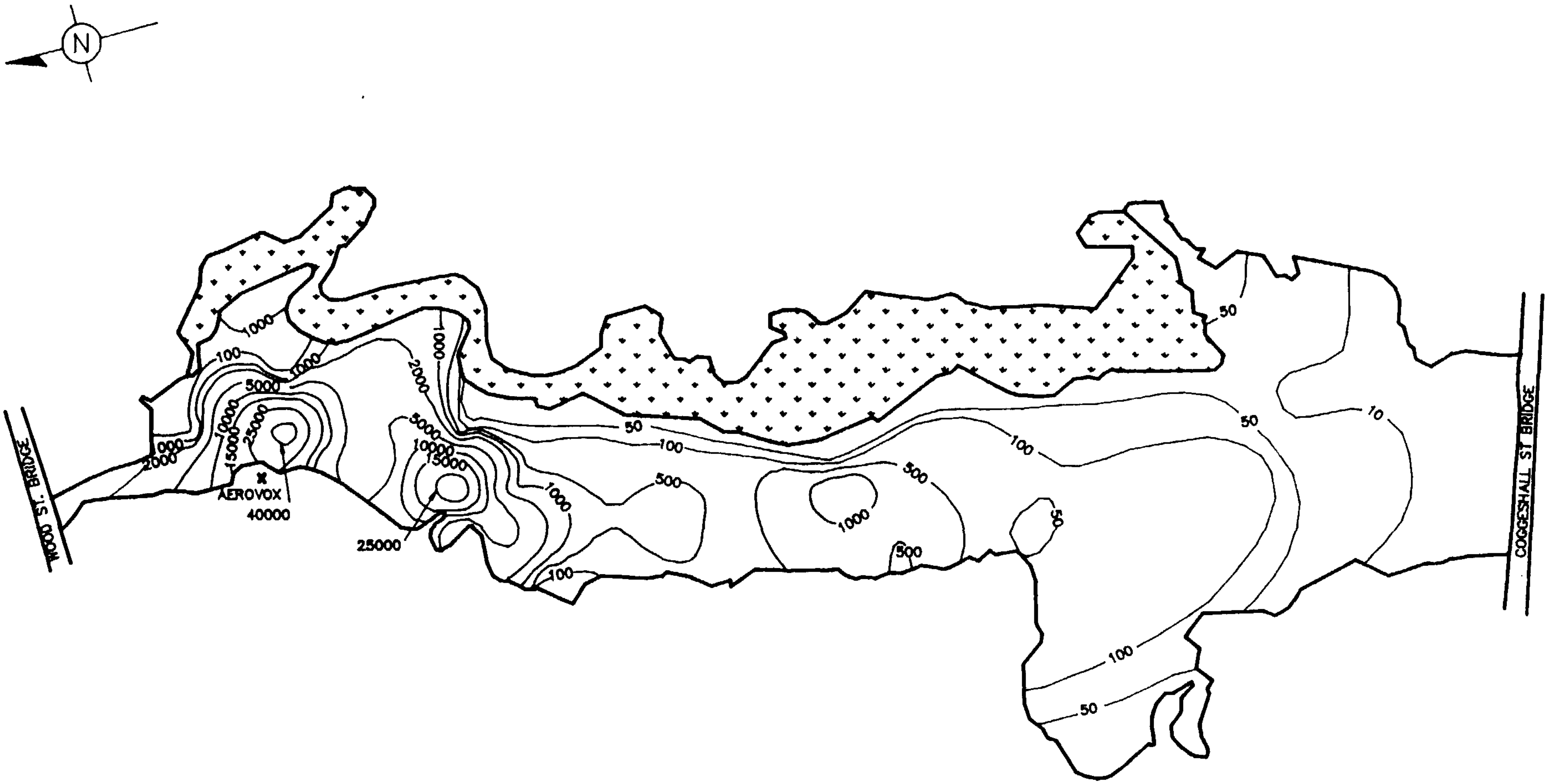
CLIENT: AVX CORPORATION				
TITLE: SITE AREA				
DATE: 8/28/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: 1:25000	FILE NO: 62926	APPROVED: L.C.S.	FIGURE NO: 1.2	PROJECT NO: 629205



BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION TITLE: NEW BEDFORD HARBOR STUDY AREAS
DATE: 10/12/89	DRAWN BY: P.J.S.	CHECKED: E.S.W.	PROJECT: NEW BEDFORD HARBOR
SCALE: AS SHOWN	FILE NO. 1.78 629217	APPROVED: L.C.S.	FIGURE NO.: 1.3 / PROJECT NO.: 6292.05



ACUSHNET
WOOD ST.
SUBSTATION
FAIRHAVEN
RESIDENTIAL
INDUSTRIAL
ACUSHNET RIVER
INDUSTRIAL
CONFINED
DISPOSAL
FACILITY
1-195
COGGESHALL ST.
NEW BEDFORD
N
HABITAT TYPES
= SALT MARSH
= PHRAGMITES
= TIDAL FLAT (MEAN LOW WATER-MEAN SEA LEVEL)
= WATER COVERAGE (AT MEAN LOW WATER)
X X = ROCKS
= OPEN FIELD
= HARDWOOD WOODLOT
0' 500' 1000' 1500'
BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079
CLIENT
AVX CORPORATION
TITLE
UPPER ESTUARY HABITATS
DATE
10/12/89
DRAWN BY
D.J.H.
CHECKED
G.M.G.
PROJECT
NEW BEDFORD HARBOR
SCALE
AS SHOWN
FILE NO.
629230
APPROVED
L.C.S.
FIGURE NO.
1.4
PROJECT NO.
6292.05



LEGEND

100 — = TOTAL PCB CONCENTRATION ISOPLETH (PPM)

= SALT MARSH

NOTES:

ISOPLETHS DEVELOPED USING INTERPOLATION OF DATA FROM UNITED STATES ARMY CORPS OF ENGINEERS (AUGUST–OCTOBER, 1985 AND AUGUST 1987) AND BATTELLE/NUS (JUNE, 1985)

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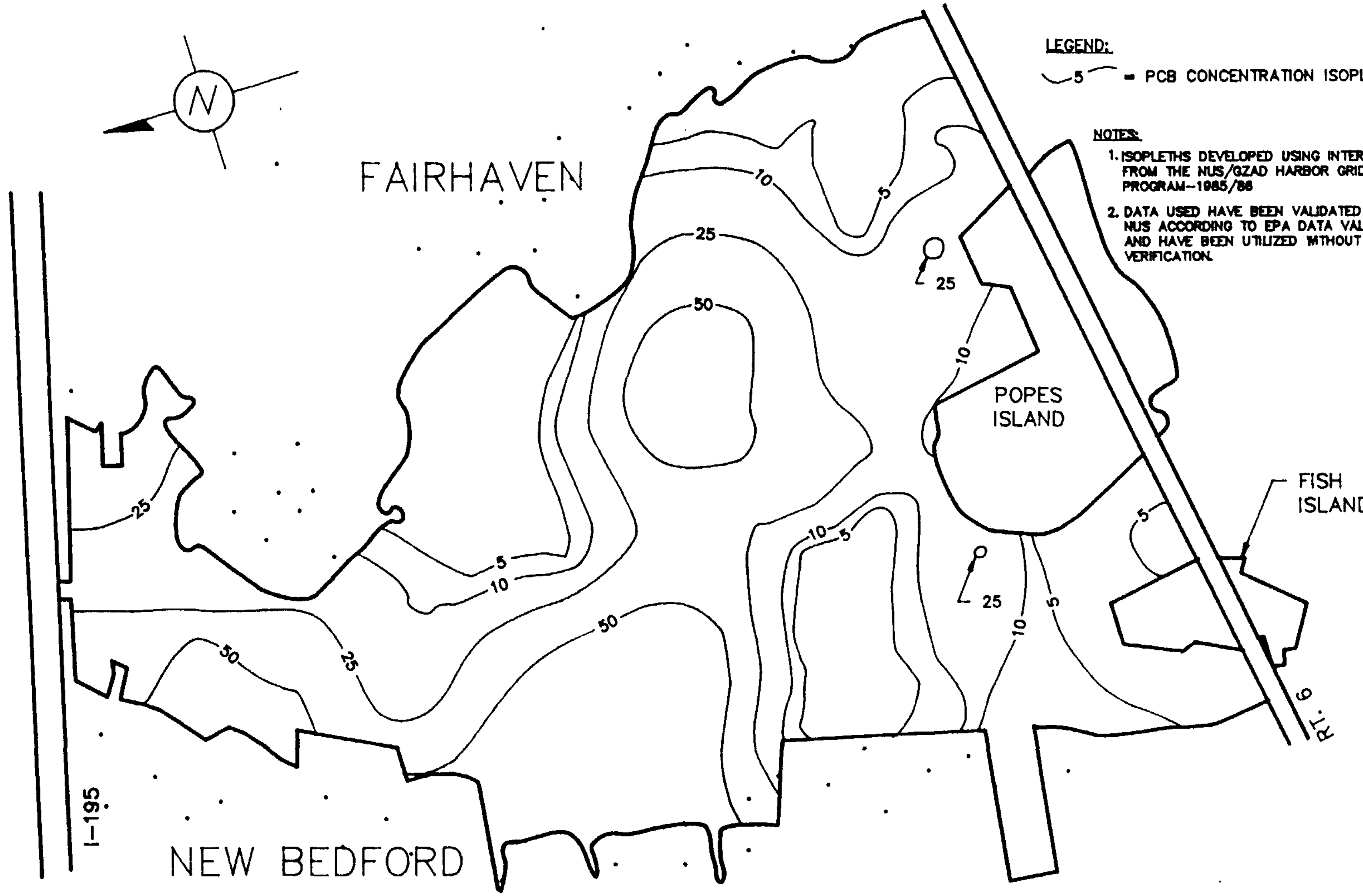
CLIENT	AVX CORPORATION		
TITLE	ISOPLETHS FOR TOTAL PCB CONCENTRATIONS 0"–12" INTERVAL		
DATE: 10/12/89	DRAWN BY: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR
SCALE: 1"=900'	FILE NO. 1.6": 629216a	APPROVED: L.C.S.	FIGURE NO.: 1.5
			PROJECT NO.: 6292.05



LEGEND:

5 = PCB CONCENTRATION ISOPLETH (PPM)

NOTES:

1. ISOPLETHS DEVELOPED USING INTERPOLATION OF DATA FROM THE NUS/GZAD HARBOR GRID SAMPLING PROGRAM—1985/86
2. DATA USED HAVE BEEN VALIDATED AND QUALIFIED BY NUS ACCORDING TO EPA DATA VALIDATION GUIDELINES AND HAVE BEEN UTILIZED WITHOUT FURTHER VERIFICATION.

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

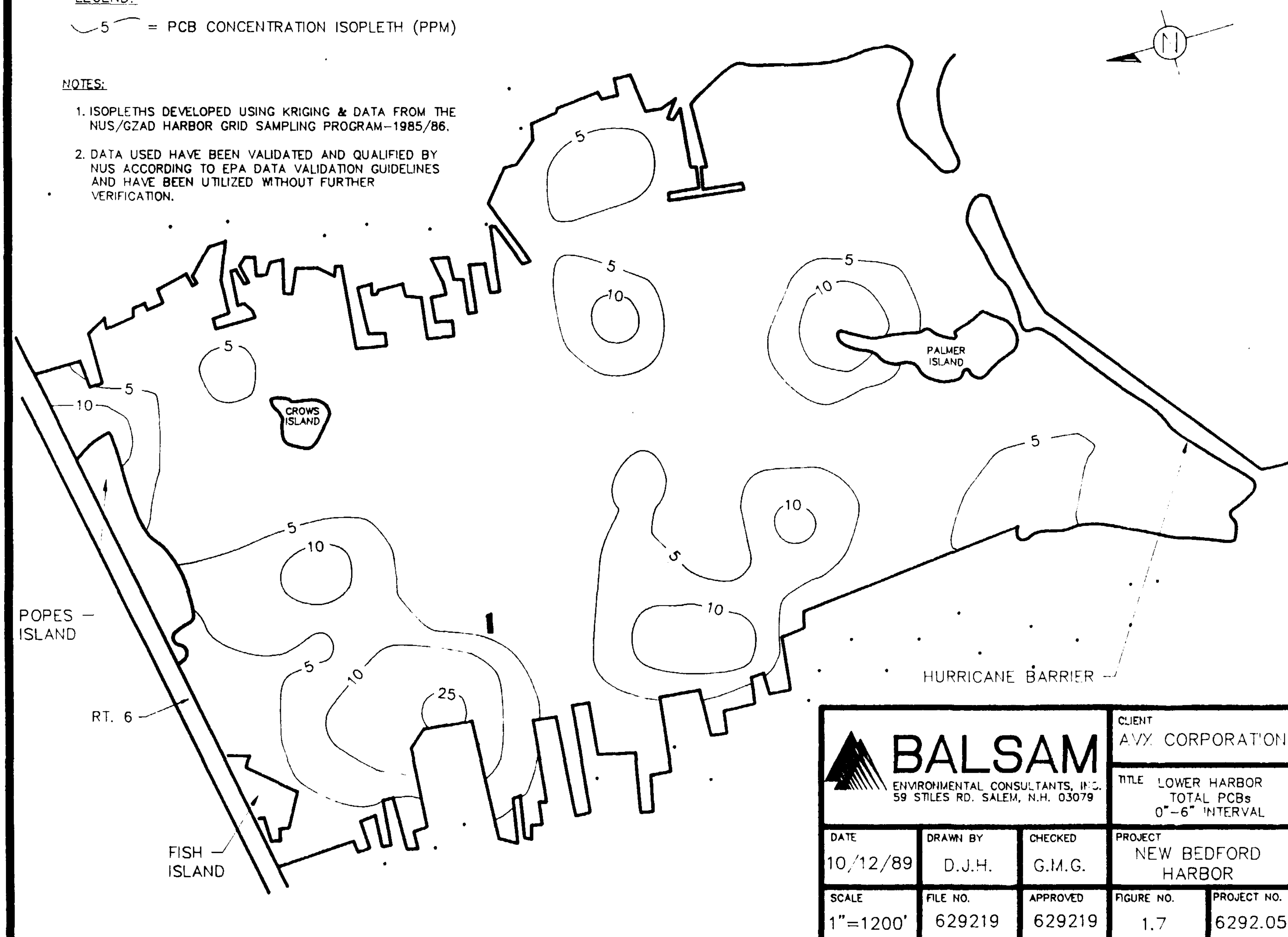
CLIENT AVX CORPORATION				
TITLE MIDDLE HARBOR TOTAL PCBs 0-6" INTERVAL				
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE 1"=1200'	FILE NO. 629229	APPROVED L.C.S.	FIGURE NO. 1.6	PROJECT NO. 6292.05

LEGEND:

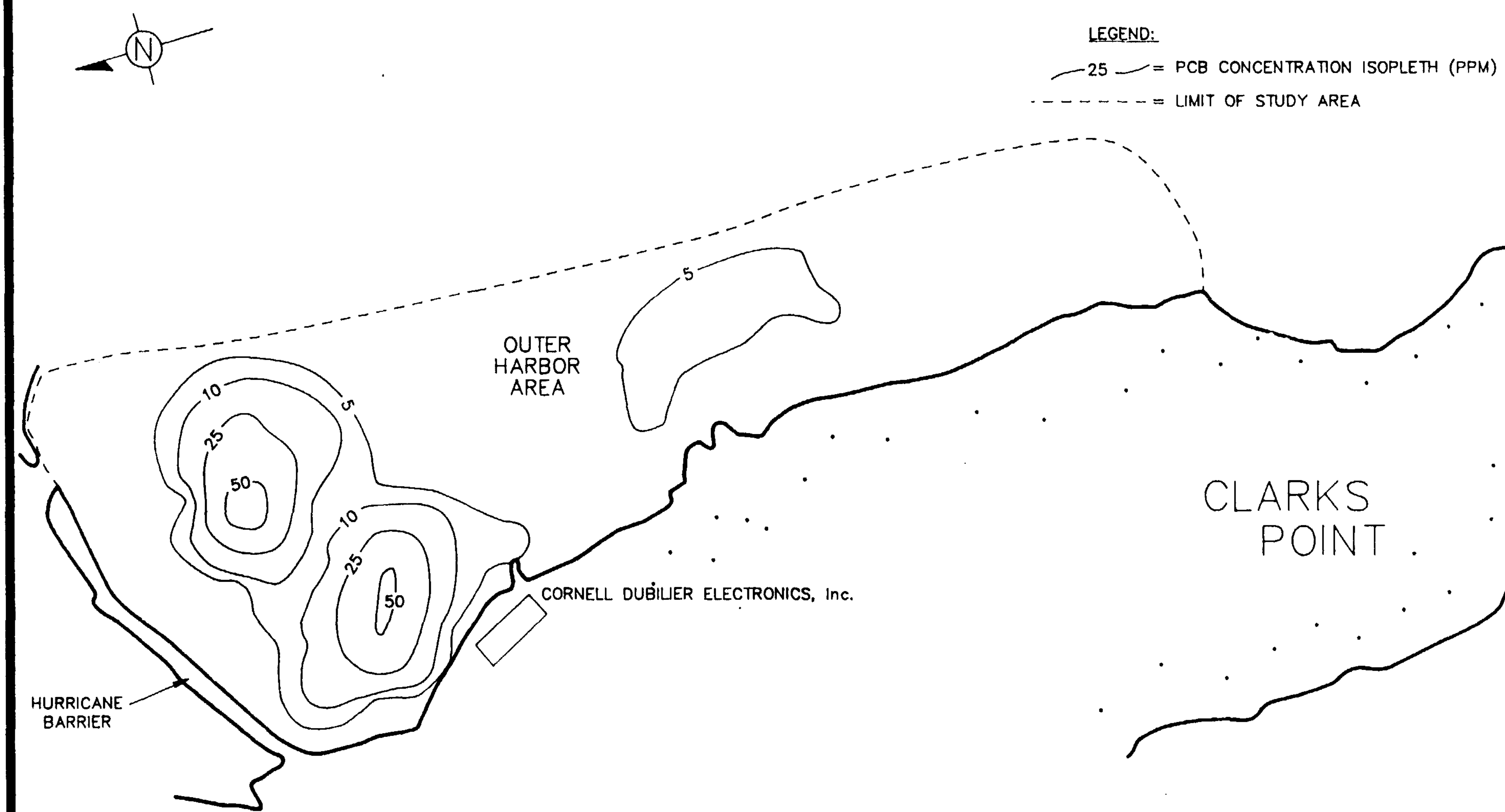
~5~ = PCB CONCENTRATION ISOPLETH (PPM)

NOTES:

1. ISOPLETHS DEVELOPED USING KRIGING & DATA FROM THE NUS/GZAD HARBOR GRID SAMPLING PROGRAM–1985/86.
2. DATA USED HAVE BEEN VALIDATED AND QUALIFIED BY NUS ACCORDING TO EPA DATA VALIDATION GUIDELINES AND HAVE BEEN UTILIZED WITHOUT FURTHER VERIFICATION.



BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE LOWER HARBOR TOTAL PCBs 0"–6" INTERVAL	
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE 1"=1200'	FILE NO. 629219	APPROVED 629219	FIGURE NO. 1.7	PROJECT NO. 6292.05



NOTES:

1. ISOPLETHS DEVELOPED USING INTERPOLATION OF DATA FROM THE NUS/GZAD HARBOR GRID SAMPING PROGRAM–1985/86.

2. DATA USED HAVE BEEN VALIDATED AND QUALIFIED BY NUS ACCORDING TO EPA DATA VALIDATION GUIDELINES AND HAVE BEEN UTILIZED WITHOUT FURTHER VERIFICATION.

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: OUTER HARBOR AREA TOTAL PCBs 0"–6" INTERVAL				
DATE: 10/12/89	DRAWN BY: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: 1"=1200'	FILE NO.: 629220	APPROVED: L.C.S.	FIGURE NO.: 1.8	PROJECT NO.: 6292.05

SCALE 1:25 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

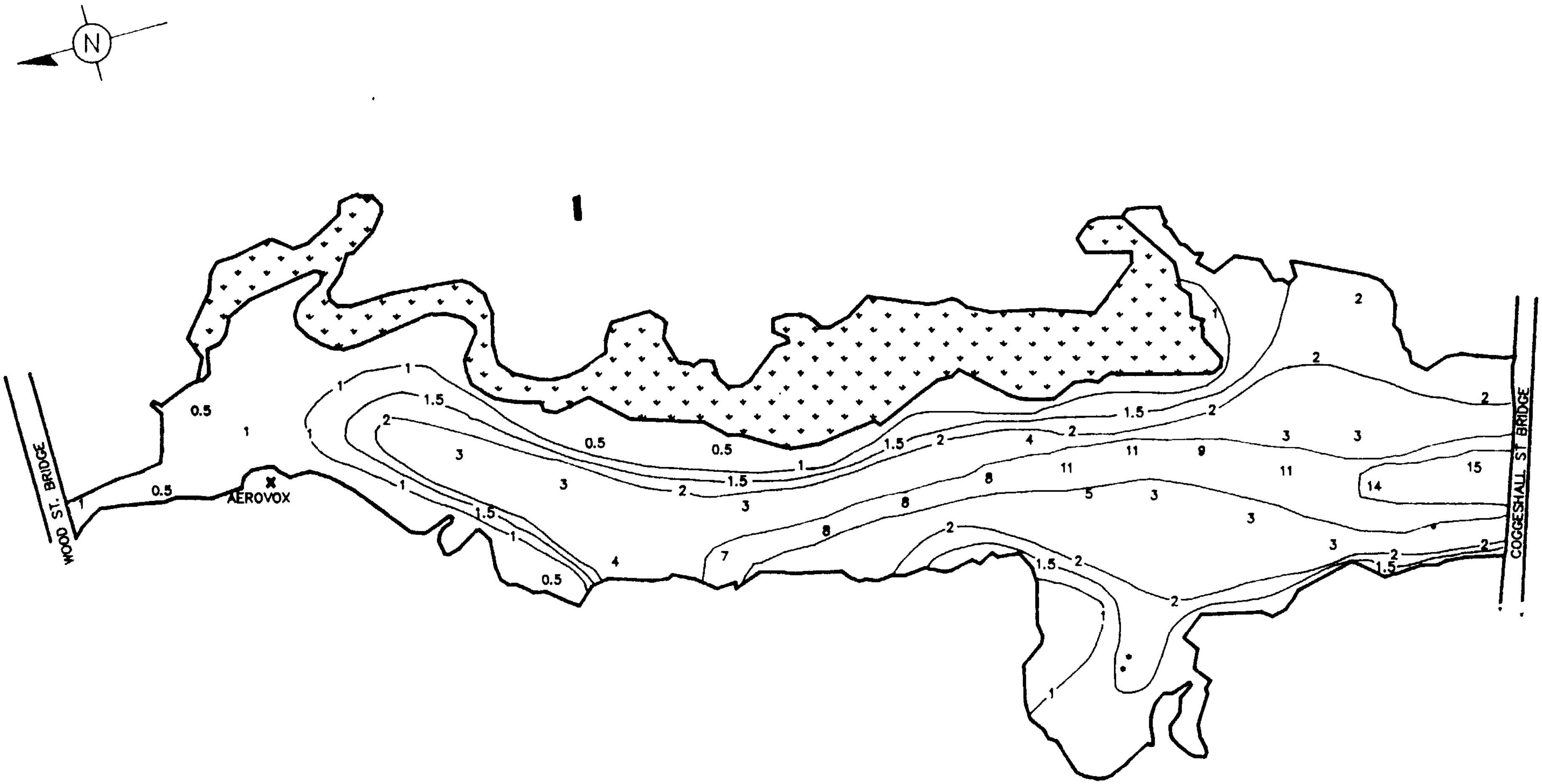
CONTOUR INTERVAL 10 FEET

DEPTH CURVES AND SOUNDINGS IN FEET— DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 3.7 FEET

SOURCE:
NEW BEDFORD NORTH QUADRANGLE
7.5 MINUTE SERIES TOPOGRAPHIC
1979

BALSAM ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: UPPER ESTUARY				
DATE: 8/28/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: 1:25000	FILE NO: 629228	APPROVED: L.C.S.	FIGURE NO: 1.9	PROJECT NO: 629205



LEGEND

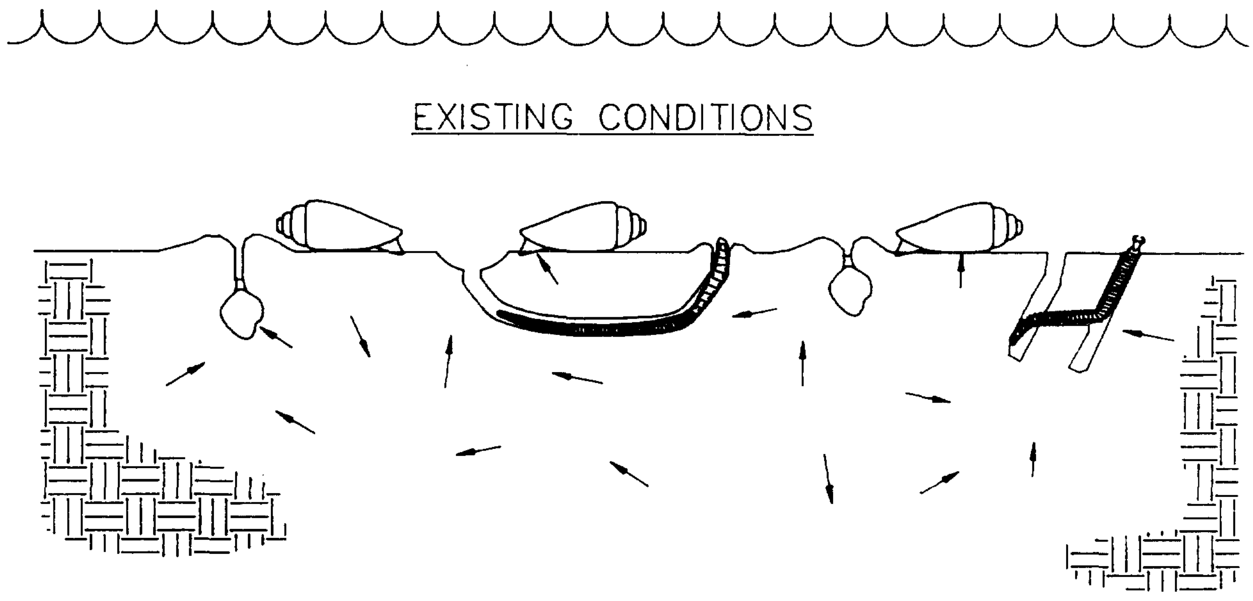
= SALT MARSH

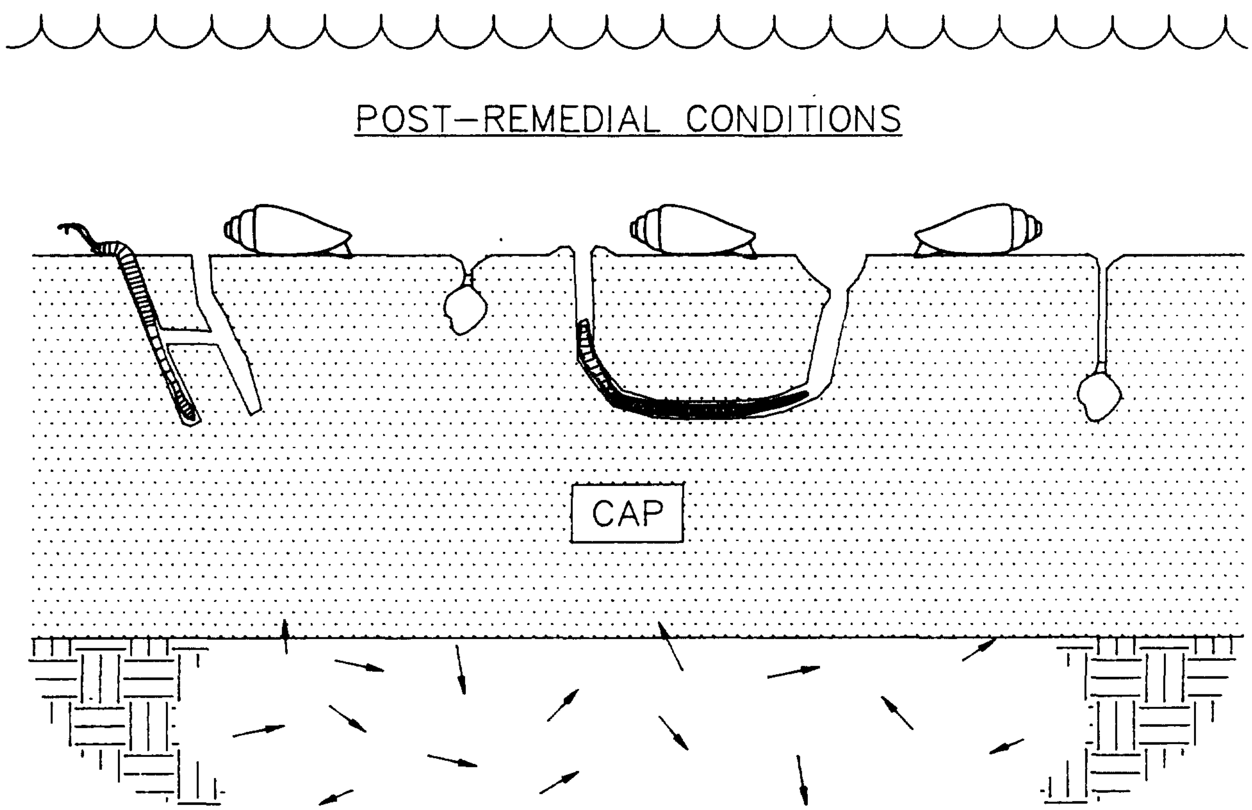
NOTES:

1. WATER DEPTH IN FEET AT MEAN LOW WATER OBTAINED FROM A U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMISTRATION, NATIONAL OCEAN SURVEY DATED MARCH 24, 1984.

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: UPPER ESTUARY WATER DEPTH				
DATE: 10/12/89	DRAWN BY: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: 1"=850'	FILE NO.: 629234	APPROVED: L.C.S.	FIGURE NO.: 1.10	PROJECT NO.: 6292.05





LEGEND:

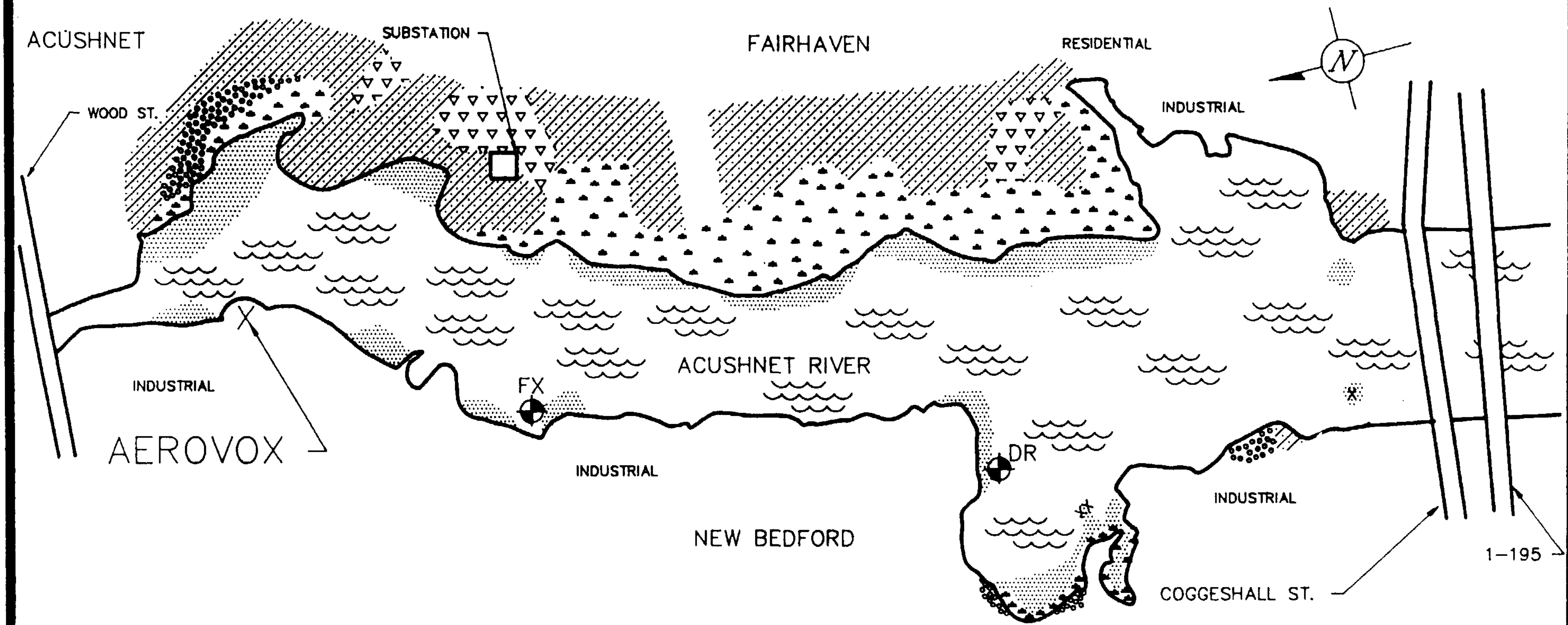
= MOLECULAR DIFFUSIVE MOVEMENT

= CONTAINMENT CAP

= EXISTING ESTUARY SEDIMENT

BALSAM ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: THEORETICAL CONTAMINANT MOVEMENT				
DATE: 10/12/89	DRAWN: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629232	APPROVED: L.C.S.	FIGURE NO: 3.1	PROJECT NO: 6292.05



HABITAT TYPES

- = OPEN FIELD
- = HARDWOOD WOODLOT
- = SALT MARSH
- = PHRAGMITES
- = TIDAL FLAT (MEAN LOW WATER-MEAN SEA LEVEL)
- = WATER COVERAGE (AT MEAN LOW WATER)
- X X = ROCKS

LEGEND:

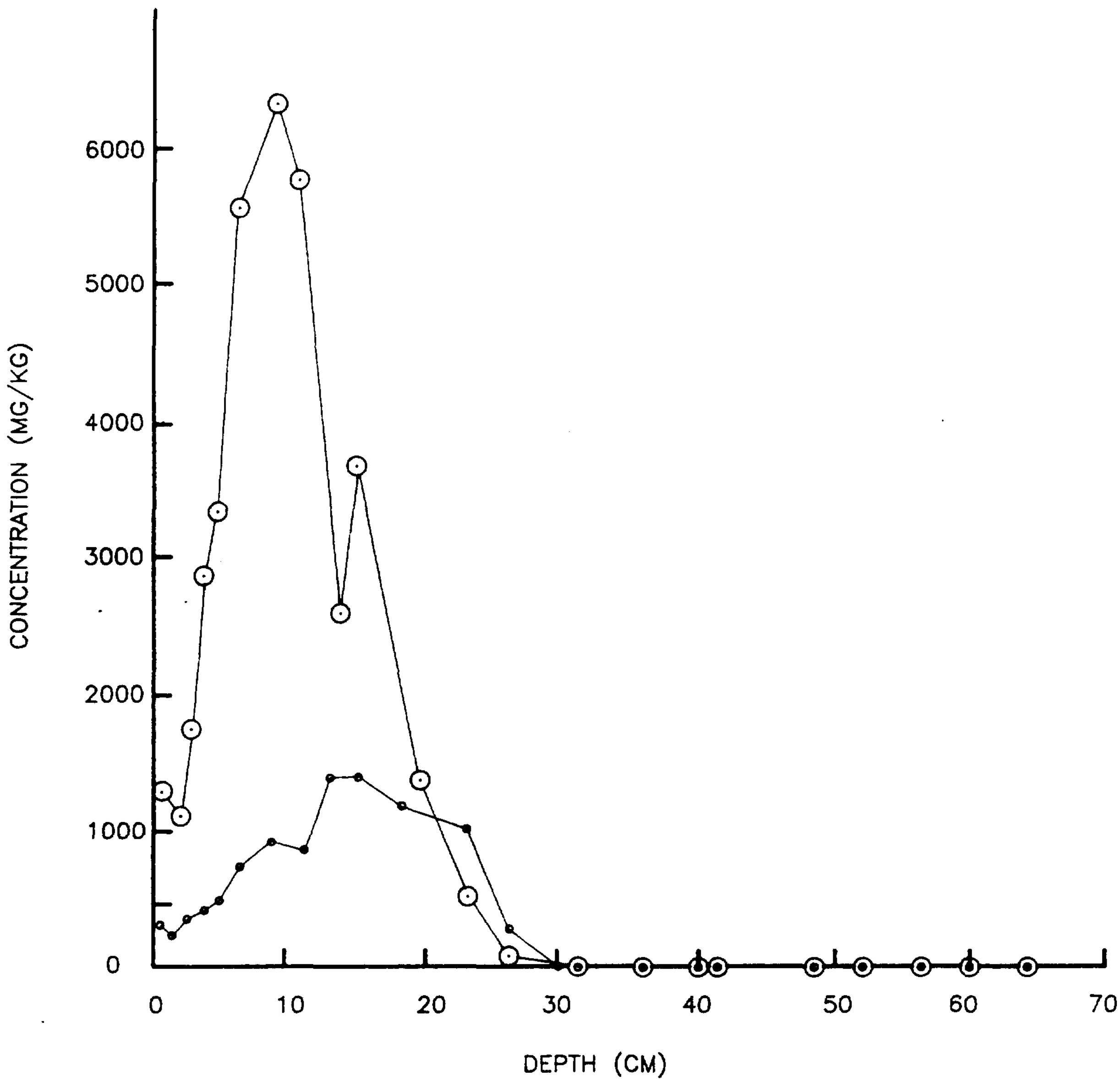
FX = SEDIMENT SAMPLING STATION AND DESIGNATION

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: THIN LAYER SEDIMENT SAMPLING STATIONS				
DATE: 10/12/89	DRAWN BY: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: 1"=900'	FILE NO.: 629233	APPROVED: L.C.S.	FIGURE NO.: 3.2	PROJECT NO.: 6292.05

PCB CONCENTRATION PROFILE

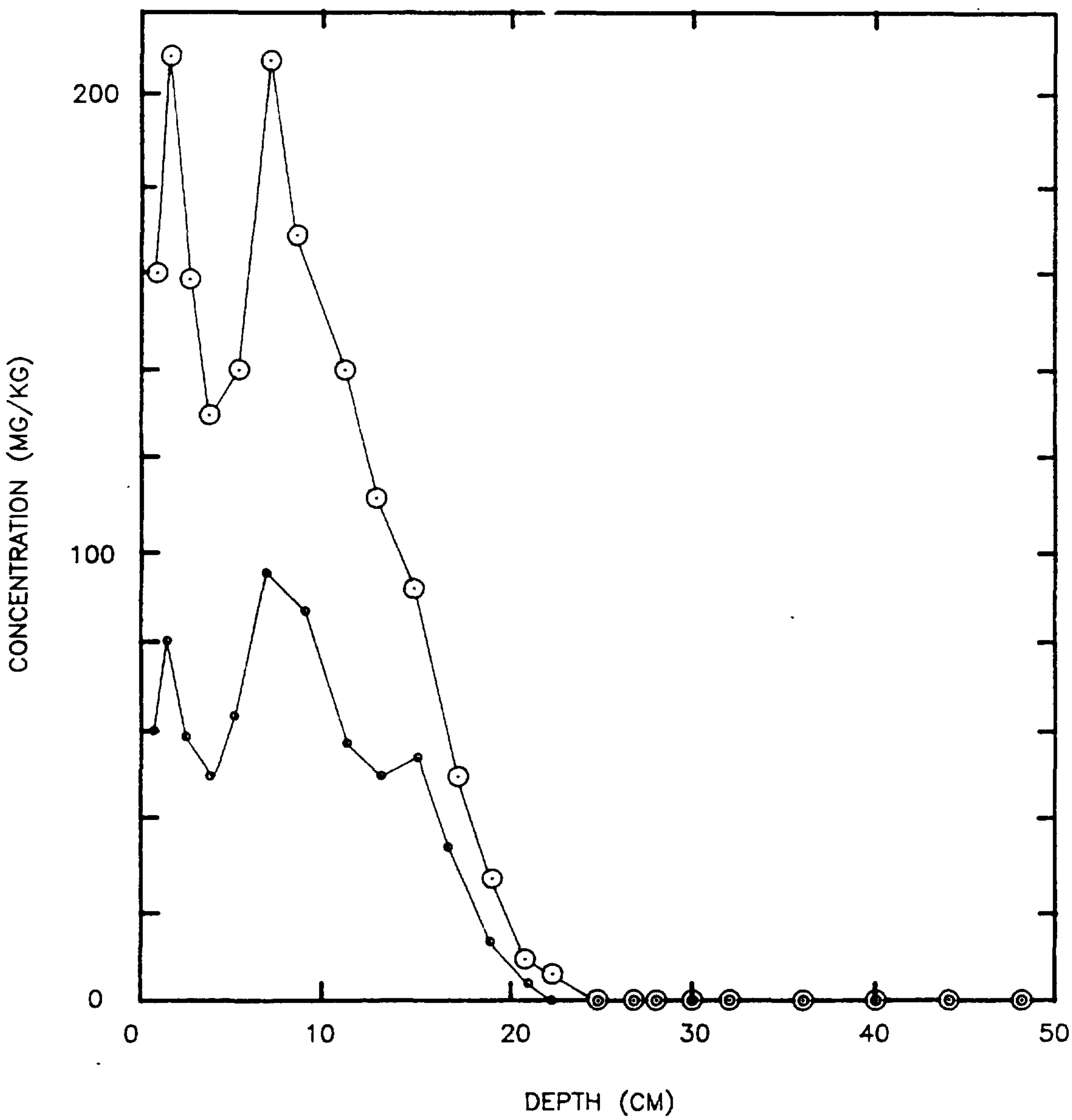
AROCLORS 1242/1016 ⊙; AROCLOR 1254 ∘
NEW BEDFORD
SAMPLE STATION FX



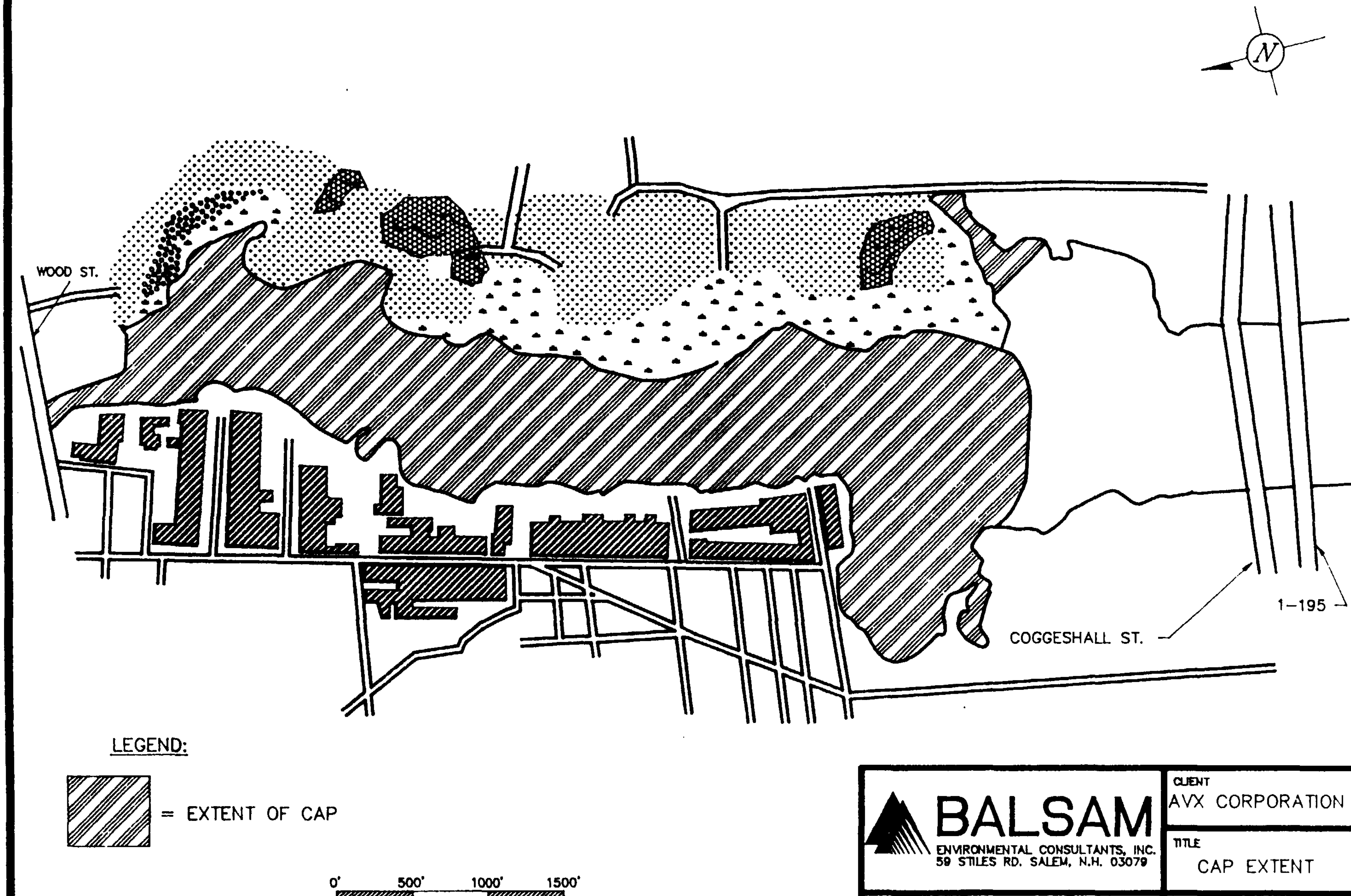
BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: PCB PROFILE STATION FX	
DATE: 10/12/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629211	APPROVED: L.C.S.	FIGURE NO: 3.3.	PROJECT NO: 6292.05

PCB CONCENTRATION PROFILE

AROCLORS 1242/1016 ⊙; AROCLOR 1254 ∘
NEW BEDFORD
SAMPLE STATION DR

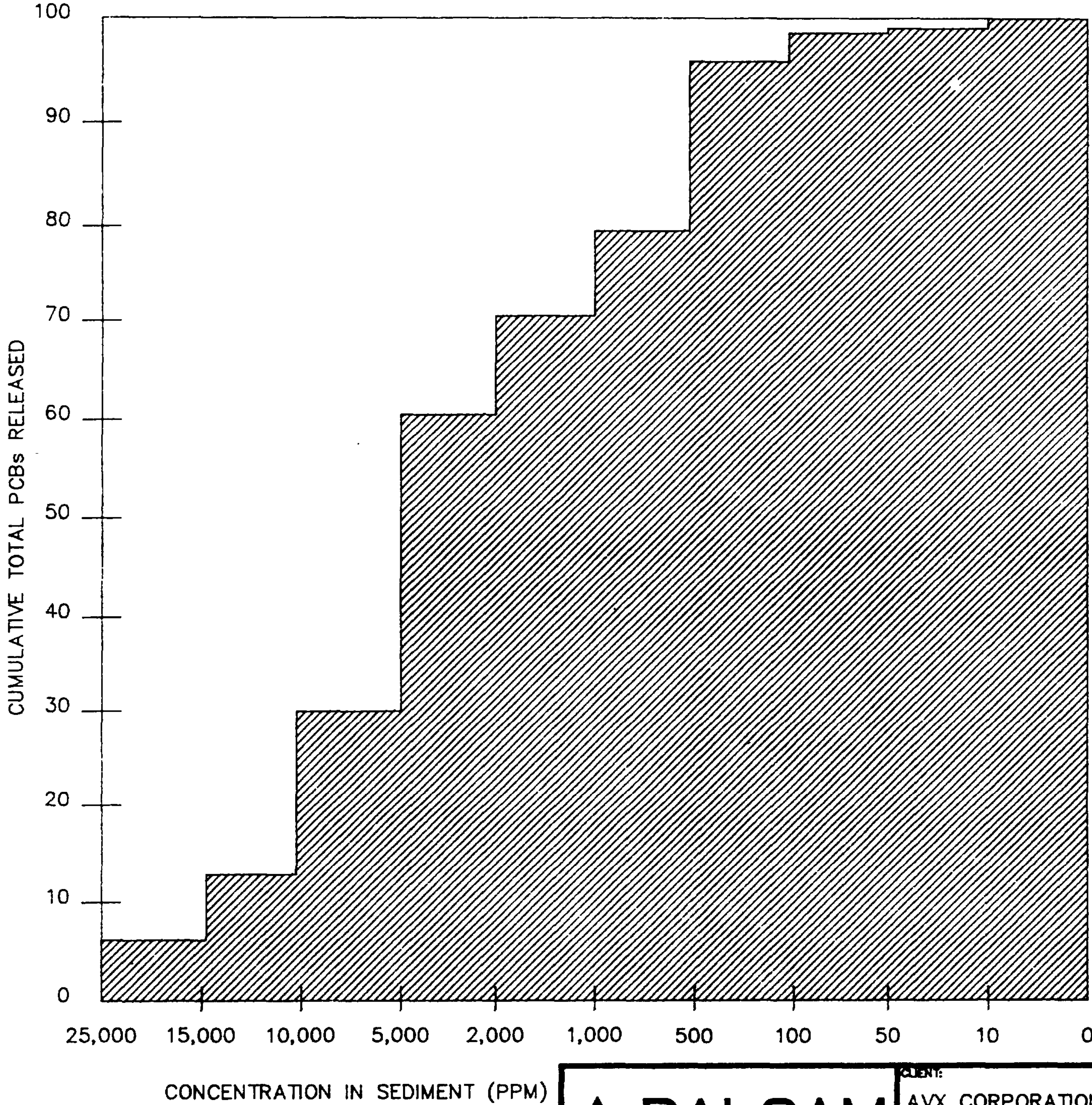


BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: PCB PROFILE STATION DR	
DATE: 10/12/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629212	APPROVED: L.C.S.	FIGURE NO: 3.4	PROJECT NO: 6292.05

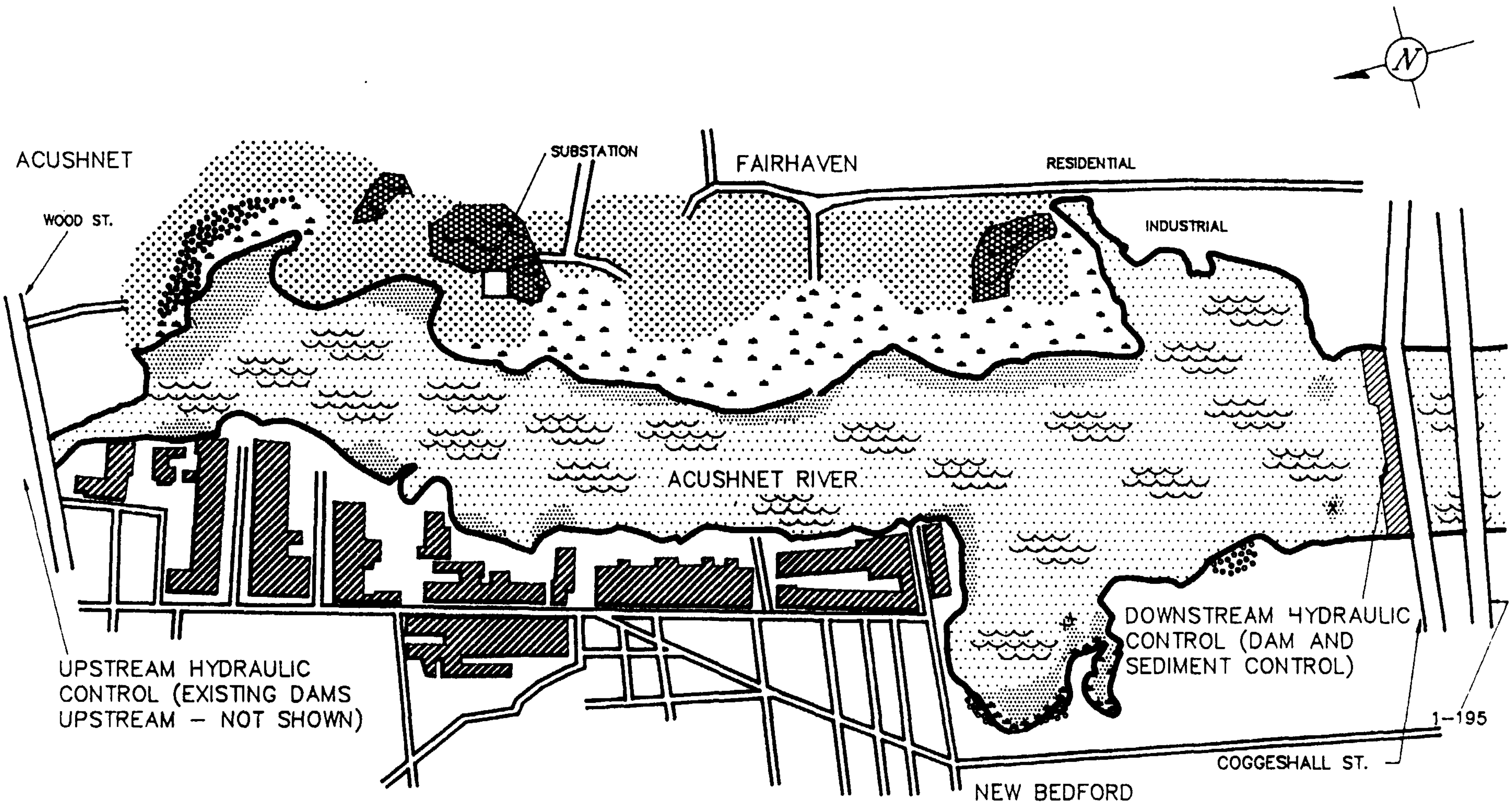


BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE CAP EXTENT	
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFROD HARBOR	
SCALE 1"=900'	FILE NO. 629231	APPROVED L.C.S.	FIGURE NO. 3.5	PROJECT NO. 6292.05

CUMULATIVE PERCENTAGE OF PCBs
RELEASED FROM UPPER ESTUARY



BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: CUMMULATIVE PCB FLUX	
DATE: 10/12/89	DRAWN: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629215	APPROVED: L.C.S.	FIGURE NO: 3.6	PROJECT NO: 6292.05

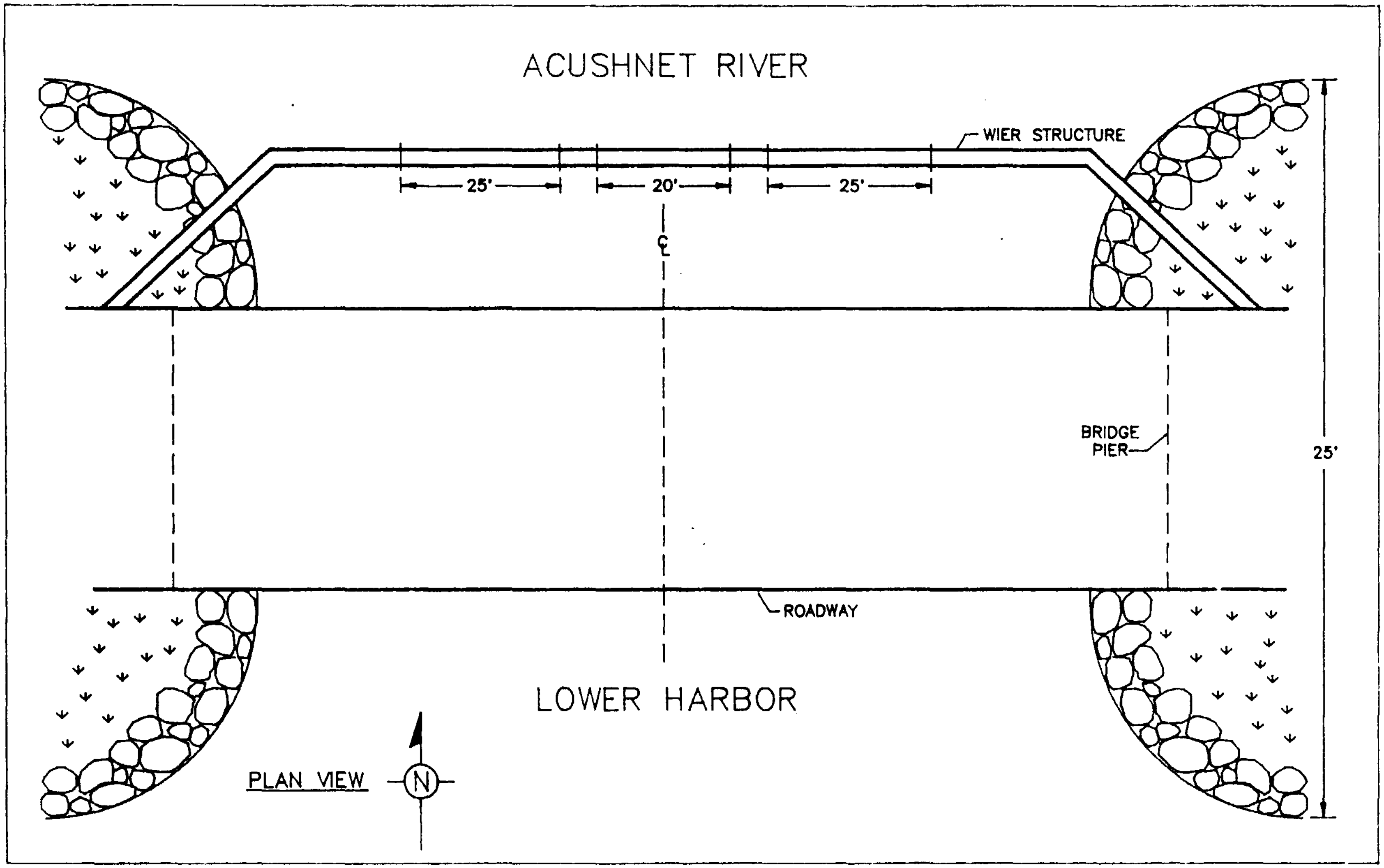


HABITAT TYPES

- = SALT MARSH
- = PHRAGMITES
- = TIDAL FLAT (MEAN LOW WATER–MEAN SEA LEVEL)
- = WATER COVERAGE (AT MEAN LOW WATER)
- X X = ROCKS
- = OPEN FIELD
- = HARDWOOD WOODLOT

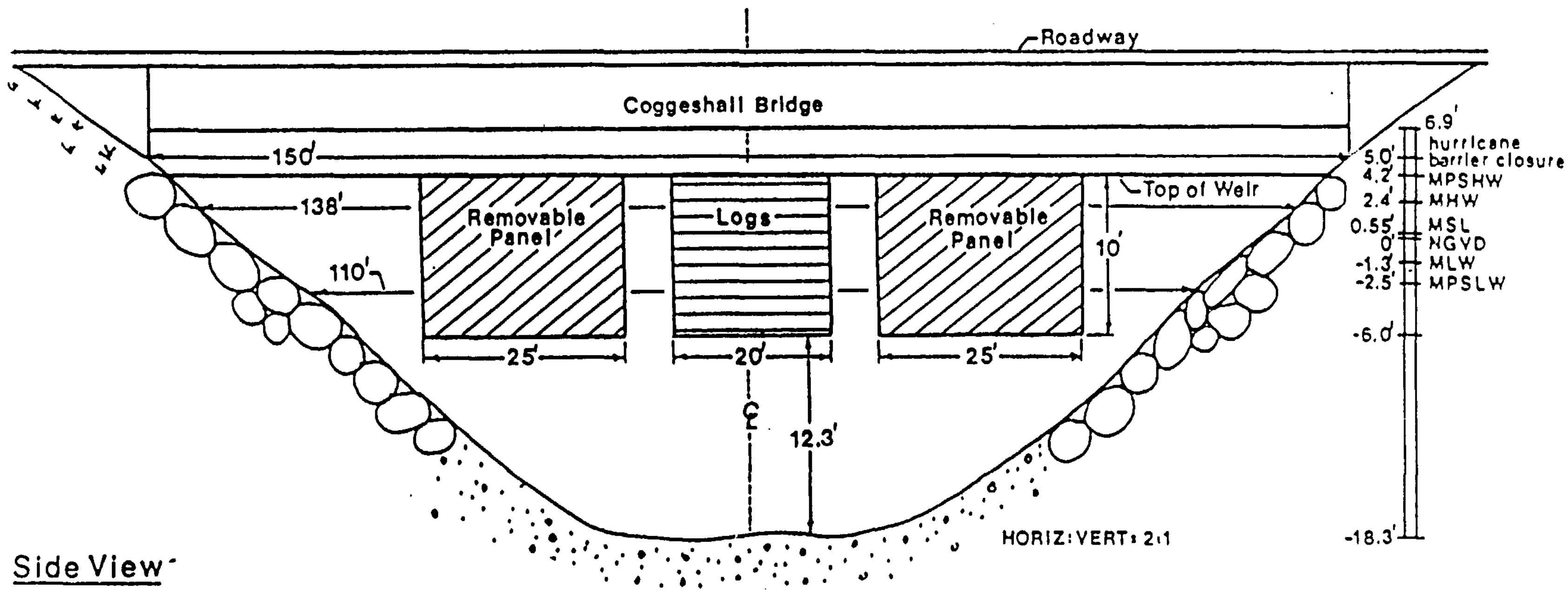
0' 500' 1000' 1500'

BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE HYDRAULIC CONTROLS	
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE AS SHOWN	FILE NO. 629227	APPROVED L.C.S.	FIGURE NO. 3.7	PROJECT NO. 6292.05



SOURCE: ASA 1988

BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H.			CLIENT AVX CORPORATION	
			TITLE PLAN VIEW PROPOSED DAM	
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE AS NOTED	FILE NO. 629223	APPROVED L.C.S	FIGURE NO. 3.8	PROJECT NO. 6292.05

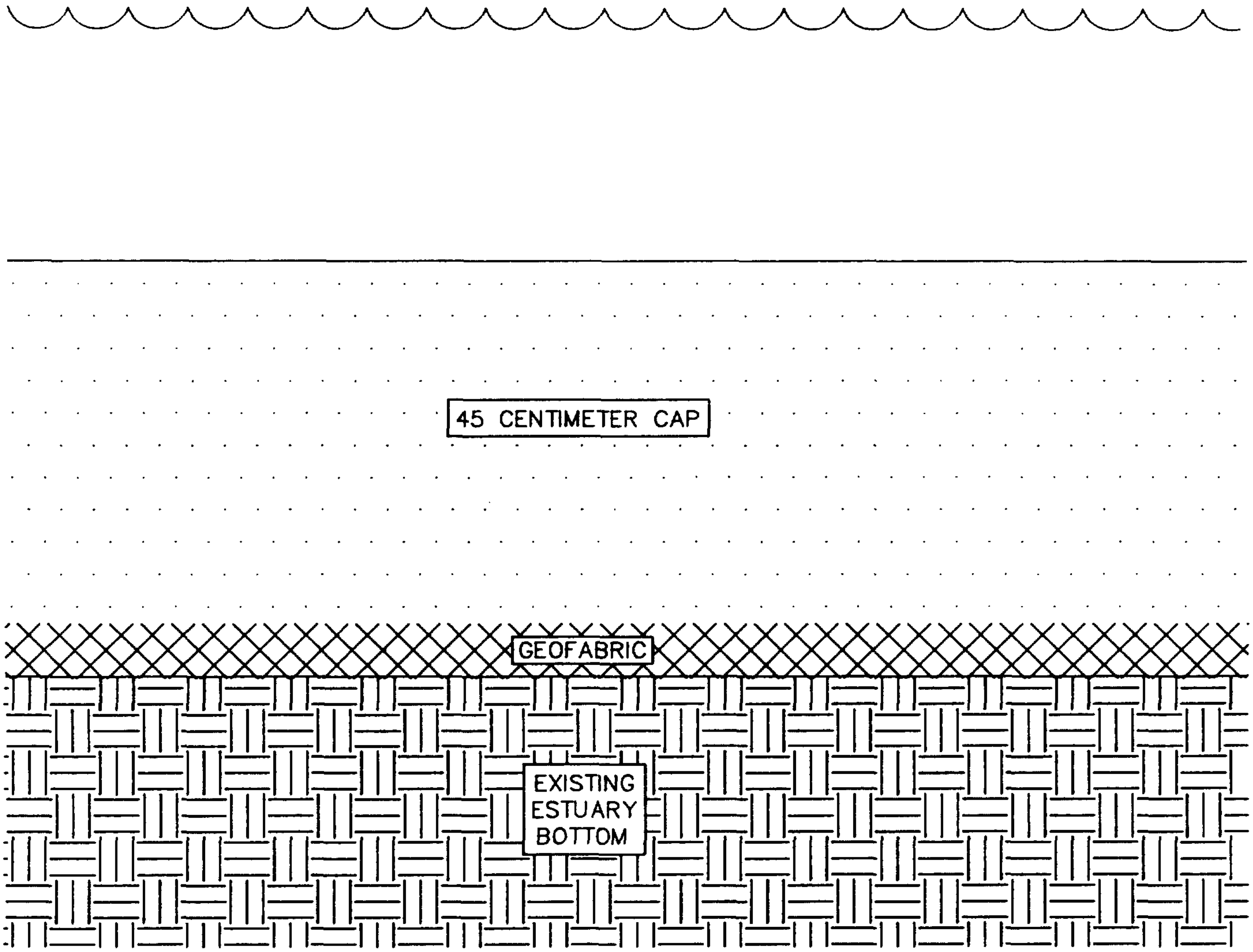


SOURCE: ASA, 1988

BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE SIDE VIEW OF PROPOSED DAM WITH ADJUSTABLE WEIR	
DATE 10/12/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE AS NOTED	FILE NO. 629222	APPROVED L.C.S.	FIGURE NO. 3.9	PROJECT NO. 6292.05

TYPICAL CAP

CROSS SECTION

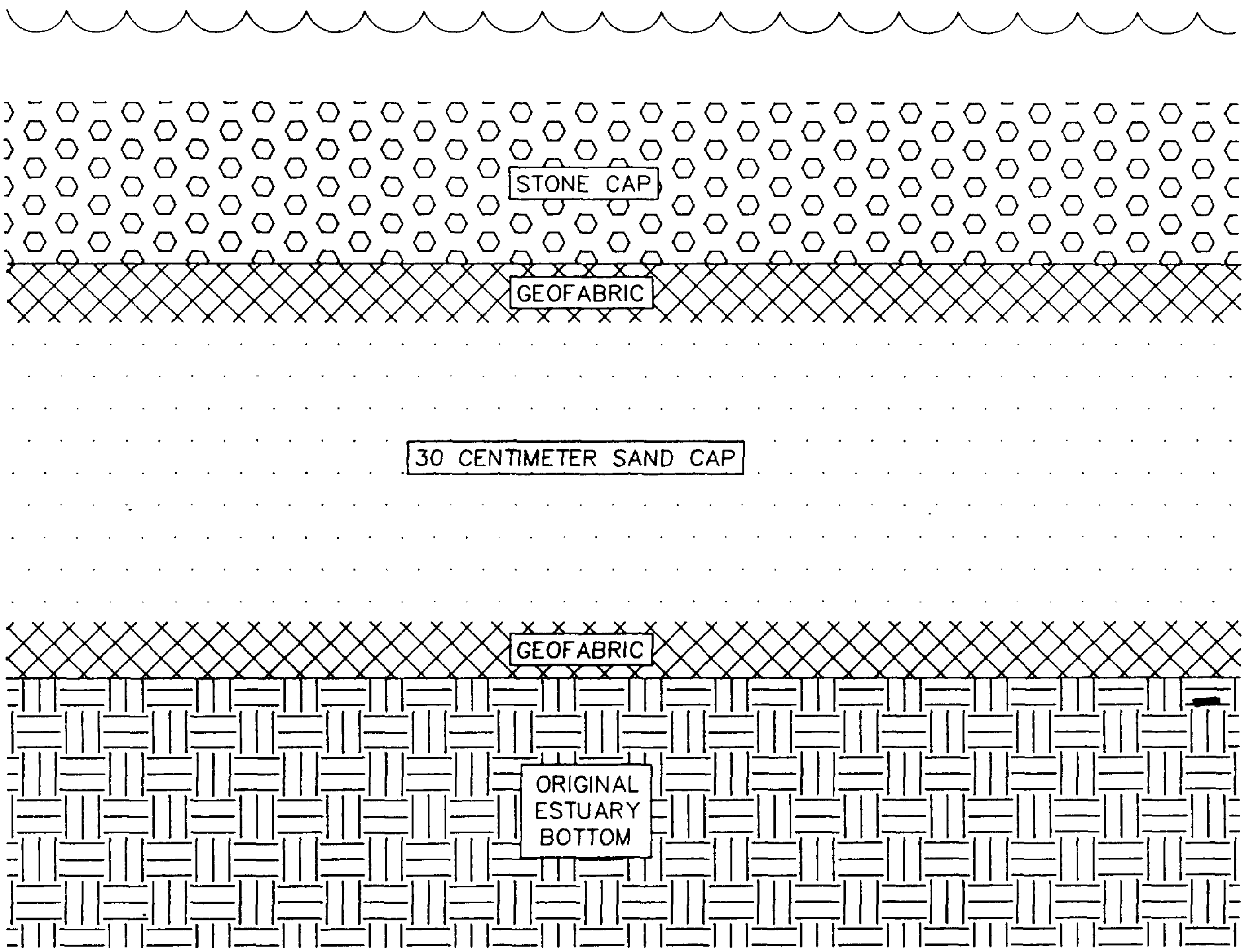


BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

			CLIENT: AVX CORPORATION	
			TITLE: TYPICAL CAP CROSS SECTION	
DATE: 10/13/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629226	APPROVED: L.C.S.	FIGURE NO: 3.10	PROJECT NO: 6292.05

TYPICAL ARMORED CAP

CROSS SECTION



BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: TYPICAL ARMORED CAP CROSS SECTION	
DATE: 10/13/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO: 629225	APPROVED: L.C.S.	FIGURE NO: 3.11	PROJECT NO: 6292.05

LEGEND

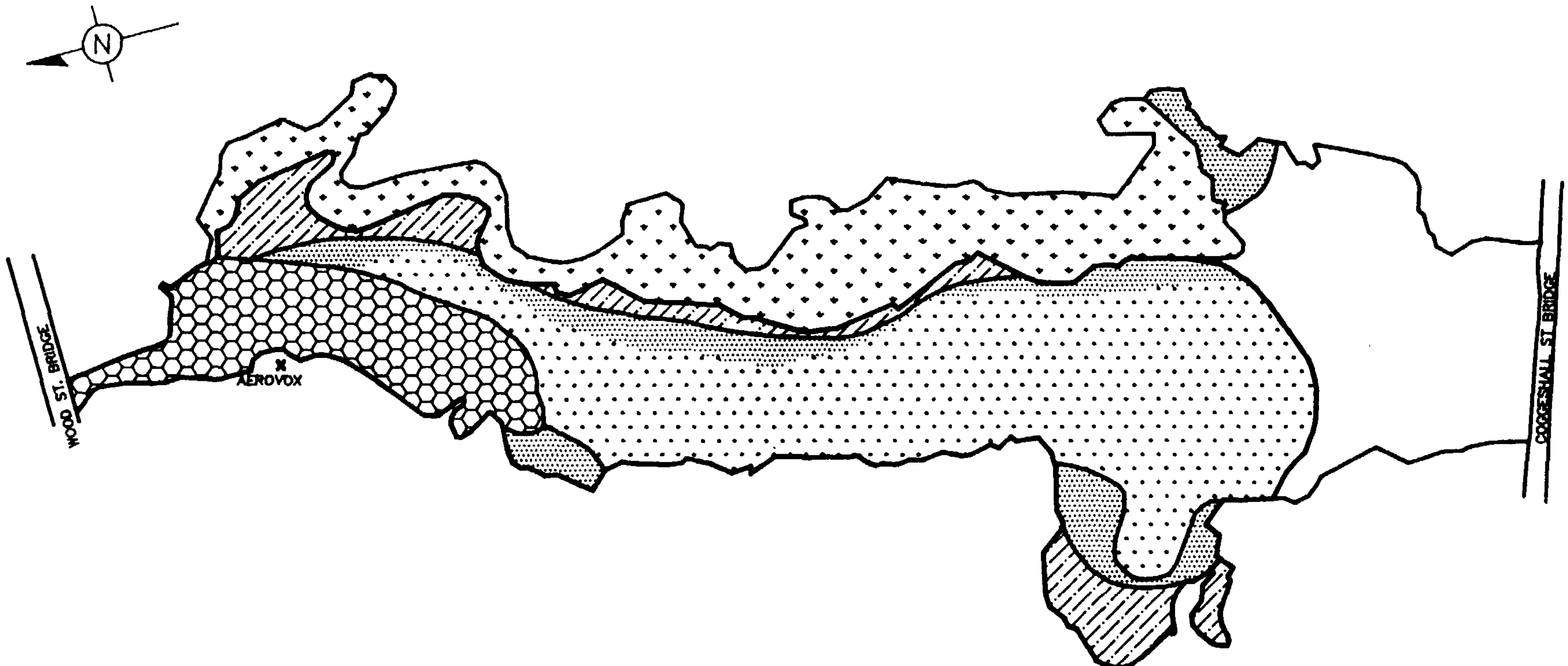
- = SALT MARSH
- — 2 — = WATER DEPTH IN FEET AT MEAN LOW WATER PRIOR TO CAPPING
- = EXTENT OF ARMORED CAP

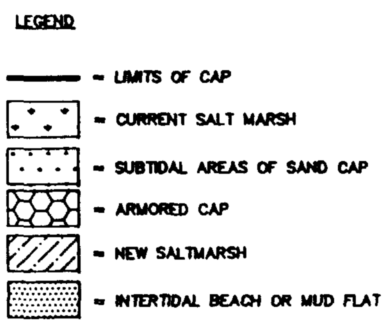
NOTES:

1. WATER DEPTH IN FEET AT MEAN LOW WATER OBTAINED FROM A U.S. DEPARTMENT OF COMMERCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, NATIONAL OCEAN SURVEY DATED MARCH 24, 1984.

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT	AVX CORPORATION			
TITLE	EXTENT OF ARMORED CAP			
DATE 10/13/89	DRAWN BY D.J.H.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE 1"=900'	FILE NO. 6292ca	APPROVED L.C.S.	FIGURE NO. 3.12	PROJECT NO. 6292.05





BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT
AVX CORPORATION

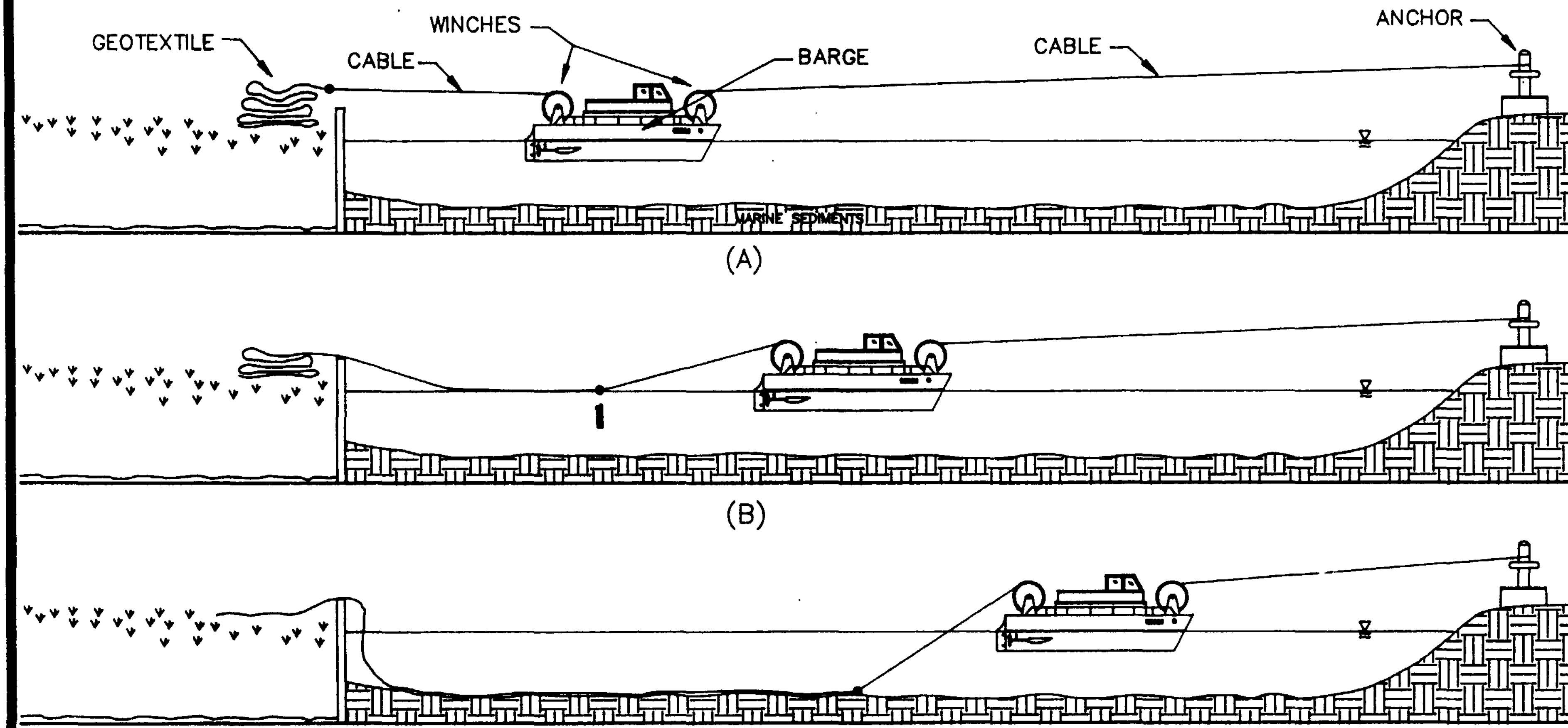
TITLE
POST REMEDIAL HABITAT

PROJECT
NEW BEDFORD HARBOR

DATE	DRAWN BY	CHECKED
10/16/89	D.J.H.	G.M.G.

SCALE	FILE NO.	APPROVED	FIGURE NO.	PROJECT NO.
1"=900'	629213a	L.C.S.	3.13	6292.05

NEAR SHORE GEOTEXTILE DEPLOYMENT



(C)

NOTE: FOLDED FABRIC MAY ALSO DEPLOYED FROM BARGE.

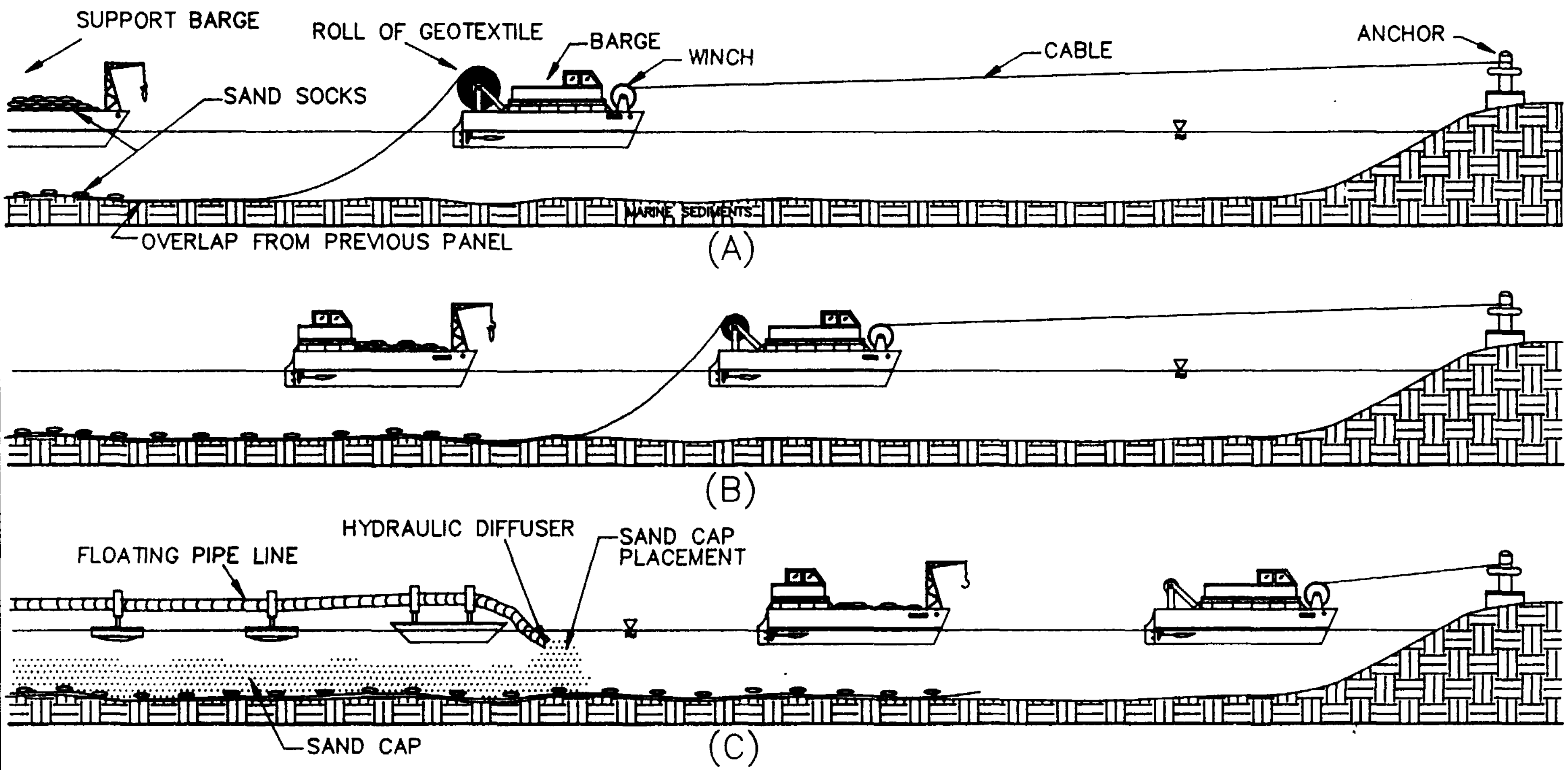
BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION

TITLE: NEAR SHORE GEOTEXTILE DEPLOYMENT

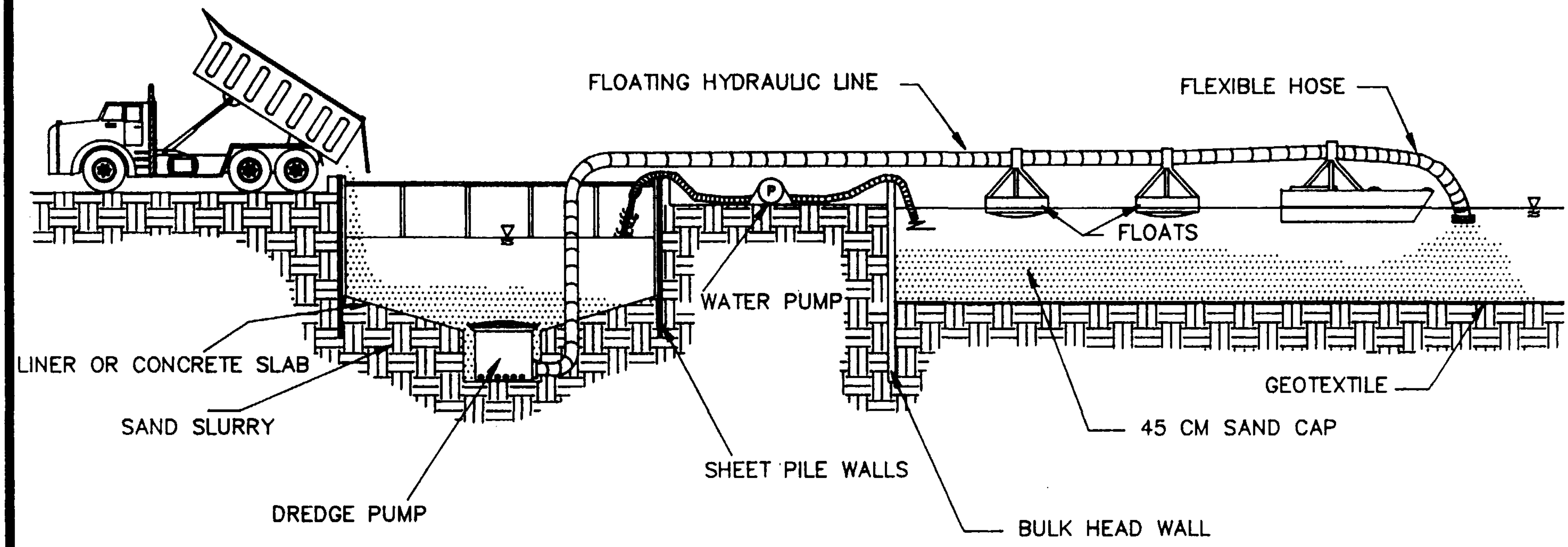
DATE	DRAWN BY	CHECKED	PROJECT
10/13/89	P.J.S.	G.M.G.	NEW BEDFORD HARBOR
SCALE	**FILE NO. 1.6"**	**APPROVED**	**FIGURE NO.** / **PROJECT NO.**
NONE	62921	L.C.S.	3.14 / 6292.05

OFF-SHORE GEOTEXTILE DEPLOYMENT

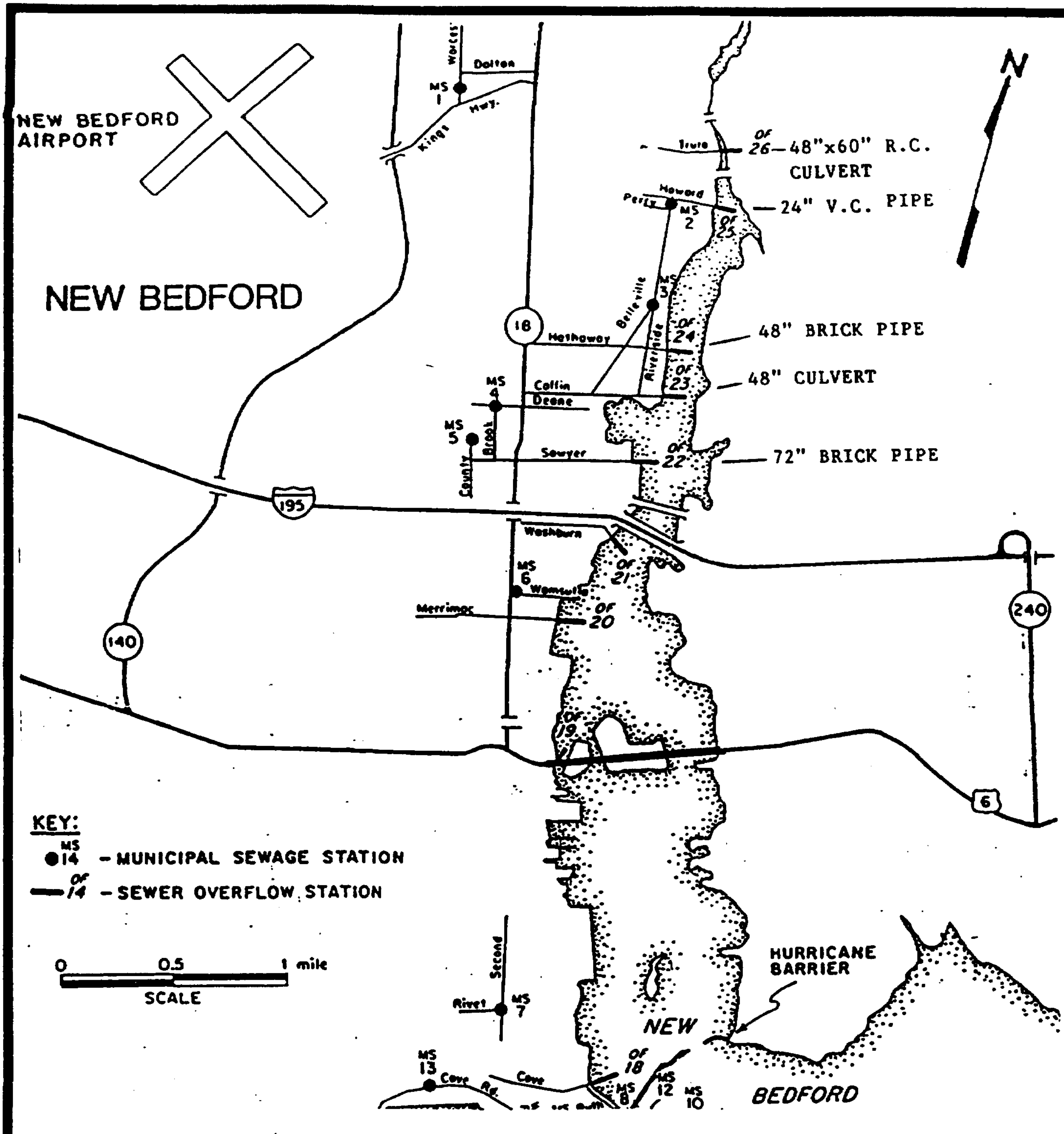


BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION
			TITLE: OFF-SHORE GEOTEXTILE DEPLOYMENT
DATE: 10/13/89	DRAWN BY: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR
SCALE: NONE	FILE NO. 1.65" 62922	APPROVED: L.C.S.	FIGURE NO. 3.15 / PROJECT NO. 6292.05

CONCEPTUAL STAGING AREA

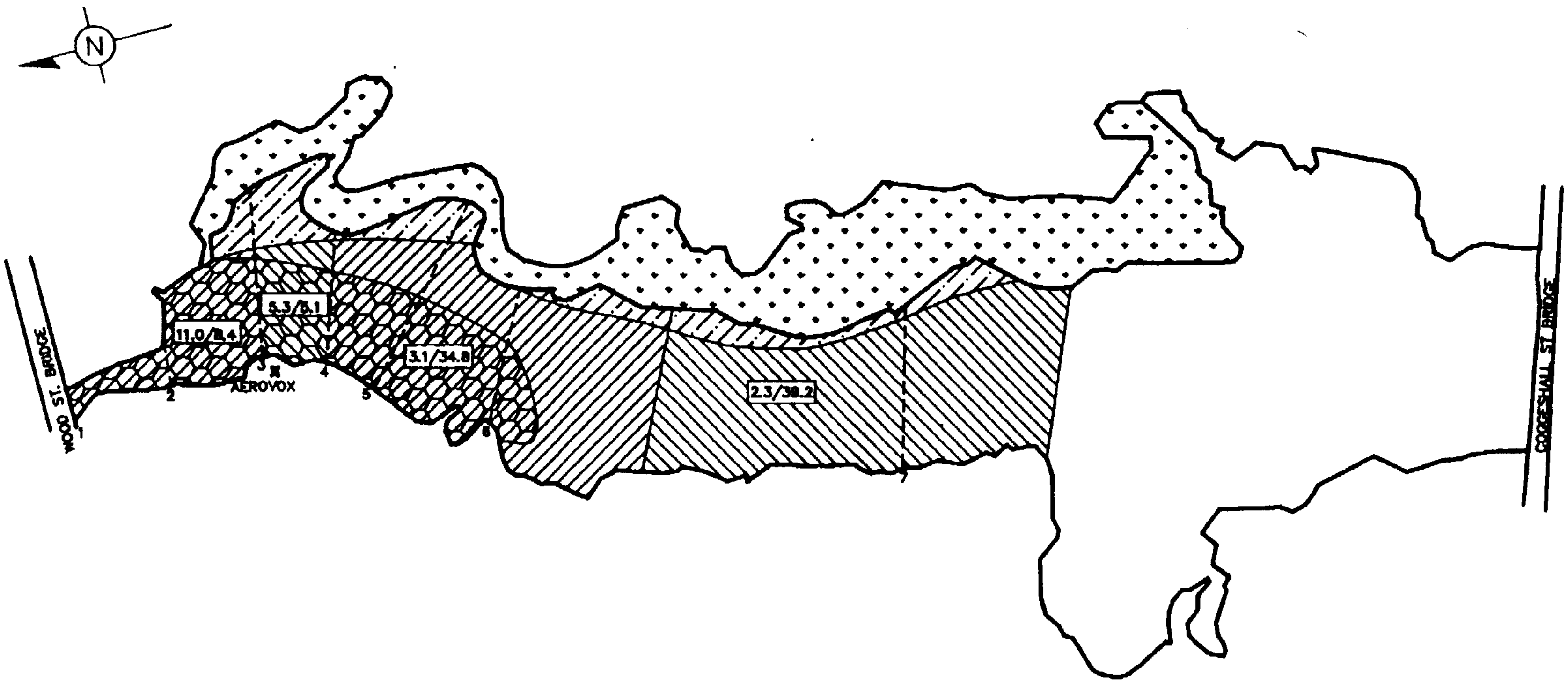


BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE CONCEPTUAL STAGING AREA	
DATE 10/13/89	DRAWN BY P.J.S.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE NONE	FILE NO. 62923	APPROVED L.C.S.	FIGURE NO. 3.16	PROJECT NO. 6292.05



SOURCE:
GCA 1983

BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT: AVX CORPORATION	
			TITLE: LOCATION OF CSOs	
DATE: 10/13/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: AS SHOWN	FILE NO: 62928	APPROVED: L.C.S.	FIGURE NO: 3.17	PROJECT NO: 6292.05



LEGEND

= SALT MARSH

2 – – – – = APPROXIMATE LOCATION OF DAMBRK CROSS-SECTIONS (FROM ASA, 1989)

5.3/3.1 = ESTIMATED CRITICAL PARTICLE DIAMETER (MM) /APPROXIMATE AREA (ACRES)

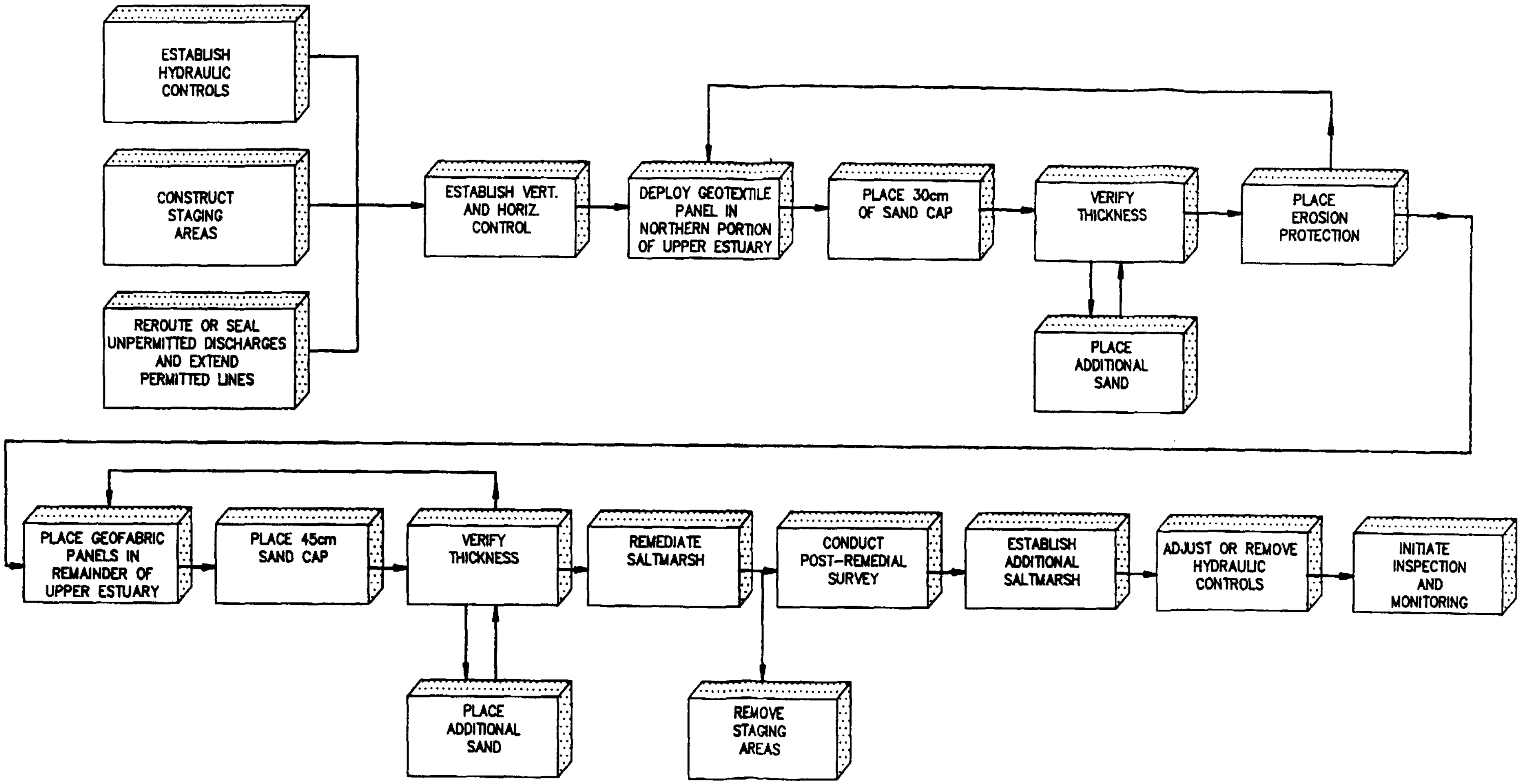
= NEW SALTMARSH

= ARMORED CAP

BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

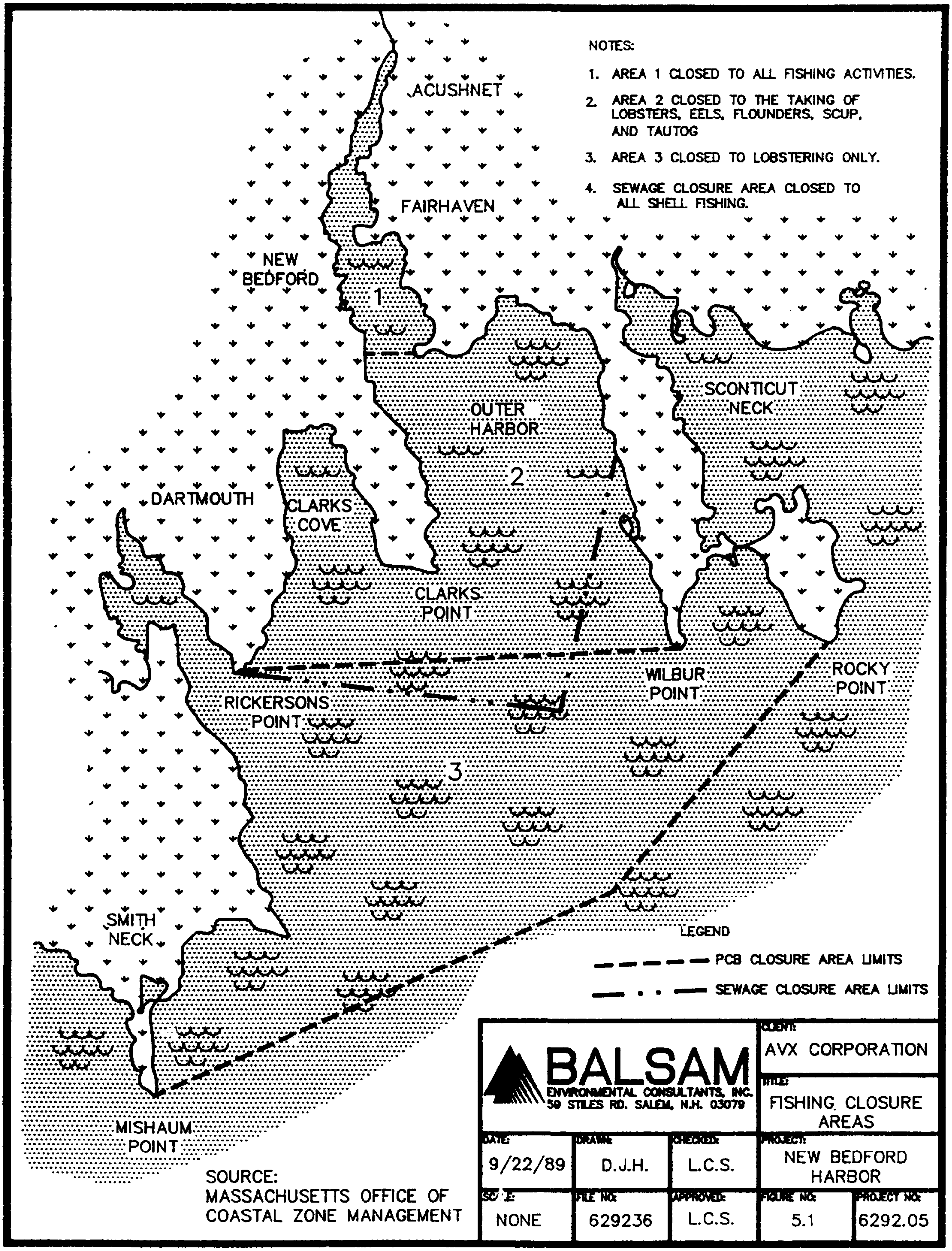
CLIENT	AVX CORPORATION			
TITLE	CRITICAL PARTICLE DIAMETERS AND AREA OF ARMORED CAP			
DATE 10/16/89	DRAWN BY D.J.H.	CHECKED E.S.W.	PROJECT NEW BEDFORD HARBOR	
SCALE 1"=900'	FILE NO. 629237	APPROVED L.C.S.	FIGURE NO. 3.18	PROJECT NO. 6292.05

CONSTRUCTION SEQUENCE

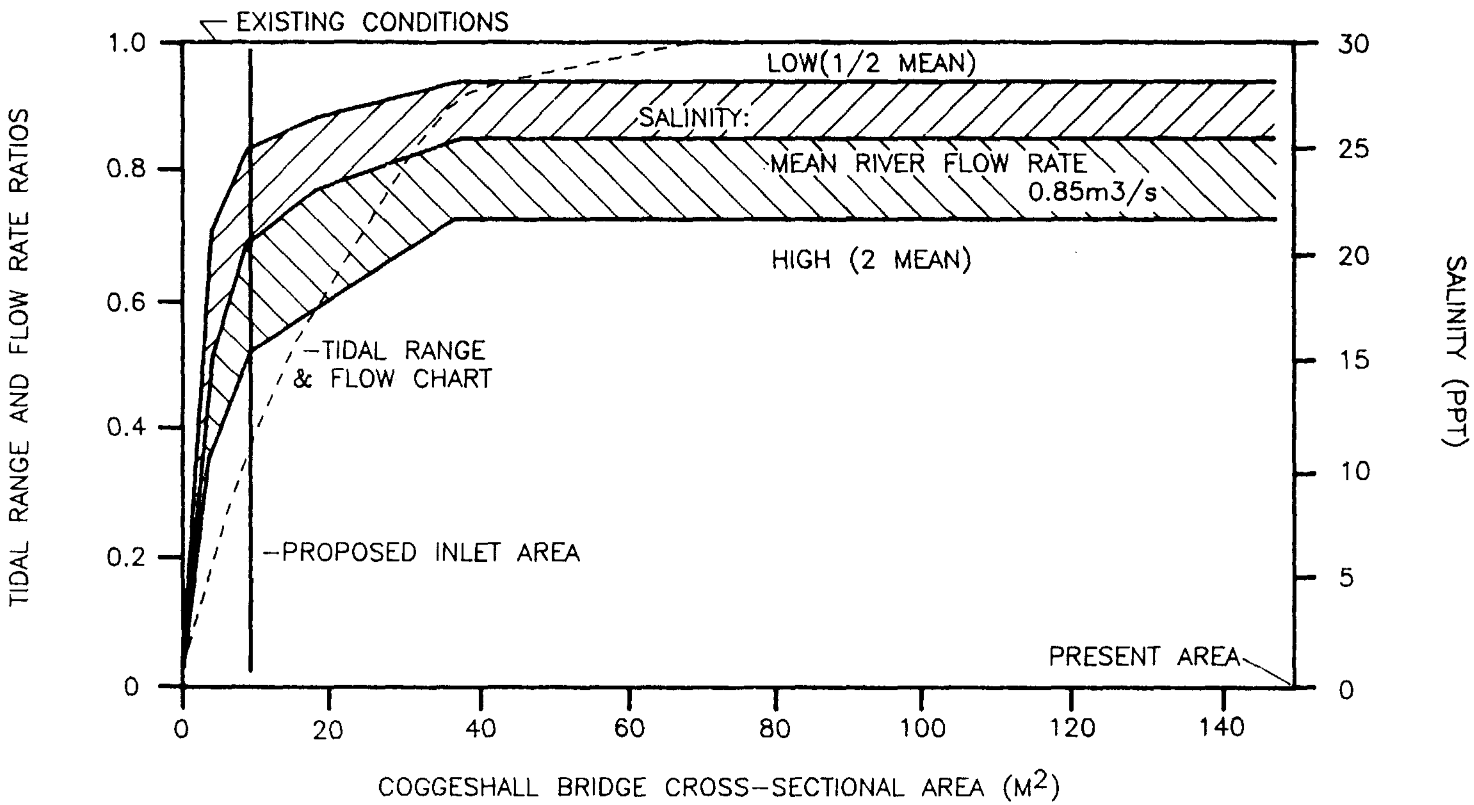


BALSAM ENVIRONMENTAL CONSULTANTS, INC.
50 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: CONSTRUCTION SEQUENCE				
DATE: 10/13/89	DRAWN: D.J.H.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: NONE	FILE NO.: 62924	APPROVED: L.C.S.	FIGURE NO.: 4.1	PROJECT NO.: 6292.05


NOTES:
1. AREA 1 CLOSED TO ALL FISHING ACTIVITIES.
2. AREA 2 CLOSED TO THE TAKING OF LOBSTERS, EELS, FLOUNDERS, SCUP, AND TAUTOG
3. AREA 3 CLOSED TO LOBSTERING ONLY.
4. SEWAGE CLOSURE AREA CLOSED TO ALL SHELL FISHING.
ACUSHNET
FAIRHAVEN
NEW BEDFORD
1
OUTER HARBOR
2
SCONTICUT NECK
DARTMOUTH
CLARKS COVE
CLARKS POINT
RICKERSONS POINT
WILBUR POINT
ROCKY POINT
3
SMITH NECK
MISHAUM POINT
LEGEND
PCB CLOSURE AREA LIMITS
SEWAGE CLOSURE AREA LIMITS
SOURCE: MASSACHUSETTS OFFICE OF COASTAL ZONE MANAGEMENT
BALSAM
ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079
CLIENT: AVX CORPORATION
TITLE: FISHING CLOSURE AREAS
DATE: 9/22/89
DRAWN: D.J.H.
CHECKED: L.C.S.
PROJECT: NEW BEDFORD HARBOR
SCALE: NONE
FILE NO: 629236
APPROVED: L.C.S.
FIGURE NO: 5.1
PROJECT NO: 6292.05

IMPACT OF COGGESHALL INLET MODIFICATIONS ON SALINITY, TIDAL RANGE,. AND FLOW CHART OF UPPER NEW BEDFORD ESTUARY

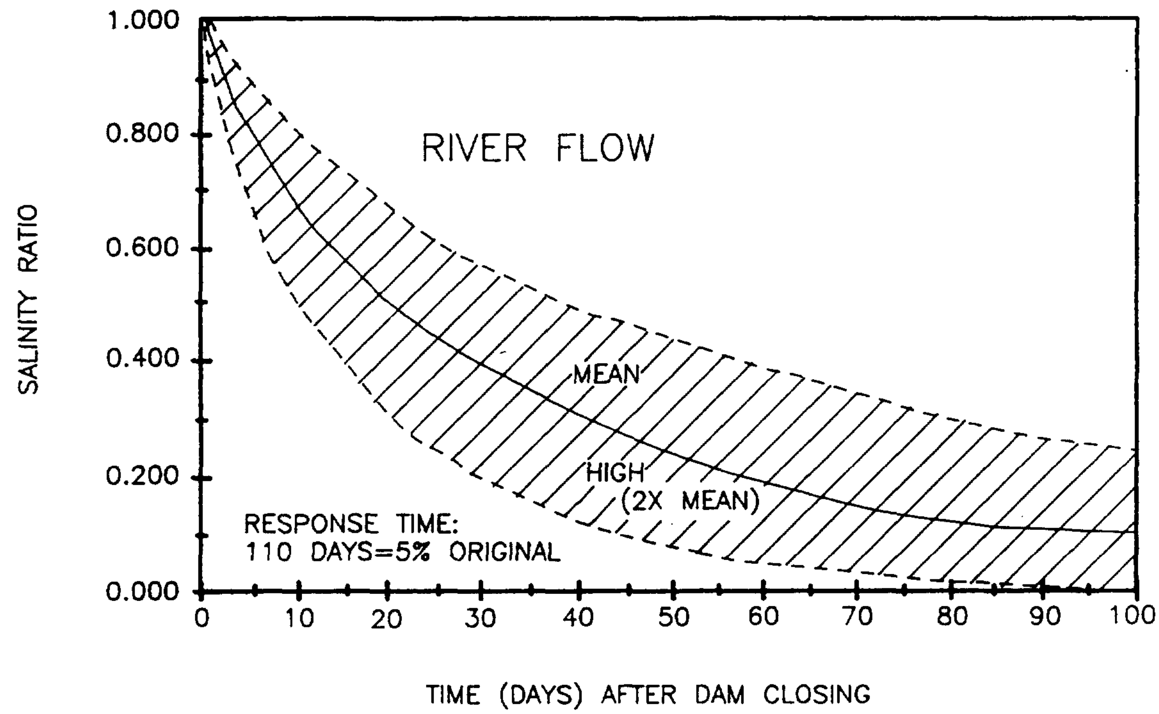


TIDAL RANGE AND DISCHARGE, AND SALINITY VERSUS CROSS-SECTIONAL AREA OF COGGESHALL ST. BRIDGE CHANNEL.

SOURCE: ASA, 1988

BALSAM ENVIRONMENTAL CONSULTANTS, INC. 59 STILES RD. SALEM, N.H. 03079			CLIENT AVX CORPORATION	
			TITLE HYDRAULIC INLET IMPACTS	
DATE 10/14/89	DRAWN BY P.J.S.	CHECKED G.M.G.	PROJECT NEW BEDFORD HARBOR	
SCALE N.T.S.	FILE NO. 62929	APPROVED L.C.S.	FIGURE NO. 5.2	PROJECT NO. 6292.05

CHANGES IN SALINITY RATIO AFTER DAM CLOSING



SALINITY RATIO (NON DIMENTIONAL), (1.0=26 PPT) VERSUS TIME (DAYS) AFTER CLOSING OF COGGESHALL ST. CHANNEL. ACUSHNET RIVER FLOWS ARE LOW (ONE-HALF MEAN), MEAN (0.85 M^3/SEC) AND HIGH (TWICE MEAN).

SOURCE: ASA, 1988

BALSAM ENVIRONMENTAL CONSULTANTS, INC.
59 STILES RD. SALEM, N.H. 03079

CLIENT: AVX CORPORATION				
TITLE: CHANGES IN SALINITY RATIO AFTER DAM CLOSING				
DATE: 10/14/89	DRAWN: P.J.S.	CHECKED: G.M.G.	PROJECT: NEW BEDFORD HARBOR	
SCALE: N.T.S.	FILE NO: 629210	APPROVED: L.C.S.	FIGURE NO: 5.3	PROJECT NO: 6292.05