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Assessment of Contaminant Loss and Sizing for Proposed Upper Harbor Confined Aquatic Disposal (CAD) Cell

New Bedford Harbor Superfund Site Massachusetts

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Preface

This report describes the modeling and assessment of the upper New Bedford Harbor CAD cell for sizing and contaminant loss, using composite sediment characteristics from testing reported in Assessment of Contaminant Loss and Sizing for Proposed Lower Harbor Confined Aquatic Disposal (CAD) Cell (Schroeder et al. 2010) for DMU composites 1, 2 and 3 from MUs 1 to 24. The design of the upper New Bedford Harbor CAD cell was based on the design presented by Apex and Jacobs (2006), but its footprint was reduced based on the ongoing annual dredging and upland disposal which has decreased the volume of dredged material and the predicted consolidation which will occur in the CAD cell. Two scenarios provided by EPA Region 1 were modeled: 5 years of mechanical dredging and placement by a small bottom dump split hull barge followed by installation of a 3-ft sand cap, and 10 years of mechanical dredging and placement by a small bottom dump split hull barge followed by installation of a 3-ft sand cap. In addition, two controls specified by EPA Region 1 to reduce the transport of suspended sediment during dredged material placement were examined: a silt curtain and a sheet pile wall enclosing 90 to 95 percent of the perimeter of the CAD cell. Consolidation modeling for sizing, dredged material placement, and contaminant fate and transport modeling for contaminant loss were performed by ERDC EL. Hydrodynamic modeling of the tidal exchange and mixing within the CAD cell was modeled using a 3D version of EFDC with a high resolution grid by ERDC CHL. The EPA Remedial Project Managers were Mr. Dave Dickerson and Ms. Elaine T. Stanley of EPA Region 1. The USACE project managers were Mr. Mark J. Anderson, Jr. and Mr. Peter Hugh of the New England District.

Dr. Paul R. Schroeder, Ms. Susan E. Bailey and Dr. Thomas J. Fredette of the Environmental Engineering Branch (EP-E), Environmental Processes and Engineering Division (EPED), EL; Dr. Carlos E. Ruiz of the Water Quality and Contaminant Modeling Branch (EP-W), EPED, EL; and Dr. Earl Hayter of the Coastal Processes Branch, Flood and Storm Protection Division, Coastal and Hydraulics Laboratory wrote this report.

This study was conducted under the direct supervision of Mr. W. Andy Martin, Chief of EP-E, and under the general supervision of Mr. Warren Lorentz, Chief of EPED, Dr. Beth Fleming, Director of EL, Dr. Jeffery P. Holland, Director of ERDC, and Col. Kevin J. Wilson, EN, Commander of ERDC.

Abstract

EPA Region 1 is evaluating the use of CAD cells as a sediment management alternative for PCB and copper contaminated sediments at the New Bedford Harbor Superfund Site (NBHSS). This report provides EPA with short- and long-term modeling results on estimated contaminant losses and physical sediment behavior during and after filling of a potential upper harbor CAD cell (UHCC) based on either a 5-year dredging schedule or a 10-year dredging schedule. This report also provides verification of CAD cell size for containment of the contaminated sediment and capping materials. The report also evaluates the use of either silt curtains or sheet pile walls surrounding the CAD cell to reduce transport of suspended sediments generated during the disposal process.

The sizing evaluation determined the surficial footprint of the CAD cell required to contain the sediment and capping material considering the side slope requirements, depth to bedrock, the potential for bulking during dredged material placement, and the potential spreading of the dredged material from its kinetic energy during its collapse in the CAD cell following placement. The contaminant loss evaluation included both short-term losses (prior to capping) and long-term losses (following capping). Short-term losses include displacement of CAD cell water contaminated by resuspension and stripping of dredged material during placement, consolidation of the dredged material, diffusion from the exposed dredged material, diffusion of contaminants to the upper water column from the contaminated CAD cell water, and mixing of the contaminated CAD cell water with the upper water column by turbulent diffusion and thermally induced overturning. Long-term losses include the diffusive flux of contaminants and the advective flux of contaminants from the expulsion of contaminated pore water from consolidation of the dredged material induced by the pressure load of the thick deposit of dredged material and capping material in the CAD cell, as well as entrainment of water in the dredged material during placement.

A 570 ft x 730 ft x 52 ft CAD cell is sufficiently large to contain 352,000 cubic yards of sediment and 38,000 cubic yards of capping materials plus the potential bulking during dredging and placement. About 2.4 ft, or 10%, bulking is expected, but this volume of bulking will be recovered (i.e., reduced to initial volume) along with another 4 to 5 ft within both the proposed five and ten years of placement operations by consolidation of the deeper CAD cell sediment. About 6 to 7 ft of additional consolidation is expected within the first forty years after capping, and as much as 9 ft in the long term beyond 40 years after capping as predicted using the U.S. Army Corps of Engineers (USACE) Primary Consolidation, Secondary Compression and Desiccation of Dredged Fill (PSDDF) model (a total of 15-16 ft post-capping).

Short-term contaminant losses to the water column above the CAD cell resulting from placement operations are predicted to be about 0.087% of the total PCB mass and 0.044% of the total copper mass placed in the CAD cell for the 5-year operations schedule, and about 0.139% of the total PCB mass and 0.062% of the total copper mass placed in the CAD cell for the 10-year

schedule, when nearly fully enclosed by a sheet pile wall. The PCB losses using a 10-year schedule are predicted to be 55% greater than using a 5-year schedule, while copper losses are predicted to 35% greater. When silt curtains are used as the enclosure instead of a sheet pile wall, the total PCB losses are predicted to be about 22% greater and the total copper losses are predicted to be about 66% greater. The difference in losses between the silt curtains and sheet pile walls are comparable to the difference in losses between a 5-year schedule and a 10-year schedule.

Resuspension and stripping of dredged material during placement will increase the dissolved contaminant concentrations in the CAD cell water to be approximately equal to the existing in-situ sediment pore water contaminant concentrations. The losses were predicted using the USACE STFATE model (Short-Term FATE of dredged material placed in open water) to predict sediment resuspension, a contaminant partitioning spreadsheet model to compute dissolved contaminant concentrations, and the USACE RECOVERY model to predict losses by diffusion.

Capping with a 3-ft sand layer is sufficient to provide long-term isolation of the contaminants in the dredged sediment from the water column. After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap. Without consideration of burial (covered by sediment deposited over time), contaminant breakthrough of the cap at a concentration of 0.01% of the pore water contaminant concentration (e.g., 0.01% of 16 ppb PCB or 0.0016 ppb PCB) as predicted by the USACE RECOVERY model will not occur for total PCBs. However, the individual Aroclor PCB 1242 was predicted to reach breakthrough (0.00137 ppb) at 6700 years, but only for the 5-year placement scenario. Breakthrough of copper at 0.006 ppb will occur at approximately 820 years. With burial promoted by the dredged material settlement, the low-level transport of contaminants through the cap and burial material will take tens of thousands of years.

1 — Executive Summary

Objectives

This work is an evaluation of a proposed CAD cell in upper New Bedford Harbor (shown in Figure 1) using the same modeling approach performed by ERDC on a proposed CAD cell in Lower New Bedford Harbor (Schroeder et al. 2010). Sediments in the upper harbor are more contaminated than those in the lower harbor and water depths are shallower, necessitating additional evaluations for a potential upper harbor CAD cell (UHCC) shown in Figures 2, 3, and 4. The work (1) confirms the CAD cell size/capacity by consolidation modeling, (2) predicts short-term contaminant loss by open water placement/surge modeling, hydrodynamic modeling, and contaminant partitioning, (3) predicts potential losses between dredging seasons, (4) predicts long-term contaminant loss following capping, (5) predicts the time to achieve contaminant breakthrough, and (6) predicts the contaminant flux concentrations at breakthrough.

Containment includes not only storage of the deposited dredged material and capping materials, but also capture of the bulk of the stripped or suspended materials during placement and the dynamic spreading of the dredged material from the kinetic energy of the discharge during its collapse in the CAD cell. Contaminant losses during placement includes (1) the partitioning of contaminants to the water column from stripped or suspended dredged material during placement, (2) discharge of pore water from the settled dredged material by consolidation (considering the entrainment of water in the dredged material during placement), (3) diffusion of contaminants from the dredged material and through the cap, and (4) the exchange of water in the CAD cell with the overlying water column. Modeling scenarios evaluated both 10-year placement and 5-year placement schedules to evaluate a range of potential budget possibilities. Additionally, two containment options for controlling mixing and water exchange within the CAD cell were considered: sheet pile walls and silt curtains.

Modeling

The contaminant partitioning data were based on the partitioning findings for the 2009 ERDC sediment composites 1 through 3 reported in the Lower Harbor CAD Cell report (Schroeder et al. 2010). Likewise the consolidation data were based on the consolidation findings for the 2009 ERDC sediment composites 1 through 3 provided by Jacobs Engineering (2009) and analyzed in the Lower Harbor CAD Cell report (Schroeder et al. 2010).

Sizing and Filling

Several modeling tasks were conducted to analyze the CAD filling, sizing and contaminant losses. A cut and fill spreadsheet analysis was perform to determine the size of CAD cell needed to contain the proposed volume of dredged material and to estimate the lift thicknesses of the annual fills for consolidation analysis. A 570’ x 730’ surface footprint was selected with a side slope of 1V:6H for the top 8 ft of depth and 1V:3H for the remaining 44 ft of depth below the existing sediment surface.

Consolidation

The consolidation of the dredged material was analyzed using the USACE PSDDF model. The PSDDF model results showed that the CAD cell size was appropriate to contain the proposed volume of dredged material, considering the entrainment of water in the dredged material, the volume of capping material, spreading of dredged material from the placement dynamics, suspended solids retention, and consolidation prior to capping. The consolidation results were analyzed to determine the predicted pore water expulsion rates for contaminant loss predictions both prior to and after capping.

The CAD sizing analysis showed that the upper harbor CAD cell would be filled with 51.2 ft of dredged material based on its in situ density. Analysis of potential water entrainment in the dredged material during both dredging and placement through the water column actually predicted no bulking; however, a conservative bulking factor of 10% was assumed. This would result in placement of 53.7 ft of dredged material and 3 ft of capping material, a total of 56.7 ft of material in our cell that is 52 ft deep. However, the PSDDF model predicted that 6.0 ft (5-year) or 7.4 ft (10-year) of pore water would be expelled from the placed dredged material prior to capping, two to three times as much water as predicted to be entrained during dredging and placement through the water column (mostly at depth from the first lift placed). Therefore, the depth of fill immediately after capping is 50.7 or 49.3 ft for the 5- and 10-year scenarios, providing a freeboard of 1.3 or 2.7 ft, respectively. After capping, an additional 3.9 or 2.8 ft of pore water is predicted to be expelled in the first 10 years, 5.6 or 4.5 ft of pore water in the first 20 years and 6.9 or 5.6 ft of pore water in the first 40 years. At 40 years, the dredged material is predicted to be nearly 70% consolidated. Up to 9 ft of additional consolidation is expected beyond 40 years (a total of 15-16 ft post-capping). Based on the PSDDF model results, much of the contaminant losses would be expected to occur during placement and prior to capping.

Placement

The open water placement of dredged material in the upper harbor CAD cell was modeled using the STFATE model to predict the entrainment of water in the deposited dredged material, the mass of dredged material suspended in the water column, the suspended solids concentration in the water column, the settling time, and the vertical and lateral distribution of suspended solids following a barge discharge of dredged material. STFATE model runs were conducted on 200-cubic yard barge discharges at the beginning and end of each dredging season to simulate the range of placement impacts for each dredging season and to estimate annual contaminant losses during placement. Suspended solids losses between the beginning and end runs were assumed to exhibit a linear response based on past experience with the model.

The STFATE model results show that about 2 to 6% of the fine-grained fraction of the dredged material remains in suspension about 3 to 4 hours after the barge discharge and disperses in the CAD cell water below the loaded draft depth of the barge, resulting in average total suspended solids (TSS) concentrations ranging from about 14 mg/L for the first season to 54 mg/L for the fifth season for the 5-year dredging plan, or 13 mg/L to 38 mg/L for the 10-year plan. The upper 10 ft of the CAD cell water, which is potentially exchangeable with the overlying water column based on higher resolution hydrodynamic modeling of the CAD cell with silt curtains and its surrounding area, is predicted to have average TSS concentrations of about 5 mg/L until the end of the last dredging season when the TSS may be as high as 76 mg/L. In a shallow saline environment such as New Bedford Harbor and the CAD cell, the TSS concentration will typically decrease to 50 mg/L within a day and to 10 mg/L within a week (NOTE: see results of field plume surveys in Section 4).

Surge dynamics of disposal into the upper harbor CAD cell were evaluated in comparison to earlier modeling efforts for the lower harbor CAD cell. The discharge plume collapse dynamics were modeled for the lower harbor CAD cell (Schroeder et al. 2010) using the USACE SURGE model to examine whether the momentum of the discharged material was sufficient to cause the dredged material to run up the side slope and out of the CAD cell. All discharges were assumed to be within the area of the level bottom, a 326-ft square, and no closer than 160 ft horizontally from the lip of the CAD cell. The dynamics were examined for sediment composites 3, 4, and 5 across the range of water depths that would exist during their placement. In all cases, the discharged material was not predicted to run up the slope above a depth of about 11 ft below the lip or about 55 ft horizontally from the lip because the difference between the elevation of the bottom of the loaded discharge barge and the elevation of the lip of the CAD cell yields insufficient potential energy to overcome the frictional and gravitational losses. Since the depth of water at the upper harbor CAD cell is even shallower than at the site of the lower harbor CAD cell, the upper harbor CAD cell is also expected to be capable of confining the dredged material during placement.

Short-Term Partitioning and Contaminant Loss

The contaminants associated with the TSS will partition with the CAD cell water. It is unlikely that the partitioning reaches equilibrium before the particles interact with particles from subsequent discharges, flocculate, and settle. The kinetics of PCB desorption in a stagnant water column is sufficiently slow that it may take weeks to reach equilibrium; however, 10 to 20% of the PCB may desorb in the first day. The partitioning of contaminants to the CAD cell water over the large number of discharges in a dredging season is predicted to be sufficient to achieve a contaminant concentration in the CAD cell water approximately equal to the pore water concentration of the sediment or dredged material, regardless of the number of dredging seasons or the type of enclosure method employed.

Short-term losses include all of the losses from placement of dredged material in the CAD cell prior to and during capping of the cell. These losses result from a number of processes including entrainment of upper CAD cell water into the flow over the CAD cell, displacement of CAD cell water by the placement of dredged material, vertical turbulent diffusion, and thermal overturn.

Entrainment. Entrainment exchanges water from the flow over the CAD cell with a portion of the CAD cell contaminated by the stripped or suspended solids of the dredged material placement. The quantity of entrainment is a function of the enclosure method and its ability to control velocities. The total entrainment loss is a function of the water exchange rate, the solids concentration in the water just below the lip of the CAD cell, the contaminant concentration associated with the solids in suspension, the duration of the placement season (placement rate), and the number of placement seasons. The solids concentration in suspension increases as the storage capacity is depleted; therefore the losses of solids increase from one placement season to the next, particularly in the last placement season.

High resolution hydrodynamic modeling of the CAD cell environ using the 3-D Environmental Fluid Dynamic Code (EFDC) model set up for NBHSS sediment transport modeling was performed to quantify the entrainment exchange rates and vertical turbulent diffusion. The hydrodynamic modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.1 fps. The tidally induced velocities are sufficiently great to exchange the water above the CAD cell, typically in six to twelve hours; however, the velocity is sufficiently low to limit any mixing below the lip of the CAD cell water, mostly in the top few feet below the lip. The differences in the hydrodynamics between enclosing the CAD cell with a silt curtain and with a sheet pile wall are predicted to be small because the CAD cell is located within a cove where the currents are predominantly tidally driven. However, under peak mixing conditions during the tidal cycle, the upward velocities in the CAD cell are sufficient to overcome the settling velocity of flocs in the top six feet of the CAD cell and entrain a fraction of the suspended solids into the overlying flow when a silt curtain is used, while this mixing is limited to the top three feet when a sheet pile wall is used. Additionally, the hydrodynamic modeling showed the potential to set up a slow vertical eddy in the CAD cell that could provide slow vertical turbulent diffusion to a depth of 10 feet below the lip of the CAD cell. Therefore, dissolved contaminants in the top ten feet of the CAD cell were subjected to turbulent dispersion and exchange with the water column above the lip of the CAD cell at the end of each dredging season in addition to the daily entrainment during the dredging season. The 0.1-fps current speed from the hydrodynamic modeling was somewhat greater than, but similar to, currents measured during 2009 CAD cell field monitoring inside a deployed silt curtain (Dragos 2009). On five separate monitoring events, currents inside the silt curtain were less than 0.07 fps while observed currents west and east of the CAD were up to 1.0 and 0.5 fps, respectively.

The annual losses due to entrainment by the flow over the CAD cell are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The overall entrainment losses are summarized in Table 9. Entrainment losses are most sensitive to the enclosure method, but are also a weak function of the length of the placement schedule. PCB losses (Aroclors 1242, 1248 and 1254) for a sheet pile wall enclosure are predicted to be 5.0 kg and 6.6 kg, respectively, for 5- and 10-year schedules, while PCB losses for a silt curtain enclosure are predicted to be 14.0 kg and 18.7 kg, respectively. Copper losses for a sheet pile wall enclosure are predicted to be 28.8 kg and 31.9 kg, respectively, for 5- and 10-year schedules, while copper losses for a silt curtain enclosure are predicted to be 81.6 kg and 90.3 kg, respectively. Entrainment accounts for 5- and 10-year schedules about 12% of the PCB losses when a sheet pile wall is used for an enclosure and 28% of the PCB losses when a silt curtain is used. Analogously, entrainment losses account on average about 36% of the copper losses when a sheet pile wall is used for an enclosure and 61% of the copper losses when a silt curtain is used. Entrainment causes a larger percent of the losses of copper because the bulk sediment copper concentration increases throughout the placement project while the bulk sediment PCB concentration decreases throughout the placement project.

Displacement. The dissolved contaminants and particulate-associated contaminants in the upper portion of the CAD cell will be lost as the CAD cell water is displaced by subsequent barge discharges. The displacement volumes are likely to be about 10 to 20% greater than the volume of sediment being dredged due to entrained water in the mechanical dredge/excavator bucket. This would amount to about 70,000 to 94,000 cubic yards per year for the 5-year dredging scenario or about 44,000 cubic yards per year for the 10-year dredging scenario. An additional 40,000 cubic yards of CAD cell water will be displaced in the final year by cap placement.

The annual losses due to displacement of the CAD cell water by the placed dredged material are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The overall displacement losses are summarized in Table 9. Displacement losses are insensitive to the enclosure method, but weakly sensitive to the storage capacity and therefore the placement schedule. Annual displacement losses are a function primarily of the annual volume placed and the annual bulk sediment concentration. The total predicted displacement losses of PCB (Aroclors 1242, 1248 and 1254) are 12.8 kg and 11.1 kg for the five or ten years of filling schedules, respectively. PCB displacement losses represent about 30% of the total losses for a 5-year placement scenario and about 17% of the total losses for a 10-year placement scenario. Annual displacement losses range from 6.0 kg in Year 1 down to 0.8 kg in Year 4 for the 5-Year scenario, and from 2.8 kg in Year 2 down to 0.35 kg in Year 7 for the 10-Year scenario. While TSS concentrations in the CAD cell tend to increase slightly from year to year throughout the dredging, PCB losses decrease throughout the dredging because dredging proceeds from the more highly contaminated (about 660 mg/kg in Composite 1) to the less contaminated (about 106 mg/kg in Composite 3) as given in Tables 1, 2, and 3. Additionally, the fraction of PCBs that are more mobile (Aroclor 1242 fraction) also decreases throughout the dredging from 65% in the first year to 44% in the last year. For the 5-year scenario, the released PCBs are about 87% Aroclor 1242 (mass loss about 0.05% of Aroclor 1242 total mass placed), 7% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 6% Aroclor 1254 (mass loss about 0.012% of Aroclor 1254 total mass placed). Similarly for the 10-year plan, released PCBs are about 86% Aroclor 1242 (mass loss about 0.04% of Aroclor 1242 total mass placed), 8% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 7% Aroclor 1254 (mass loss about 0.011% of Aroclor 1254 total mass placed). About 95% of the released PCBs are predicted to be dissolved.

The total predicted displacement losses of copper are 20.7 kg and 19.0 kg for the five or ten years of filling schedules, respectively. Copper displacement losses represent about 29% and 19% of the total losses from a sheet pile wall enclosed CAD cell for 5-year and 10-year placement scenarios, respectively. For a CAD cell enclosed by a silt curtain, copper displacement losses represent about 17% and 12% of the total losses for 5-year and 10-year placement scenarios, respectively. Annual displacement losses range from 3.2 kg in Year 1 down to 5.4 kg in Year 5 for the 5-Year scenario, and from 1.5 kg in Year 1 down to 2.8 kg in Year 10 for the 10-Year scenario. The copper displacement losses represent about 0.012 % of the total mass of copper removed from the associated dredging for the 5-Year scenario, with about 83% of the released copper predicted to be dissolved.

Turbulent Diffusion. Contaminant losses from the CAD cell after placement of the annual lift is driven by turbulent diffusion from the upper ten feet below the lip of the CAD cell to the upper exchangeable water column. The annual loss of contaminants by turbulent diffusion from the lower water column is predicted to be limited to about the top 106,600 cubic yards (10 feet) of contaminated CAD cell water after the annual placement operation ceases. These losses are expected to be largely independent of the enclosure method and are predicted to be nearly all in dissolved form because the TSS concentrations should decrease rapidly by settling each year after disposal operations cease. Because the CAD cell water becomes as contaminated as the sediment pore water, loss of contaminants from the CAD cell water by turbulent diffusion are comparable to the contaminant losses by displacement during dredged material placement. The annual losses due to turbulent diffusion of the CAD cell water are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The total turbulent diffusion losses are summarized in Table 9. Turbulent diffusion losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The total predicted turbulent diffusion losses of PCB (Aroclors 1242, 1248 and 1254) are 10.4 kg and 22.4 kg for the five or ten years of filling schedules, respectively. PCB turbulent diffusion losses represent about 25% of the total losses for a 5-year placement scenario and about 34% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 9.2 kg and 23.1 kg for the five or ten years of filling schedules, respectively. Copper turbulent diffusion losses represent about 10% of the total losses for a 5-year placement scenario and about 19% of the total losses for a 10-year placement scenario.

Thermal Overturn. An additional potential loss of contaminants independent of the enclosure method is the exchange of CAD cell water in the fall or winter by the cold dense water diving into the CAD cell and thermally overturning the contaminated CAD cell water and subjecting the contaminated water to flow from the CAD site. However, due to the shallow depth of the overlying water column and the mixing that would occur, this mechanism is likely to limit the exchange to no more than 5 feet of water or 65,500 cubic yards in the CAD cell. Any losses between dredging seasons would be partially offset by decreasing the predicted losses during the next dredging season because the initial contaminant concentration in the CAD cell water at the start of the next dredging season would be lower.

The annual losses due to thermal overturn of the CAD cell water are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The total thermal overturn losses are summarized in Table 9. Thermal overturn losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The total predicted thermal overturn losses of PCB (Aroclors 1242, 1248 and 1254) are 10.2 kg and 20.2 kg for the five or ten years of filling schedules, respectively. PCB thermal overturn losses represent about 24% of the total losses for a 5-year placement scenario and about 31% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 12.6 kg and 26.6 kg for the five or ten years of filling schedules, respectively. Copper turbulent diffusion losses represent about 14% of the total losses for a 5-year placement scenario and about 22% of the total losses for a 10-year placement scenario.

Total Short-term Losses. Table 10 presents the overall potential contaminant losses resulting from placement for the four scenarios modeled. For a CAD cell nearly fully enclosed in a sheet pile wall using a 5-year dredging plan, the total predicted losses are 38.3 kg PCB and 71.2 kg copper. For the 10-year sheet pile enclosure scenario, the total losses are 60.4 kg PCB and 100.6 kg copper. For the 5-year plan, these losses represent 0.087% of the mass of the three PCB Aroclors placed in the CAD cell (0.136% of Aroclor 1242, 0.026% of Aroclor 1248 and 0.039% of Aroclor 1254), and 0.044% of the copper placed in the CAD cell. For the 10-year plan, the losses represent 0.14% of the three PCB Aroclors (0.22% of Aroclor 1242, 0.038% of Aroclor 1248 and 0.062% of Aroclor 1254), and 0.062% of the copper placed in the CAD cell. The PCB losses using a 10-year schedule are predicted to be 55% greater than using a 5-year schedule, while copper losses are predicted to 35% greater. When silt curtains are used as the enclosure instead of a sheet pile wall, the total PCB losses are predicted to be about 22% greater and the total copper losses are predicted to be about 66% greater. The difference in losses between the silt curtains and sheet pile walls are comparable to the difference in losses between a 5-year schedule and a 10-year schedule. The PCB mass loss rates are more than an order of magnitude lower than reported PCB losses from dredging operations at other Superfund sites.

Long-Term Contaminant Loss from Capped CAD Cell

The contaminant fate and transport from the capped CAD cell were evaluated in two parts. The first part was evaluated during the period of dredged material consolidation based on partitioning and contaminant transport associated with pore water advection induced by consolidation. In the center section, sixty-six percent or seventy-four percent of the consolidation for the five and ten year dredging scenarios is completed 40 years after capping, but meaningful contaminant transport by pore water expulsion is limited to the first two to four years. The second part was evaluated for the long term, after significant pore water advection ceases. During the long term, contaminant transport is dominated by diffusion of contaminants from the dredged material and into the sand cap. Long-term contaminant fate and transport from the capped CAD cell was modeled without considering contaminant degradation or transformation using the USACE RECOVERY model. In reality, contaminant degradation and transformation can be expected to occur over the long-term and therefore losses are likely to be lower than predicted.

Contaminant fluxes associated with the advection of water resulting from dredged material consolidation were estimated for a 52-ft deep UHCC using a spreadsheet based on CAP modeling results for the LHCC (Schroeder et al. 2010). The contaminant concentration associated with the sand capping material in equilibrium with the surficial dredged material pore water was calculated. Then, the thickness of the sand cap contaminated by the mass of contaminants in the expelled pore water during the initial forty years of consolidation was computed for each contaminant of concern. The CAD pit will expel water only upward for the four cell sections as the native harbor bottom sediments forming the walls of the CAD have very low porosity relative to the dredged sediment and therefore the native sediments will resist flow of pore water. The results showed that the contaminants transported from the dredged material by pore water advection and diffusion would be contained in the bottom of the cap. This is true for all sections of the cap, even in the center section, which had the largest settlement. The contaminant and sediment profiles from the end of the advection dominated period (up to 5 years when advection is greater than 10 cm/yr) were used as the initial conditions for the long-term, diffusion dominated modeling using the RECOVERY model.

The RECOVERY model was used to compute contaminant concentrations in the cap as a function of time and to predict the time required for breakthrough of the contaminants for three of the four separate sections of the CAD cell due to differences in dredged material thickness and predicted settlement. Each section represents about one quarter of the area of the CAD cell, with the center section being 17.5% of the area and rings 1, 2 and 3 being 25%, 29%, and 28.5% of the area, respectively. The first section represents the center of the CAD cell and includes the entire part of the cell that has a level bottom. The next three sections are concentric bands around the center covering the remainder of the sloped area of the CAD cell. Each band has successively thinner dredged material thicknesses and smaller settlements. Contaminant breakthrough, as applied here, is based on a limiting contaminant flux of surficial pore water concentration that might start to pose a meaningful risk to receptors; in this case, a relative flux or concentration of 0.01% of the original flux or in-situ pore water concentration of the sediment was used to define breakthrough. The RECOVERY model showed that the most mobile of the contaminants in the cap was copper, followed by PCB Aroclors 1242, 1248 and 1254. Contaminant breakthrough through the 3-foot cap by copper at a concentration of 0.006 ppb is predicted to occur only after 820 years of diffusion. The peak concentration in copper is predicted to be 0.07% of its initial concentration (about 0.028 to 0.038 ppb) and occurs at 2200 years. Breakthrough for Aroclor 1242, a pore water concentration of 0.00137 ppb in the surficial layer of the cap, was predicted to occur only for the 5-year schedule, occurring at 6700 years, just before reaching its peak concentration of 0.00139 ppb at 7100 years. Pore water concentrations Aroclors 1248 and 1254 in the surficial layer of the cap peaked at about 17,000 and 15,000 years, respectively, with concentrations on the order of 10^{-15} and 10^{-9} ppb, and therefore did not reach the breakthrough concentrations of 0.0001 ppb PCB Aroclor 1248 and 0.00012 ppb PCB Aroclor 1254. The model shows that a stable 3-foot cap is highly effective in isolating the contaminated dredged material. Since about 14 to 16 ft of settlement is predicted for the center section of the CAD cell, there is a very large potential for at least 14 to 16 ft of burial over the life of the CAD cell. If this burial were considered in the long-term fate and transport modeling, the CAD cell would be effective for all contaminants for tens of thousands of years. In reality, the contaminant concentrations in the bioactive zone will be controlled by the deposition of surrounding contaminated materials onto the cap, and not by contaminant migration by the buried dredged material.

Conclusions

1. The proposed 570-foot by 730-foot rectangular CAD cell excavated 52 ft below the existing sediment surface is sufficient in size to hold the sediments and cap proposed for an upper harbor CAD cell and to contain the lateral spread and collapse of the dredged material discharge during placement.

2. About 2.4 ft of water will be entrained in the dredged material during placement, but all of this water along with 4 to 5 ft of pore water is predicted to be expelled from the consolidating dredged material during the five or ten years of placement.

3. An additional 5.5 to 7 ft of settlement and pore water expulsion is predicted to occur within 40 years after cap placement. Up to 9 ft of additional consolidation is expected beyond 40 years.

4. Dredged material resuspension will occur during placement, resulting in predicted average TSS concentrations ranging from 14 to 54 mg/L for the 5-year scenario and 13 to 38 mg/L for the 10-year scenario, and both dissolved and particulate-associated contaminant release to the water column overlying the CAD cell. The TSS concentrations just below the lip of the CAD cell are predicted to be about 5 mg/L except during the last year of placement when it will increase to about an average of 40 mg/L.

5. The resuspension predictions appear to be a reasonable and conservative representation of the behavior of actual plumes observed during similar dredged material placement in a City of New Bedford CAD cell in 2009.

6. Hydrodynamic modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.1 fps when enclosed in a silt curtain and less than 0.05 fps when enclosed in a sheet pile walls. The velocity is sufficiently great to exchange the water above the CAD cell, typically in three to six hours when enclosed in a silt curtain and in twelve to twenty-four hours when enclosed in a sheet pile walls.

7. The predicted velocities in the CAD cells are sufficiently low to limit mixing below the lip of the CAD cell water, mostly in the top few feet. However, higher resolution hydrodynamic modeling of the CAD cell environ performed using the 3-D EFDC model set up for sediment transport modeling showed the potential to set up a slow vertical eddy in the CAD cell. The eddy could provide slow mixing to a depth of 10 feet below the lip of the CAD cell. The upward currents in the eddy exceed the settling velocities of the suspended solids in only a small fraction of the area, over a shallow depth and only for a small fraction of the time. The extent of the area, depth and time are a function of the enclosure. With a sheet pile wall, the area is about 10%, the depth is about 3 feet, and the time is 13%, while with a silt curtain, the area is about 15%, the depth is about 6 feet, and the time is 20%. The differential velocities between settling and upflow are 0.1 mm/sec or less for the sheet pile wall enclosure and 0.5 mm/sec or less for the silt curtain enclosure. Therefore, use of silt curtains rather than a sheet pile wall would potentially cause up to ten times as much loss of suspended solids and their associated contaminants, but the loss of suspended solids is restricted to the supply of suspended solids by turbulent diffusion of the discharge plume at the bottom of the CAD cell. The difference in flow through velocity for the two enclosures would yield an increase in suspended solids supply by a factor of two to three.

8. The slow vertical eddy in the CAD cell with either enclosure was predicted to provide slow mixing to a depth of 10 feet below the lip of the CAD cell. Therefore, dissolved contaminants in the top ten feet of the CAD cell were subjected to turbulent diffusion and exchange with the water column above the lip of the CAD cell.

9. Dissolved contaminant concentrations in the CAD cell water (but not the overlying water) during filling will become approximately equal to the sediment pore water being placed in the CAD cell.

10. Short-term contaminant losses were predicted for four mechanisms: entrainment by overlying flow, displacement by placed material, post-placement turbulent diffusion, and thermal

overturn. All four mechanisms contribute significantly to PCB losses but their relative contributions are dependent on the placement scenario.

11. PCB entrainment losses (Aroclors 1242, 1248 and 1254) for a sheet pile wall enclosure are predicted to be 5.0 kg and 6.6 kg, respectively, for 5- and 10-year schedules, while PCB losses for a silt curtain enclosure are predicted to be 14.0 kg and 18.7 kg, respectively. Copper entrainment losses for a sheet pile wall enclosure are predicted to be 28.8 kg and 31.9 kg, respectively, for 5- and 10-year schedules, while copper losses for a silt curtain enclosure are predicted to be 81.6 kg and 90.3 kg, respectively.

12. The total predicted displacement losses of PCB (Aroclors 1242, 1248 and 1254) are 12.8 kg and 11.1 kg for the five or ten years of filling schedules, respectively. For the 5-year scenario, the released PCBs are about 87% Aroclor 1242 (mass loss about 0.05% of Aroclor 1242 total mass placed), 7% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 6% Aroclor 1254 (mass loss about 0.012% of Aroclor 1254 total mass placed). Similarly for the 10-year plan, released PCBs are about 86% Aroclor 1242 (mass loss about 0.04% of Aroclor 1242 total mass placed), 8% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 7% Aroclor 1254 (mass loss about 0.011% of Aroclor 1254 total mass placed). About 95% of the released PCBs are predicted to be dissolved. The total predicted displacement losses of copper are 20.7 kg and 19.0 kg for the five or ten years of filling schedules, respectively. Copper displacement losses represent about 29% and 19% of the total losses from a sheet pile wall enclosed CAD cell for 5-year and 10-year placement scenarios, respectively. For a CAD cell enclosed by a silt curtain, copper displacement losses represent about 17% and 12% of the total losses for 5-year and 10-year placement scenarios, respectively.

13. Contaminant losses from the CAD cell after placement of the annual lift is driven by turbulent diffusion from the upper ten feet below the lip of the CAD cell (the top 106,600 cubic yards) to the upper exchangeable water column. Turbulent diffusion losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The total predicted turbulent diffusion losses of PCB (Aroclors 1242, 1248 and 1254) are 10.4 kg and 22.4 kg for the five or ten years of filling schedules, respectively. PCB turbulent diffusion losses represent about 25% of the total losses for a 5-year placement scenario and about 34% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 9.2 kg and 23.1 kg for the five or ten years of filling schedules, respectively.

14. An additional potential loss of contaminants independent of the enclosure method is the exchange of CAD cell water in the fall or winter by the cold dense water diving into the CAD cell and thermally overturning the contaminated CAD cell water and subjecting the contaminated water to flow from the CAD site. However, due to the shallow depth of the overlying water column and the mixing that would occur, this mechanism is likely to limit the exchange to no more than 5 feet of water or 65,500 cubic yards in the CAD cell. The total predicted thermal overturn losses of PCB (Aroclors 1242, 1248 and 1254) are 10.2 kg and 20.2 kg for the five or ten years of filling schedules, respectively. The total predicted turbulent diffusion losses of copper are 12.6 kg and 26.6 kg for the five or ten years of filling schedules, respectively.

15. For a sheet-pile enclosed CAD cell, the total losses based on all four processes for the 5-year dredging plan are predicted to be 38.3 kg PCB and 71.2 kg copper, which is 0.087% of the PCB and 0.044% of the copper mass being placed in the CAD cell. About 97% of the PCB losses and 86% of the copper losses are predicted to be dissolved. For the 10-year dredging schedule, the total losses are predicted to be 60.4 kg PCB (0.139% of mass placed) and 100.6 kg copper (0.062%). About 98% of the PCB and 90% of the copper mass loss is predicted to be dissolved.

16. For a silt curtain enclosed CAD cell, the total losses of PCBs are predicted to be 22% greater than the losses for a sheet pile wall enclosed CAD cell. Likewise, the total losses of copper from a silt curtain enclosed CAD cell are predicted to be 66% greater than the losses for a sheet pile wall enclosed CAD cell.

17. The predicted losses of PCBs from a 10-year disposal schedule are predicted to be 55% greater than the predicted losses from a 5-year disposal schedule, while the predicted losses of copper from a 10-year disposal schedule are predicted to be 35% greater than the predicted losses from a 5-year disposal schedule.

18. All combinations of schedules and enclosures have losses that are at least an order of magnitude smaller than typical mechanical dredging losses. The worst combination (silt curtain and 10-year schedule) has losses that are about twice as large as the best combination (sheet pile wall and 5-year schedule). The losses did not consider the potential losses from installation and removal of the enclosures.

19. After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap by adsorption on the capping media.

20. A stable 3-ft cap would be highly effective in isolating the contaminated dredged material. Without consideration of burial (i.e., the additional sediment deposition that will take place over time into the bowl-shaped CAD cell depression formed by consolidation after the cap is placed), copper is predicted to break through the cap in approximately 820 years, while PCB 1242 is predicted to just barely break through at 6700 years. The breakthrough PCB 1242 concentration is nearly the same as the predicted peak concentration in the cap's bioactive zone. No breakthroughs of PCB Aroclors 1248 and 1254 are predicted. Again, breakthrough, as used here, is defined as the condition when the contaminant flux or bioactive zone pore water concentration increases to levels of 0.01% of the original flux or sediment pore water contaminant concentration. With burial promoted by the estimated 14 to 16 feet of post-capping settlement, the transport of contaminants through the cap and burial material will take tens of thousands of years to achieve the breakthrough.

2 — Introduction

Background

Report Objectives

This work is an evaluation of a proposed CAD cell in upper New Bedford Harbor (shown in Figure 1) using the same modeling approach performed by ERDC on a proposed CAD cell in Lower New Bedford Harbor (Schroeder et al. 2010). Sediments in the upper harbor are more contaminated than those in the lower harbor and water depths are shallower, necessitating additional evaluations for a potential upper harbor CAD cell (UHCC) shown in Figures 2, 3 and 4. The work (1) confirms the CAD cell size/capacity by consolidation modeling, (2) predicts short-term contaminant loss by open water placement/surge modeling, hydrodynamic modeling, and contaminant partitioning, (3) predicts potential losses between dredging seasons, (4) predicts long-term contaminant loss following capping, (5) predicts the time to achieve contaminant breakthrough, and (6) predicts the contaminant flux concentration at breakthrough. The primary objective of this report is to provide EPA Region 1 with short- and long-term modeling results on estimated contaminant losses and physical sediment behavior during and after filling of a proposed CAD cell being considered as a sediment management alternative at the NBHSS. The secondary objective is to provide verification of CAD cell size for containment of the contaminated sediment and capping materials.

The quantification of contaminant losses was estimated for dredged material placement, from consolidating exposed dredged material prior to capping, and from long-term diffusion following capping after consolidation becomes insignificant. Containment includes not only capture and storage of the dredged material and capping materials, but also the bulk of the stripped or resuspended materials during placement and the dynamic spreading of the dredged material from the kinetic energy of the discharge during its collapse in the CAD cell. Contaminant losses during placement includes the partitioning of contaminants to the water column from stripped or resuspended dredged material during placement, discharge of pore water from the settled dredged material by consolidation (considering the entrainment of water in the dredged material during placement), diffusion of contaminants from the dredged material and through the cap, and the exchange of water in the CAD cell with the overlying water column.

General Setting

New Bedford Harbor, located in southeastern Massachusetts, is a relatively shallow coastal estuary (Figure 1). It is connected to Buzzards Bay to the south. The main freshwater flow enters in the north from the Acushnet River. A 9-m deep (30-ft) Federal navigation channel extends from Buzzards Bay into the harbor along with a 7.6-m deep (25-ft) anchorage and adjacent 4.6-m deep (15-ft) and 3.0-m deep (10-ft) channels, which serve the Town of Fairhaven. The harbor is home to one of the nation's largest commercial fishing fleets.

Modeling Study Background

The alternative under consideration in this report is a CAD cell in the upper harbor (Figures 2, 3, and 4). The CAD cell would be created by excavating into the natural glacial sediments in the bottom of the harbor in order to create storage and isolation for the contaminated sediments. CAD cells are already in use in New Bedford Harbor by the city (USEPA 2009) and have also been successfully used in New England in Boston, Providence, New London, Hyannis, and Norwalk (Fredette 2006). The exact footprint of the upper harbor CAD cell is yet to be determined, but consistent with the state's long-term Dredged Material Management Plan would be located between Coffin Ave. and Rt. 195 bridge, and would be sized to dispose approximately 352,000 cy of Superfund dredged material.

The material to be placed in the upper harbor CAD cell would be the remaining more highly contaminated Superfund sediments primarily located in the upper harbor. Filling of the CAD cell is anticipated to extend over five to ten years followed by capping to isolate the contaminants from the environment. An estimated 352,000 cubic yards of sediment will be placed into the UHCC. The basis of this estimate is shown below. Note this estimate assumes that MUs 25-37 would be placed in the LHCC, and the vegetated MUs would be disposed off-site:

MUs 1-24, 102-105:	532,885 cy	(FWEC, 2003)
10% additional for cleanup passes:	53,289 cy	(conservative approach)
Subtotal:	586,174 cy	
Less dredged through 2010:	- 184,370 cy	
Assumed dredging 2011 and 2012:	- 50,000 cy	(i.e., ROD Amendment 2013)
Total:	351,804 cy	

The sediment properties and bulk contaminant concentrations are reported in Tables 1 and 2 for all of the MUs. Modeling scenarios evaluated both a 10-year placement and 5-year placement schedule (given in Table 3) to evaluate a range of potential budget possibilities. Disposal will proceed from the more contaminated MUs to less contaminated MUs. Figure 5 shows PCB concentration by MU. Modeling scenarios included a UHCC enclosed by sheet pile walls and a second alternative where only a silt curtain enclosure is used to minimize potential contaminant loss during placement.

CAD Cell Design Used for Modeling

The CAD cells originally evaluated by Apex Companies had a 650' x 830' surface footprint (shown in Figure 3) and a maximum depth 52 feet deeper than the surrounding harbor floor, which has an average depth of 4 ft MLLW (Apex and Jacobs 2006). The originally proposed volume used to determine the 650’ x 830’ cell has now been decreased as a result of annual dredging and offsite placement since the 2006 report; therefore, a 570’ x 730’ surface footprint for the CAD cell was used in the modeling as shown in Figure 4. Side slopes for the top eight feet of the CAD cell were set at 1V:6H to provide stable slopes for the organic surface sediments and for the remaining 44 ft of depth the side slopes were set at 1V:3H for the glacial till and decomposed/fractured rock which can hold a steeper slope than the organic surface sediments. The CAD cell with its containment features is shown in Figure 4, showing a 200-ft opening for barge entry. Disposal into the CAD cell will be based on placement in 150 to 200 cubic yard increments from a split hull, bottom dump barge with a draft of six feet and a hopper 60 feet long. Two to four barge dumps per day was assumed. The barges were assumed to contain about 15% captured water and 85% sediment by volume. The dredged material was assumed to entrain additional water during placement from the descent through the water column and the collapse and spreading of the material on the bottom.

Study Approach

This study focuses primarily on modeling short- and long-term losses of contaminants for the upper harbor CAD cell using the existing and/or newly collected data. The models are briefly described here and greater detail on their application is provided in later sections of this report. Model descriptions for STFATE, PSDDF, and RECOVERY/CAP are based on Schroeder et al. (2004).

STFATE. The short-term fate of dredged material model (STFATE) mathematically models the physical processes determining the short-term fate of dredged material disposed at open-water sites within the first few hours after disposal.

Major Capabilities:

- Estimates receiving water concentrations of suspended solids, dredged material liquid and suspended phases, and dissolved contaminants as a function of time and location.
- Estimates the percentage of suspended solids deposited on the bottom as a function of time and location and the thickness of deposition.

SURGE. The SURGE model mathematically predicts the collapse and spread of the discharge cloud after it impacts the bottom using the mass and velocity of the discharge cloud as predicted by the STFATE model. The model is used to determine whether the energy of the discharge is sufficient for material to run up the sides of the CAD cell and out of the cell.

Major Capabilities:

- Predicts the distance that the discharge material will run up the slope, considering the kinetic energy of the discharge, change in potential energy, and frictional losses.
- Predicts deposition location by size class, considering the critical shear stress of each size class and the velocity of the collapsing cloud of discharge material.

PSDDF. The consolidation, compression, and desiccation of dredged fill (PSDDF) model provides a mathematical model to estimate the storage volume occupied by a layer or layers of dredged material in a confined disposal facility (CDF) or for underwater placement as a function of time.

Major Capabilities:

- Determines the final or ultimate thickness and elevation of multiple lifts of dredged material placed at given time intervals.
- Determines the time rate of settlement for multiple lifts and therefore the surface elevation of the dredged material fill as a function of time.
- Determines the water content, void ratio, total and effective stress, and pore pressure for multiple lifts as a function of time.

RECOVERY/CAP. The contaminant release from bottom sediments model (RECOVERY/CAP) is a screening-level model to assess the long-term impact of contaminated bottom sediments on surface waters. The model couples contaminant interaction between the water column and the bottom sediment, as well as between the contaminated and clean bottom sediments. Processes incorporated in the model are sorption, decay, volatilization, burial, resuspension, settling, bioturbation, and pore-water diffusion.

Major Capabilities:

- Allows for a rapid analysis of recovery scenarios for contaminated sediments and cap evaluations.
- Simulates behavior of organics in a real system with a limited amount of data.
- Predicts desorption of contaminants from sediments.

3 — Modeling

Data Sources

The contaminant partitioning properties used in this modeling were developed from the partitioning findings for the 2009 ERDC sediment composites 1 through 3 reported in the Lower Harbor CAD Cell report (Schroeder et al. 2010). Likewise, the consolidation properties were developed from the consolidation findings for the 2009 ERDC sediment composites 1 through 3 provided by Jacobs Engineering (2009) and analyzed in the Lower Harbor CAD Cell report (Schroeder et al. 2010).

The following data sources (reports and data bases) along with other technical reports and background information obtained at http://www.epa.gov/ne/nbh/techdocs.html were considered in the development of other modeling parameters to describe the CAD cell design, sediment properties, hydrodynamics, bathymetry and dredging operations for evaluation of the CAD cells.

Reviewed reports and data bases (supplied by the New England District) include:

1. Technical Memorandum, Preliminary CAD Cell Volume Capacity Analysis. 2006. Apex Companies and Jacob Engineering Group.

2. Draft CDF C Groundwater Model Technical Memorandum. 2001. Foster Wheeler Corp.

3. 12-Volume Engineering Feasibility Study. 1988-89. Technical Report EL-88-15, Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

4. New Bedford, Sawyer Street Quarterly Groundwater Sampling, Analytical Results, March 1992 - March 2001.

5. Quarterly Sampling at Sawyer Street CDF, October 2004-October 2006. 2006. ENSR/AECOM.

6. Overview of the New Bedford Harbor Physical/Chemical Modeling Program, April 1, 1991 (available at www.epa.gov/ne/nbh).

7. Volumes, Areas and Properties of Sediment by Management Units. 2003. Foster Wheeler report.

8. Dredged Material Management Plan (DMMP) EOEA No. 11669, Draft Environmental Impact Report (DEIR) for New Bedford and Fairhaven, Massachusetts. April 30, 2002. Prepared for Office of Coastal Zone Management, City of New Bedford, MA and Town of Fairhaven, MA. Prepared by Maguire Group Inc., Foxborough, MA.

9. New Bedford Harbor Superfund Pilot Study, Evaluation of Dredging and Dredged Material Disposal. May 1990. U.S. Army Engineer New England Division.

10. Declaration for the Record of Decision, New Bedford Harbor Superfund Site, Upper and Lower Harbor Operable Unit, New Bedford, Massachusetts. September 1998. U.S. Environmental Protection Agency - Region 1, New England.

11. Final Sediment Monitoring Summary Report 2006 Remedial Dredging, Environmental Monitoring, Sampling, and Analysis, New Bedford Harbor Superfund Site, New Bedford Harbor, MA. May 2007. Battelle for USACE New England District.

12. Battelle Sediment Data Base.

Modeling Assumptions

This report presents modeling results for the upper harbor CAD cell (UHCC). Modeling scenarios include a UHCC enclosed by sheet pile walls and a second alternative where only a silt curtain enclosure is used. Since a UHCC is only in the evaluation stage, a preliminary design was not available; therefore, a generic design was developed based on review of the existing CAD cells that have been created by the City of New Bedford and the design report for the upper harbor CAD cell (Apex and Jacobs 2006). The general location of the UHCC is shown as Upper Harbor CAD Cell Site in Figure 2. The CAD cell with its containment features is shown in Figure 4, showing a 200-ft opening for barge entry. The CAD cells originally evaluated by Apex Companies had a 650' x 830' surface footprint (shown in Figure 3) and a maximum depth 52 feet deeper than the surrounding harbor floor, which has an average depth of 4 ft MLLW (Apex and Jacobs 2006). The originally proposed volume used to determine the 650' x 830' cell has now been decreased as a result of annual dredging and offsite placement since the 2006 report; therefore, a 570' x 730' surface footprint for the CAD cell was used in the modeling as shown in Figure 4. Side slopes for the top eight feet of the CAD cell were set at 1V:6H to provide stable slopes for the organic surface sediments and for the remaining 44 ft of depth the side slopes were set at 1V:3H for the glacial till and decomposed/fractured rock which can hold a steeper slope than the organic surface sediments. Due to the sloping sides, the CAD cell was divided into 4 sections for modeling consolidation and short-term contaminant loss after capping as shown in Figure 6. Each section was modeled independently and their profiles are shown in Figures 32 through 35. The center section and Ring 1 received dredged material every dredging season while Rings 2 and 3 only received material after the CAD was filled to their bottom elevations. The thickness of a lift in the sloped ring sections was computed to be the volume of material in the lift divided by the area of the section. As there is a smaller depth of material placed in the outer rings, there is less consolidation and pore water advection, and an overall lower mass of contaminants. The center section comprises 17.5% of the area and 36% of the storage. Rings 1, 2 and 3 comprise 25%, 29% and 28.5% of the area, but 39%, 20%, and 4% of the storage, respectively.

The dredging and disposal operations were assumed to be performed by mechanical means with placement in 150 to 200 cubic yard increments from a split hull, bottom dump barge with a draft of six feet and a hopper 60 feet long. Four barge dumps per day was assumed for the 5-year placement schedule while two dumps per day for the 10-year placement schedule. A scaled schematic of the disposal operation and CAD cell is shown in Figure 7. The barges were assumed to contain about 15% captured water and 85% sediment by volume. The dredged material was assumed to entrain additional water during placement from the descent through the water column and the collapse and spreading of the material on the bottom. The quantity of water entrained is a function of the water column depth. More water will be entrained initially when the CAD cell is empty than at the end when the CAD cell is almost full because the discharge will have greater energy and time to entrain water when the CAD cell is less full. Much of the entrained water will be released during the dredging season as the placed material settles and consolidates.

The contaminant partitioning data were based on the partitioning findings for the 2009 ERDC sediment composites 1 through 3 reported in the Lower Harbor CAD Cell report (Schroeder et al. 2010). Likewise the consolidation data were based on the consolidation findings for the 2009 ERDC sediment composites 1 through 3 (Figures 8 through 10) provided by Jacobs Engineering (2009) and analyzed in the Lower Harbor CAD Cell report (Schroeder et al. 2010).

Modeling was performed using the same approaches and models as in the evaluation of the Lower Harbor CAD Cell (Schroeder et al. 2010). The filling schedule(s) for the UHCC (Table 3) was assumed to proceed from the areas represented by Composite 1 first, then Composite 2, and lastly Composite 3, for both the 5-year and 10-year dredging scenarios modeled. The modeling scenarios assumed the CAD cell is filled during each dredging season with mechanically dredged and placed material and then left idle between dredging seasons. After the last of the materials from MUs to be placed in the Upper Harbor CAD Cell is placed, the CAD cell is then left idle until the next construction season when the CAD cell is capped with unwashed sand, maintaining the content of fine-grained and organic material. Negligible new deposition on top of the CAD material from outside the CAD cell via bottom load or suspended load was assumed. Similarly, negligible erosion or resuspension of bed sediments or cap materials from the CAD cell was assumed. A limited exchange of CAD cell water was assumed between dredging seasons.

During filling, dredged material will be stripped and resuspended from the discharge, releasing both particulates with their associated contaminants and pore water with its dissolved contaminants. The pore water will also contain dissolved organic carbon (DOC) and contaminants associated with the DOC. Facilitated transport of contaminants was not specifically assumed, but the partitioning coefficients developed from the SBLT and pore water analysis include the partitioning associated with the DOC as being part of the dissolved contaminants. The particulates, while suspended, partition their contaminants with the CAD cell water. The suspended particulates slowly flocculate and then settle in the CAD cell, leaving the dissolved contaminants and DOC to accumulate in the CAD cell water. However, new particulates are introduced into the water column for each barge dump (two times per day for the 10-year placement schedule and four times per day for the 5-year placement schedule during the placement season, creating a somewhat steady suspended solids concentration that increases slowly throughout the season and then decreases in the week or two following cessation of placement operations.

The currents in the CAD cell below the top few feet are predicted to be too low to transport particulates to the surface or to resuspend bedded material. Releases from bedded dredged material are limited to pore water expulsion and diffusion. Bioturbation was assumed only in the long-term evaluation after capping. Water and contaminant exchange are assumed in the upper few feet of the CAD cell by turbulent mixing and by displacement during material placement. After material placement operations cease for the dredging/construction season, diffusion of contaminants from the lower water column to the upper water column of the CAD cell was assumed to occur.

For consolidation modeling purposes, the material placed in a dredging season was represented as a single lift at the end of the dredging season. The volume of the lift and its void ratio were estimated based on the placement operation and the characteristics of the sediment composite, incorporating the entrainment and densification that occurs during the placement season. The lift was assumed to contain the entire mass of sediment particles dredged, i.e. there were no losses of particulates.

After placement is completed and the dredged material and suspended solids have been allowed to settle and densify, a cap will be placed to close the CAD facility. The required cap thickness is dependent on the cap design objectives, accounting for bioturbation, consolidation, erosion, and operational considerations. For the purposes of this evaluation, the cap thickness was set to be 3 feet. Unwashed, natural sand was chosen for the capping material, which would typically have a small fraction of organic carbon and fines that would improve the retardation of contaminants in the cap as modeled for the Lower Harbor CAD Cell (Schroeder et al. 2010).

Modeling Results

Sizing and Filling

A cut and fill spreadsheet analysis was performed to determine the size of CAD cell needed to contain the proposed volume of dredged material and to estimate the lift thicknesses of the annual fills for consolidation analysis. The volume of the CAD cell was computed using the formula for the volume of a prismoid. To account for the notched area in the southeast corner, the volumes and area were modeled as being rectangular, with the cell length reduced to account for the area outside the notch. The volume of each foot of the prismoid was used to compute the average thickness of each lift of material in each of the four modeling sections of the CAD cell shown in Figure 6. The analysis showed that a 570’ x 730’ surface footprint for the CAD cell would be sufficient to contain the dredged material and cap for either the 5-year or 10-year dredging scenario. Additional freeboard will develop as the dredged material releases its entrained water and consolidates under the loading of the dredged material and capping material.

Consolidation

The consolidation of the dredged material after placement in the CAD cell was analyzed using the USACE PSDDF model. Due to the sloping side walls of the cell, the consolidation was analyzed in four sections as shown in Figure 6. The PSDDF model results showed that the CAD cell size was appropriate to contain the proposed volume of dredged material, considering the entrainment of water in the dredged material, the volume of capping material, spreading of dredged material from the placement dynamics, suspended solids retention, and consolidation prior to capping. The consolidation results were analyzed to determine the predicted pore water expulsion rates for contaminant loss predictions both prior to and after capping.

The CAD sizing analysis showed that the center of the upper harbor CAD cell would be filled with 51.2 ft of dredged material based on its in situ density. Analysis of potential water entrainment in the dredged material during both dredging and placement through the water column actually predicted no bulking; however, a conservative bulking factor of 10% was assumed. This would result in placement of 53.7 ft of dredged material and 3 ft of capping material, a total of 56.7 ft of material in our cell that is 52 ft deep. The annual lifts and their void ratios are given in Tables 4a and 4b. However, the PSDDF model predicted that 6.0 ft (5-year) or 7.4 ft (10-year) of pore water would be expelled from the placed dredged material prior to capping, two to three times as much water as predicted to be entrained during dredging and placement through the water column (mostly at depth from the first lift placed). The fill height of the center section as a function of time is shown in Figure 11 and the fill heights of all four sections after capping are shown in Figure 12 (Note that Time 0 in Figure 12 is after capping whereas Time 0 in Figure 11 is from the start of filling). Therefore, as shown in Figure 13, the depth of fill immediately after capping is approximately 50.7 ft or 49.3 ft for the 5- and 10-year scenarios, providing a freeboard of 1.3 ft or 2.7 ft, respectively. After capping, an additional 3.9 or 2.8 ft of pore water (5- year and 10-year scenarios, respectively) is predicted to be expelled in the first 10 years, 5.6 and 4.5 ft of pore water in the first 20 years, and 6.9 and 5.6 ft of pore water in the first 40 years. At 50 years after the start of filling, the dredged material is predicted to be 66% (5-year) or 74% (10-year) consolidated. Up to 9 ft of additional consolidation is expected beyond 40 years (a total of 15-16 ft post-capping). Based on the PSDDF model results, much of the contaminant losses would be expected to occur during placement and prior to capping.

<u>Placement</u>

The open water placement of dredged material in the UHCC was modeled using the USACE STFATE model to predict the entrainment of water in the deposited dredged material, the mass of dredged material suspended in the water column, the suspended solids concentration in the water column, the settling time, and the vertical and lateral distribution of suspended solids following a barge discharge of dredged material. STFATE model runs were conducted on 200-cubic yard barge discharges at the beginning and end of each dredging season to simulate the range of placement impacts for each dredging season and to estimate annual contaminant losses during placement. Results for placements between the beginning and end were assumed to produce results linearly between these two extremes. The predicted resuspension of fine-grained dredged material is shown in Tables 5a and 5b. The STFATE model results indicate that about 2 to 6% of the fine-grained fraction of the dredged material remains in suspension about 3 to 4 hours after the barge discharge and disperses in the CAD cell water below the loaded draft of the barge, resulting in predicted average TSS concentrations ranging from about 15 mg/L in the first year to 40 mg/L in the fifth lift for the 5-year dredging plan, or 13 mg/L for the first lift to 30 mg/L for the tenth lift for the 10-year plan. In a shallow saline environment such as New Bedford Harbor and the CAD cell, the TSS concentration at the bottom of the CAD cell will typically decrease to 50 mg/L within a day and to 10 mg/L within a week, while concentrations just below the lip of the CAD cell would typically fall below 10 mg/L above background within a day and below 2 mg/L above background within a week. However, this should be regarded as a generalization as recent monitoring of a CAD cell in New Bedford Harbor (Dragos 2009) observed suspended solids levels returning to background typically within two hours.

Surge dynamics of disposal into the UHCC were evaluated in comparison to earlier modeling efforts for the LHCC. The discharge plume collapse dynamics were modeled for the LHCC (Schroeder et al. 2010) using the USACE SURGE model to examine whether the momentum of the discharged material was sufficient to cause the dredged material to run up the side slope and out of the CAD cell. All discharges were assumed to be within the area of the level bottom, a 326-ft square, and no closer than 160 ft horizontally from the lip of the CAD cell. The dynamics were examined for sediment composites 3, 4 and 5 across the range of water depths that would exist during their placement. In all cases the discharged material was not predicted to run up the slope above a depth of about 11 ft below the lip or about 55 ft horizontally from the lip because the difference between the elevation of the bottom of the loaded discharge barge and the elevation of the lip of the CAD cell yields insufficient potential energy to overcome the frictional losses. Since the depth of water at the UHCC is even shallower than at the site of the LHCC, the UHCC is also expected to be capable of confining the dredged material during placement.

CAD Cell Hydrodynamics

Mixing within the CAD cell will affect the settling of resuspended dredged material and loss of dissolved and particulate-associated contaminants by the placement operations. The nature and intensity of the mixing is a function of the hydrodynamic regime of the site and the CAD cell configuration. The tide-induced circulation in the proposed CAD cell in upper New Bedford Harbor was modeled using the general vertical coordinate (GVC) version of EFDC (Environmental Fluid Dynamics Code), which is a 3D public domain surface water modeling system that invokes the hydrostatic pressure assumption (Hamrick, 2007a,b,c,d). The EFDC model setup for New Bedford Harbor is described next.

An EFDC model that used a Cartesian grid of a portion of Buzzards Bay and New Bedford Harbor with 7,882 cells (see Figure 14) was used to construct the water surface elevation boundary conditions at the entrance to the hurricane barrier to drive an EFDC model of just New Bedford Harbor (see Figure 15). The former model will be referred to as the BB-NBH model, and the latter model will be referred to as the CAD cell model. As shown in Figure 16, the grid for the latter model was finer in proximity to the Upper Harbor CAD cell to better represent the geometry and bathymetry in the CAD cell. The open water tidal boundary for the CAD cell model was located at the entrance to the hurricane barrier (see Figure 15). As seen in Figure 16, the CAD cell is represented using approximately 220 cells of varying size, with the smallest cell being 8 m in the lateral direction and 14.1 m in the longitudinal direction. The lateral/ longitudinal directions are with respect to the tidal flow into and out of the embayment on the west shore of the upper harbor portion of New Bedford Harbor in which the CAD cell is located. As such, the longitudinal direction is in the east-west direction, and the lateral direction is in the north-south direction. The thin black line around the blue colored CAD cell in Figure 16 represents the enclosing walls.

Time series of wind velocity, water surface elevations at the open water boundaries in Buzzards Bay, and discharges of two small rivers (one is the Acushnet River) into the northern shoreline of the BB-NBH model were used for the boundary conditions in the BB-NBH model. The water surface elevation boundary conditions for the BB-NBH model at the model's open water boundaries in Buzzards Bay were generated using an EFDC model of Buzzards Bay (referred to as the BB model). The curvilinear-orthogonal grid for the BB model is shown in Figure 17. The BB model had 5,662 cells, and included a short reach of the Cape Cod Canal (see Figure 17) that connects Buzzards Bay and Cape Cod. Time series of wind velocity, water surface elevations at the open water boundaries in Buzzards Bay (labeled in Figure 17), and discharges of three small rivers into the western boundary were used for the boundary conditions in the BB model. The Cape Cod Canal and Acushnet River at the upstream end of the New Bedford Harbor are also open water boundaries of the BB model. The tidal open water boundary conditions for the BB model were generated by interpolation of tidal constituents in the Western North Atlantic ADCIRC database of tidal constituents.

Time series of wind velocity, water surface elevations at the open water boundary (entrance to hurricane barrier), and discharge of the Acushnet River into the northern open water boundary were used for the boundary conditions in the CAD cell model. Time series of water surface elevations and current velocities measured at different locations throughout the CAD cell and BB-NBH models' domains were used in calibrating and validating these hydrodynamic models.

EFDC uses a sigma or stretched vertical coordinate. In the sigma coordinate formulation, the number of vertical layers is the same in all grid cells. In the GVC version, the number of vertical layers does not have to be the same in all grid cells. The CAD cell model used three layers to represent the water column for all grid cells except those within the upper harbor CAD cell. A vertical slice through the grid along the centerline of the CAD cell is shown in Figure 18. As seen in this figure, eleven vertical layers are used to represent the water column for the twelve model grid cells (in the longitudinal direction) at the center of the CAD cell, and a single row/column of grid cells around the sides of the CAD cell are used to represent the side slopes of the CAD cell. The use of more vertical layers in the deeper CAD cell allows for a more accurate prediction of the vertical circulation of water below the lip of the CAD cell. The CAD cell represented in the CAD cell model was assumed to be filled up to 20 ft (6.1 m) below the lip. As seen in Figure 18, five water column layers represented the side slopes.

The CAD cell model was used to represent two alternate CAD cell designs: a CAD cell without side walls (but enclosed by a silt curtain), and a CAD cell with sheet pile walls around three sides and across part of the fourth (i.e., east) side. A plan view of the latter, with a 200 ft (61 m) opening for barge entry along the east side is shown in Figure 16.

The CAD cell model was run for both CAD cell designs for 32 days using a 0.25 sec time step. Such a small time step was necessary to achieve a stable solution. The first two days of these simulations were used to spin-up the hydrodynamic model, and the last 30-days of the model runs were used in the analysis. 30-day model runs were analyzed in order to examine the variation in the circulation within the CAD cell over a 29.5 day lunar month.

Figure 19 shows the vertical velocity distribution in the open CAD cell at one time step during a flood tide. For orientation purposes, north is into the page. Plunging type flow is seen on the right (east) side of the CAD cell, with upward circulation on the left (west) side. Figure 20 shows the vertical velocity distribution at a different stage of a flood tide. Converging flow near the x-axis value of 320 m is seen in this figure indicates the presence of two circulation cells within the CAD cell – the cell on the west side has counterclockwise rotation, and the cell on the east side has clockwise rotation. In interpreting these figures, keep in mind that the flow in the CAD cell is fully three-dimensional (3D), and not limited to the shown east-west oriented vertical plane. The 3D flow structure is seen more clearly when one views Figures 20 and 21. In the latter figure, the circulation in a north-south oriented vertical plane (i.e., perpendicular to the vertical plan shown in Figure 20) located approximately 60 m from the back (west) end of the CAD cell. Downward oriented flow is seen on the right (north) side of this figure, whereas upward oriented flow is seen on the left (south) side.

The objective of the analysis performed on the results from these two model runs was to determine if any suspended sediment (whether flocs or aggregates) inside the CAD cell would be advected out by the tide-induced vertical circulation. This could only occur if the upward vertical velocities were greater than the downward settling velocities of the suspended sediment. The specific procedure performed to accomplish this objective is the following. The 30-day time series of vertical velocities predicted in every water column layer in every grid cell inside the CAD cell was compared to the downward settling velocities of flocs and cohesive sediment bed aggregates determined using the Particle Imaging Camera System (PICS) during a field study performed in New Bedford Harbor in November 2008. PICS was developed at ERDC and is used to measure the in situ settling speeds of suspended flocs and aggregates (Smith and Friedrichs, 2010). PICS collects digital video of particle settling within a small settling column. Image sequences collected by PICS were analyzed with automated particle tracking software to produce size, settling velocity, and density (estimated) distributions of particles suspended at the sampling location. The mean floc and aggregate settling velocities for the sediments in New Bedford Harbor were found to be 0.3 and 0.8 mm/s, respectively. The findings from this analysis are discussed next.

The analysis of both model runs (with and without a sheet pile enclosed CAD cell) showed that bed aggregates would not be expected to be advected out of the CAD cell as the mean settling velocity for aggregates is usually higher than the upward vertical velocities in any of the 11 water column layers in any of the grid cells inside the CAD cell over the 30-day model runs. For the times and locations when the vertical velocities are higher than the settling velocity, the differences in velocities are on the order of 0.1 mm/s or smaller. As such, only aggregates just below the rim of the CAD cell would have any chance of being advected out of the cell during the relatively short periods of time when the upward vertical velocity is higher than the downward settling velocity.

For suspended flocs, there are times during the 30-day model run for the case with the sheet pile enclosed CAD cell when the upward vertical velocities are slightly higher than the floc settling speed, but this occurs only occasionally (approximately 13% of the time over the 30-day period) in some of the grid cells inside the CAD cell (up to about 10% of the area at any given time). For the vast majority of the times and locations when the vertical velocities are higher than the settling velocity, the differences in velocities are on the order of 0.5 mm/s or smaller. As such, only flocs in the top meter or so below the rim of the CAD cell would have any chance of being advected out of the cell during the time periods when the upward vertical velocity is higher than the downward settling velocity. The conclusion from this analysis is that flocs would hardly ever be advected out of a sheet pile enclosed CAD cell, and that this would possibly occur only for the portion of the flocs whose settling speed is less than the mean floc settling speed used in this analysis.

For the times during the 30-day model run for the CAD cell with only a silt curtain enclosure when the upward vertical velocities are higher than the floc settling velocity (approximately 20% of the time over the 30-day period), the differences in velocities are on the order of 1 mm/s or smaller. Further analysis of the model results showed that only flocs in the top 2 m or so below the rim of the CAD cell in up to about 15% of the area at any given time would have any chance of being advected out of the cell during the time periods when the upward vertical velocity is higher than the downward settling velocity. The conclusion from this analysis is that flocs should seldom be advected out of the silt curtain enclosed CAD cell, though for the portion of flocs whose settling speed is less than the mean floc settling speed used in this analysis a slightly higher percentage of flocs in the upper 20 % of the cell below the rim might be advected above the CAD cell rim. The difference in results for the two CAD cell designs is not unexpected since the tide-induced flow into the cove where the CAD cell is proposed to be located would flow over the top of the CAD cell without enclosing walls. This would entrain some of the water in the upper part of the CAD cell and cause slightly higher upward vertical velocities.

An analysis of tide-induced circulation in the CAD cell indicated that velocities in the lower half of the CAD cell are very small, typically less than 0.05 ft/s, and as such, mixing with water from the upper half of the cell will be extremely limited during fair weather conditions. The modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.1 fps. The velocity is sufficient to rapidly exchange the water above the CAD cell, typically in three to six hours with silt curtains and twelve to twenty-four hours with a sheet pile wall enclosure.

The conclusions from this analysis pertain to the times when fair weather conditions occur in New Bedford Harbor. Higher flow velocities and therefore enhanced mixing would occur in the harbor during high wind conditions and during heavy rainfall events, e.g., nor'easters, as the flow rates in the Acushnet River would be significantly increased. The increased flows and mixing might lead to advection of flocs out of the CAD cell during such events.

Short-Term Partitioning and Contaminant Loss

Contaminants associated with the TSS resulting from resuspension during placement will partition with the CAD cell water. It is unlikely that the partitioning reaches equilibrium before the particles interact with particles from subsequent discharges, flocculate and settle. Most particles will remain in suspension less than a day. The kinetics of PCB desorption in a stagnant water column is sufficiently slow that it may take weeks to reach equilibrium; however, 10 to 20% of the PCB may desorb in the first day (Gong, et al., 1998; Ghosh, et al., 1999). The partitioning of contaminants to the CAD cell water from the resuspension of the large number of discharges in a dredging season is predicted to be sufficient to achieve a contaminant concentration approximately equal to the pore water concentration of the sediment or dredged material in the first half of each dredging season. The predicted dissolved and total concentration of contaminants in the CAD cell as a function of time based on the resuspension and partitioning model results are given in Tables 6a and 6b and plotted in Figures 22 through 25. The total concentration at the top of the CAD cell will be somewhat lower because the TSS at the top will be appreciably lower than the average for all but the last lifts.

The suspended and dissolved contaminants may be lost from the CAD cell by four principal mechanisms in the short term before the CAD cell is capped and during capping. These mechanisms include entrainment of upper CAD cell water into the flow over the CAD cell, displacement of CAD cell water by the placement of dredged material, vertical turbulent diffusion, and thermal overturn.

Entrainment. Entrainment exchanges water from the flow over the CAD cell with a portion of the CAD cell contaminated by the stripped or suspended solids of the dredged material placement. The quantity of entrainment is a function of the enclosure method and its ability to control velocities. The total entrainment loss is a function of the water exchange rate, the solids concentration in the water just below the lip of the CAD cell, the contaminant concentration associated with the solids in suspension, the duration of the placement season (placement rate), and the number of placement seasons. The solids concentration in suspension increases as the storage capacity is depleted; therefore the losses of solids increase from one placement season to the next, particularly in the last placement season.

High resolution hydrodynamic modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.1 fps. The tidally induced velocities are sufficiently great to exchange the water above the CAD cell, typically in six to twelve hours; however, the velocity is sufficiently low to limit any mixing below the lip of the CAD cell water, mostly in the top few feet below the lip. The differences in the hydrodynamics between enclosing the CAD cell with a silt curtain and with a sheet pile wall are predicted to be small because the CAD cell is located within a cove where the currents are predominantly tidally driven. However, under peak mixing conditions during the tidal cycle, the upward velocities in the CAD cell are sufficient to overcome the settling velocity of flocs in the top six feet of the CAD cell when a silt curtain is used, while this mixing is limited to the top three feet when a sheet pile wall is used. Additionally, the hydrodynamic modeling showed the potential to set up a slow vertical eddy in the CAD cell that could provide slow mixing to a depth of 10 feet below the lip of the CAD cell. Therefore, dissolved contaminants in the top ten feet of the CAD cell were subjected to turbulent dispersion and exchange with the water column above the lip of the CAD cell. The 0.1-fps current speed from the hydrodynamic modeling was somewhat greater than, but similar to, currents measured during 2009 CAD cell field monitoring inside a deployed silt curtain (Dragos 2009). On five separate monitoring events currents inside the silt curtain were less than 0.07 fps while observed currents west and east of the CAD were up to 1.0 and 0.5 fps, respectively.

The upward currents in the eddy exceed the settling velocities of the suspended solids in only a small fraction of the area, over a shallow depth and only for a small fraction of the time. The extent of the area, depth and time are a function of the enclosure. With a sheet pile wall, the area is about 10%, the depth is about 3 feet, and the time is 13%, while with a silt curtain, the area is about 15%, the depth is about 6 feet, and the time is 20%. The differential velocities between settling and upflow are 0.1 mm/sec or less for the sheet pile wall enclosure and 0.5 mm/sec or less for the silt curtain enclosure. Therefore, use of silt curtains rather than a sheet pile wall would potentially cause up to ten times as much loss of suspended solids and their associated contaminants, but the loss of suspended solids is restricted to the supply of suspended solids by turbulent diffusion of the discharge plume at the bottom of the CAD cell. The difference in flow through velocity for the two enclosures would yield an increase in suspended solids supply by a factor of two to three. The potential exchange between the CAD cell water and the overlying water column by entrainment due to shear at the interface between the two waters is predicted to be about 200% greater with the use of silt curtains due to higher vertical velocities in the CAD cell when compared to the use of a sheet pile wall. However, the increase in contaminant losses from the CAD cell from this mixing (entrainment) is small because discharge losses during placement is small in the top ten feet of the CAD cell during placement except in the last 10% of the filling. The predicted TSS in the top five feet is shown in Figures 26a and 26b along with the average TSS concentration in the CAD cell.

The annual losses due to entrainment by the flow over the CAD cell are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The overall entrainment losses are summarized in Table 9. Entrainment losses are most sensitive to the enclosure method, but are also a weak function of the length of the placement schedule. PCB losses (Aroclors 1242, 1248 and 1254) for a sheet pile wall enclosure are predicted to be 5.0 kg and 6.6 kg, respectively, for 5- and 10-year schedules, while PCB losses for a silt curtain enclosure are predicted to be 14.0 kg and 18.7 kg, respectively. Copper losses for a sheet pile wall enclosure are predicted to be 28.8 kg and 31.9 kg, respectively, for 5- and 10-year schedules, while copper losses for a silt curtain enclosure are predicted to be 81.6 kg and 90.3 kg, respectively. Entrainment accounts for 5- and 10-year schedules about 12% of the PCB losses when a sheet pile wall is used for an enclosure and 28% of the PCB losses when a silt curtain is used. Analogously, entrainment losses account on average about 36% of the copper losses when a sheet pile wall is used for an enclosure and 61% of the copper losses when a silt curtain is used. Entrainment causes a larger percent of the losses of copper because the bulk sediment copper concentration increases throughout the placement project while the bulk sediment PCB concentration decreases throughout the placement project.

Displacement. The dissolved contaminants and particulate-associated contaminants in the upper portion of the CAD cell will be lost as the CAD cell water is displaced by subsequent barge discharges. The displacement volumes are likely to be about 10 to 20% greater than the volume of sediment being dredged due to entrained water in the mechanical dredge/excavator bucket or overdredging. This would amount to about 70,000 to 94,000 cubic yards per year for the 5-year dredging scenario or about 44,000 cubic yards per year for the 10-year dredging scenario. The corresponding target volumes of sediment dredged would be 59,000 to 79,000 cubic yards or about 35,000 cubic yards, respectively, for the 5- and 10-year dredging plans. An additional 40,000 cubic yards of CAD cell water will be displaced in the final year by cap placement. The average contaminant concentrations and mass losses for each lift and contaminant are given in Tables 6, 7 and 8.

The annual losses due to displacement of the CAD cell water by the placed dredged material are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The overall displacement losses are summarized in Table 9. Displacement losses are insensitive to the enclosure method, but weakly sensitive to the storage capacity and therefore the placement schedule. Annual displacement losses are a function primarily of the annual volume placed and the annual bulk sediment concentration. The total predicted displacement losses of PCB (Aroclors 1242, 1248 and 1254) are 12.8 kg and 11.1 kg for the five or ten years of filling schedules, respectively. PCB displacement losses represent about 30% of the total losses for a 5-year placement scenario and about 17% of the total losses for a 10-year placement scenario. Annual displacement losses range from 6.0 kg in Year 1 down to 0.8 kg in Year 4 for the 5-Year scenario, and from 2.8 kg in Year 2 down to 0.35 kg in Year 7 for the 10-Year scenario. While TSS concentrations in the CAD cell tend to increase slightly from year to year throughout the dredging, PCB losses decrease throughout the dredging because dredging proceeds from the more highly contaminated (about 660 mg/kg in Composite 1) to the less contaminated (about 106 mg/kg in Composite 3) as given in Tables 1, 2, and 3. Additionally, the fraction of PCBs that are more mobile (Aroclor 1242 fraction) also decreases throughout the dredging from 65% in the first year to 44% in the last year. For the 5-year scenario, the released PCBs are about 87% Aroclor 1242 (mass loss about 0.05% of Aroclor 1242 total mass placed), 7% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 6% Aroclor 1254 (mass loss about 0.012% of Aroclor 1254 total mass placed). Similarly for the 10-year plan, released PCBs are about 86% Aroclor 1242 (mass loss about 0.04% of Aroclor 1242 total mass placed), 8% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 7% Aroclor 1254 (mass loss about 0.011% of Aroclor 1254 total mass placed). About 95% of the released PCBs are predicted to be dissolved. These losses were computed by averaging the predicted concentrations shown in Figures 22 to 24 for each lift (given in Table 6) and then multiplying the averages by the volume of CAD water displaced by each lift given above.

The total predicted displacement losses of copper are 20.7 kg and 19.0 kg for the five or ten years of filling schedules, respectively. Copper displacement losses represent about 29% and 19% of the total losses from a sheet pile wall enclosed CAD cell for 5-year and 10-year placement scenarios, respectively. For a CAD cell enclosed by a silt curtain, copper displacement losses represent about 17% and 12% of the total losses for 5-year and 10-year placement scenarios, respectively. Annual displacement losses range from 3.2 kg in Year 1 down to 5.4 kg in Year 5 for the 5-Year scenario, and from 1.5 kg in Year 1 down to 2.8 kg in Year 10 for the 10-Year scenario. The copper displacement losses represent about 0.012 % of the total mass of copper removed from the associated dredging for the 5-Year scenario, with about 83% of the released copper predicted to be dissolved. These losses were computed by averaging the predicted concentrations shown in Figures 25a and 25b for each lift (given in Table 6) and then multiplying the averages by the volume of CAD water displaced by each lift given above.

Turbulent Diffusion. Contaminant losses from the CAD cell after placement of the annual lift is driven by turbulent diffusion from the upper ten feet below the lip of the CAD cell to the upper exchangeable water column. These losses are expected to be largely independent of the enclosure method and are predicted to be nearly all in dissolved form because the TSS concentrations should decrease rapidly by settling each year after disposal operations cease. Because the CAD cell water becomes as contaminated as the sediment pore water, loss of contaminants from the CAD cell water by turbulent diffusion are comparable to the contaminant losses by displacement during dredged material placement. Turbulent diffusion losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The annual losses of contaminants by turbulent diffusion from the CAD cell in addition to the losses accounted by entrainment are predicted to be limited to the dissolved contaminant mass in about the top 106,600 cubic yards (10 feet) of contaminated CAD cell water after the annual placement operation ceases.

The annual losses due to turbulent diffusion of the CAD cell water are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The total turbulent diffusion losses are summarized in Table 9. The total predicted turbulent diffusion losses of PCB (Aroclors 1242, 1248 and 1254) are 10.4 kg and 22.4 kg for the five or ten years of filling schedules, respectively. PCB turbulent diffusion losses represent about 25% of the total losses for a 5-year placement scenario and about 34% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 9.2 kg and 23.1 kg for the five or ten years of filling schedules, respectively. Copper turbulent diffusion losses represent about 10% of the total losses for a 5-year placement scenario and about 19% of the total losses for a 10-year placement scenario.

Thermal Overturn. An additional potential loss of contaminants independent of the enclosure method is the exchange of CAD cell water in the fall or winter by the cold dense water diving into the CAD cell and thermally overturning the contaminated CAD cell water and subjecting the contaminated water to flow from the CAD site. However, due to the shallow depth of the overlying water column and the mixing that would occur, this mechanism is likely to limit the exchange to no more than 5 feet of water or 65,500 cubic yards in the CAD cell. Any losses between dredging seasons would be partially offset by decreasing the predicted losses during the next dredging season because the initial contaminant concentration in the CAD cell water at the start of the next dredging season would be lower.

The annual losses due to thermal overturn of the CAD cell water are given in Tables 7a and 7b for a CAD cell with a sheet pile enclosure, and in Tables 8a and 8b for a CAD cell with a silt curtain enclosure. The total thermal overturn losses are summarized in Table 9. Thermal overturn losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The total predicted thermal overturn losses of PCB (Aroclors 1242, 1248 and 1254) are 10.2 kg and 20.2 kg for the five or ten years of filling schedules, respectively. PCB thermal overturn losses represent about 24% of the total losses for a 5-year placement scenario and about 31% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 12.6 kg and 26.6 kg for the five or ten years of filling schedules, respectively. Copper turbulent diffusion losses represent about 14% of the total losses for a 5-year placement scenario and about 22% of the total losses for a 10-year placement scenario.

Total Short-term Losses. Table 10 presents the overall potential contaminant losses resulting from placement for the four scenarios modeled. For a CAD cell nearly fully enclosed in a sheet pile wall using a 5-year dredging plan, the total predicted losses are 38.3 kg PCB and 71.2 kg copper. For the 10-year sheet pile enclosure scenario, the total losses are 60.4 kg PCB and 100.6 kg copper. For the 5-year plan, these losses represent 0.087% of the mass of the three PCB

Aroclors placed in the CAD cell (0.136% of Aroclor 1242, 0.026% of Aroclor 1248 and 0.039% of Aroclor 1254), and 0.044% of the copper placed in the CAD cell. For the 10-year plan, the losses represent 0.14% of the three PCB Aroclors (0.22% of Aroclor 1242, 0.038% of Aroclor 1248 and 0.062% of Aroclor 1254), and 0.062% of the copper placed in the CAD cell. The PCB losses using a 10-year schedule are predicted to be 55% greater than using a 5-year schedule, while copper losses are predicted to 35% greater. When silt curtains are used as the enclosure instead of a sheet pile wall, the total PCB losses are predicted to be about 22% greater and the total copper losses are predicted to be about 66% greater. The difference in losses between the silt curtains and sheet pile walls are comparable to the difference in losses between a 5-year schedule and a 10-year schedule. The PCB mass loss rates are more than an order of magnitude lower than reported PCB losses from dredging operations at other Superfund sites.

Long-Term Contaminant Loss from Capped CAD Cell

The contaminant fate and transport from the capped CAD cell were evaluated in two parts. The first part was evaluated during the period of dredged material consolidation based on partitioning and contaminant transport associated with pore water advection induced by consolidation. The consolidation flux and contaminant flux were estimated for the CAD cell. In the center section, sixty-six percent or seventy-four percent of the consolidation for the five and ten year dredging scenarios is completed 40 years after capping, but meaningful contaminant transport by pore water expulsion is limited to the first two to four years, after which the contaminant flux from the uppermost contaminated dredged material layer by pore water advection is less than the contaminant flux by diffusion. The consolidation fluxes (pore water expulsion) predicted by the PSDDF model are shown in Figures 27a and 27b respectively for the 5-year and 10-year dredging plans. The second part was evaluated for the long term, after significant pore water advection ceases. During the long term, contaminant transport is dominated by diffusion of contaminants from the dredged material and into the cap. Long-term contaminant fate and transport from the capped CAD cell was modeled without considering contaminant degradation or transformation using the USACE RECOVERY model.

Contaminant fluxes associated with the advection of water resulting from dredged material consolidation were estimated for a 52-ft deep UHCC using a spreadsheet analysis. The contaminant concentration associated with the sand in equilibrium with the pore water advected into the cap was calculated. Based on equilibrium partitioning, the contaminant concentrations in the contaminated layer at the bottom of the cap are predicted to be 1.6 mg Aroclor 1242/kg , 1.3 mg Aroclor 1248/kg, 0.72 mg Aroclor 1254/kg, and 1.1 mg copper /kg. The thickness of sand containing the contaminant mass was then determined to track the migration of contaminants into the cap. The CAD pit will expel water upward for the four cell sections because the native harbor bottom sediments forming the walls of the CAD have very low porosity and permeability (0.44 and 10^{-6} fpd, respectively) relative to the dredged sediment (0.7 and 10^{-4} fpd) and therefore the native sediments will resist flow of pore water. Figure 28 shows the flux of contaminants into the cap during the first 40 to 45 years after capping.

The results showed that the contaminants transported from the dredged material by pore water advection and diffusion would be contained in the bottom of the cap due to adsorption on the capping media. This is true for all sections of the cap, even in the center section, which had the largest settlement. The maximum distances to which the contaminants are predicted to migrate into the cap are shown in Figure 29. The contaminant and sediment profiles from the end of the CAP model runs were used as the initial conditions for the long-term, diffusion dominated modeling using the RECOVERY model.

The predictions of long-term contaminant flux from a CAD facility require the physical and chemical characterizations of the dredged material and capping materials. The RECOVERY model for prediction of contaminant flux requires a chemical description of the materials and contaminant partitioning characteristics between the pore water and materials. The chemical characterization and partitioning data are given in Table 11. The contaminant concentrations represent the results of a weighted average composite of the contaminated dredged materials (sediments) in the three composite materials envisioned for the UHCC. Figures 11, 12, 13 and 30 show the material thickness immediately after the placement of the cap.

The RECOVERY model was run on three of the four separate sections of the CAD cell, as shown in Figure 6, due to differences in dredged material thickness and predicted settlement. Each section represents about one quarter of the area of the CAD cell, with the center section being 17.5% of the area and rings 1, 2, and 3 being 25%, 29%, and 28.5% of the area, respectively. The first section represents the center of the CAD cell and includes the entire part of the cell that has a level bottom. The next three sections are concentric bands around the center covering the remainder of the sloped area of the CAD cell. Each band has successively thinner dredged material thicknesses and smaller settlements; the thickness and cumulative settlement of the four sections after capping are shown respectively in Figures 30 and 31 as a function of time. The physical and chemical properties of the three composite materials and the capping material as well as the layer structures for the three sections examined with the RECOVERY model are shown in the conceptual model schematics in Figures 32 to 35. Ring 3 (Figure 35) was not modeled as it was apparent there would be no contaminant transport through the cap as the thickness of the cap would be greater than the average thickness of contaminated material beneath it. For the center and Rings 1 and 2, the figures do not display the thin layer of cap that was contaminated at 40 years post capping, as calculated in the discussion above. The thickness that is contaminated differs by contaminant. For the 5-year scenario the contaminants have migrated into the cap 0.045 ft, 0.004 ft, 0.009 ft, and 0.261 ft for PCBs 1242, 1248, and 1254 and copper, respectively. For the 10-year scenario the contaminated migration distances are 0.039 ft, 0.004 ft, 0.008 ft, and 0.229 ft for PCBs 1242, 1248, and 1254 and copper, respectively. The contaminant concentration in the contaminated portion of the cap was predicted to be 1.613, 1.294, 0.721, and 1.121 mg/kg for PCBs 1242, 1248, and 1254 and copper, respectively.

The RECOVERY model was run for a period of simulation sufficient to capture the peak concentration, 10,000 to 20,000 years, for each contaminant and each section. The performance of each cap section are essentially identical since the upper profile of the section with respect to cap and sediment properties are identical as shown in Figures 32 to 35. To show the long-term performance of the cap, the predicted surficial sediment concentrations of Aroclor 1242 and copper are shown in Figures 36 and 37. Copper is a conservative representative of all of the contaminants because it is the most mobile in the sediment and in the cap. The concentrations predicted for the bioactive zone (i.e., top four inches of cap) throughout the first 500 years of cap life are more than 7 orders of magnitude lower than the concentrations in the sediments being capped. Peak concentrations for the center section are 1.2E-04 mg PCB 1242/kg, 4.1E-15 mg PCB 1248/kg, 6.1E-10 mg PCB 1254/kg, and 1.1E-03 mg Cu/kg, which occur at 7300, 17,300, 14,600, and 2,200 years, respectively.

Figures 38 and 39 show the predicted Aroclor 1242 and copper concentrations of the pore water in the bioactive zone as a function of time based on RECOVERY model results. Pore water concentrations initially in the sediment in contact with the cap were predicted based on equilibrium partitioning to be 0.014 mg/L, 0.001 mg/L, 0.001 mg/L, and 0.056 mg/L for PCB 1242, PCB 1248, PCB 1254, and copper, respectively. The ratio of contaminant concentrations in the bioactive zone pore water to that below the cap at peak are 7.5E-05, 3.2E-15, 8.4E-10, and 6.6E-04 for PCB 1242, PCB 1248, PCB 1254, and copper, respectively which shows the effectiveness of the cap in reducing contaminant exposures in both the benthic zone and water column. This shows that the cap reduces contaminant exposures by at least 4 orders of magnitude for PCBs and 3 orders of magnitude for copper at peak concentrations; exposure is reduced by at least 14 orders of magnitude for PCBs and 5 orders of magnitude for copper throughout the first 500 years. At 500 years, the pore water concentrations of dissolved contaminants in the bioactive zone of the cap were predicted to be 1.2E-10 ng/L (parts per trillion) PCB 1242, 1E-37 ng/L PCB 1248, 2E-25 ng/L PCB 1254, and 0.3 ng/L copper.

To evaluate long-term effectiveness, contaminant breakthrough times were predicted where contaminant breakthrough of the 3-foot cap was defined as a pore water concentration in the bioactive zone (mixed layer) greater than 0.01% of the initial sediment pore water concentration (a concentration approaching the long-term risk goal; e.g., 0.01% of 14 ppb PCB or 0.0014 ppb PCB). Simulations were run as long as 20,000 years to reach peak concentrations. Breakthrough was predicted for copper at 820 years at a concentration of 0.006 ppb. The copper concentration achieved its long-term peak cap pore water concentration of 0.038 ug/L at 2200 years. Breakthrough for Aroclor 1242 at a concentration of 0.0014 ppb was only predicted to occur for the 5-year schedule at 6700 years. The average peak concentration of Aroclor 1242 is approximately 0.001 ppb at 7100 years. Aroclors 1248 and 1254 peak at about 17,000 and 15,000 years, respectively, with respective concentrations on the order of 10^{-15} and 10^{-9} ppb. Therefore, Aroclors 1248 and 1254 do not reach the breakthrough concentrations of 0.0001 ppb PCB 1248 and 0.00012 ppb PCB 1254. Since about 14 to 16 ft of settlement is predicted for the center section of the CAD cell, there is a very large potential for up to 14 to 16 ft of burial over the life of the CAD cell. If this burial were considered in the long-term fate and transport modeling, the CAD cell would be effective for all contaminants for a much longer period, tens of thousands of years. The three-foot cap thickness assumed for the CAD facility is predicted to be an effective isolation layer for all of the contaminants of concern.

Impacts of an Accelerated Filling Schedule

In the event that project implementation allows for a faster filling schedule (i.e., five years for filling rather than ten) the following discussion summarizes the likely impact of such a schedule change. The likely impacts are:

1. An accelerated schedule would reduce the time available for consolidation of the dredged material after placement in the CAD cell and prior to capping. Examination

of the rate of consolidation indicates that consolidation prior to capping could be reduced from about 14 ft to 10.7 ft. The CAD cell is sufficiently large to accommodate either filling schedule.

2. Contaminant losses by entrainment in the overlying flow during placement will be reduced with the accelerated schedule. Despite the water exchange volume being proportional to the quantity of disposal time, the reduction in contaminant losses is much less than the reduction of disposal time because much of the contaminant losses by entrainment occurs in the final year of disposal when the contaminant concentrations in the upper portion of the CAD cell water is greatest. The accelerated schedule would reduce entrainment PCB losses by about 25% and entrainment copper losses by about 10%.

3. The quality of the CAD cell water is not likely to change between the two schedules because it is predicted to be in equilibrium with the dredged material. While the average annual placement losses of PCBs and copper are approximately twice as high using the accelerated schedule, these losses occur over half as many dredging seasons. Therefore, there is little difference in the total losses due to displacement between the two scenarios. Both schedules are predicted to yield displacement losses of approximately 12 kg PCBs and 20 kg Cu.

4. Accelerating the placement schedule will increase the number of loads or the size of the loads. Increasing the number of loads would permit less time for settling and increase the surface water displacement and disturbance by barges and tugs, resulting potentially in an additional loss of suspended sediment and associated contaminants. However, the disposal modeling showed that four barge loads per day instead of two barge loads per day would not significantly affect the suspended solids concentrations throughout the first 90% of the proposed project. Though not modeled, a more preferable alternative would be to increase the size of the barge load which would enhance settling and have a lower loss of suspended sediment. Larger barge loads are released deeper in the water column, have less entrainment of water during its descent to the bottom of the CAD cell, and maintain a greater density difference to provide stability on the bottom.

5. Contaminant losses between dredging seasons by turbulent diffusion and thermal overturn will be greatly reduced with the accelerated schedule because up to 12 ft of contaminated CAD cell water is lost after each dredging season. For a 5-year scenario about 41 ft of water is lost while for a 10-year scenario about 94 is predicted to be lost. Therefore, the accelerated schedule would potentially decrease post-dredging losses by 56%. However, since the contaminant concentrations are not constant over time, the actual reduction in losses are 52% for PCBs and 56% for copper.

6. Accelerating the placement schedule is estimated to result in a net decrease in PCB loss of about 23 kg (or 35%) and net decrease in Cu loss of about 32 kg (or 26%). However, this savings may not be realized if adequate settling is not maintained due to a loss of quiescent settling time by more frequent disposal events.

7. A reduction in consolidation prior to capping will increase the quantity of consolidation after capping and increase pore water expulsion through the cap.

However, the additional mass of contaminants in the pore water expulsion is very small and is not estimated to meaningfully impact the long-term contaminant loss after capping or contaminant breakthrough.

4 — Discussion

Modeling Results and Field Plume Surveys

The modeling results appear to be a reasonable and conservative representation of the behavior of actual plumes. In a separate study, plume monitoring was conducted on five separate events that placed New Bedford Harbor sediment into one of the existing City of New Bedford CAD cells (Dragos 2009). The CAD surveyed had a maximum depth of about 37 feet. The entire CAD cell was surrounded by a silt curtain with access of vessels controlled by one section of the curtain which was used as a gate. Plume monitoring used Acoustic Doppler Current Profilers (ADCP) to measure acoustic backscatter from sediment in the water column and direct water sampling of total suspended solids (TSS) to calibrate the acoustic data. The five events included one occasion in April, three occasions in May, and one in July 2009. Plume transects were conducted by two separate vessels inside and outside of the silt curtain. Monitoring of the plume during these events began before disposal and continued up to 0.75 hr to 1.5 hr after disposal.

Results from the plume monitoring showed initially intense plumes throughout much of the water column within the CAD cell shortly after disposal with maximum measured TSS of 226 mg/l (May 27, 2009 event) and ADCP interpolated values of similar magnitude. In all cases, the plumes were shown to rapidly settle and generally remain within the CAD cell. Results reported from surveys collected approximately 50 minutes following disposal showed plumes as ranging in TSS concentrations from background levels to 50 mg/l and limited largely to the bottom of the CAD.

Although detailed comparison of the model results to the field results was beyond the scope of the present effort, a quick comparison to model results from one of the STFATE model runs was conducted. The model run analyzed used sediment from composite 1 placed into a CAD cell 39 feet deep (by this time the simulated CAD was partially filled), similar to the actual CAD that was surveyed. Results from model output 50 minutes after disposal showed similar, although somewhat higher TSS values than reported by Dragos (2009). Model values showed plume maximums of 20 mg/l TSS at a 5 ft depth, 65 mg/l at 10 ft, 75 mg/l at 25 ft, and 247 mg/l at 37 ft. Based upon this quick analysis it appears the model provides a reasonable projection of plume behavior and possibly a moderate over-prediction of TSS levels.

Relative Magnitude of Contaminant Losses and Uncertainty

The contaminant losses from the upper harbor CAD cell to the overlying water column are predominantly associated with exchange of the contaminated CAD cell water due to the long filling schedule (entrainment, CAD water displacement, turbulent diffusion and thermal overturn). Only displacement losses are largely independent of filling schedule. The contaminant losses represent 0.11% of the total mass of PCB disposed in the cell with a silt curtain enclosure for the 5-year dredging scenario (0.16% of Aroclor 1242, 0.05% of Aroclor 1248 and 0.06% of Aroclor 1254), and 0.076% of the total mass of copper placed in the cell. The losses for the 10-year silt curtain dredging scenario represent 0.17% of the total mass of PCB disposed in the cell (0.25% of Aroclor 1242, 0.07% of Aroclor 1248 and 0.09% of Aroclor 1254), and 0.10% of the total mass of copper placed in the cell. About 50% of the PCB losses and 75% of the copper losses occur during the placement operations in a CAD cell enclosed by a silt curtain. The losses are driven by partitioning and the CAD cell water is predicted to approximate the pore water of the sediments being placed. The partitioning results agree well with the measured pore water concentrations, providing confidence in the predictions. The losses would be greater if there were significant exchanges of CAD cell water with the overlying water column on a periodic basis, e.g., in response to storms. These exchanges are not expected, but they provide a source of uncertainty. A sheet pile enclosure around the perimeter of the CAD cell would reduce the flow over the CAD cell by about 70%, which would decrease the potential exchanges by entrainment. The losses from a CAD cell enclosed by a silt curtain are predicted to be 22% greater for PCB and 66% greater for copper than those for a sheet pile enclosed cell.

The predicted short-term losses are small in comparison to typical TSS losses from mechanical dredging, which range from 0.5 to 2% (Palermo et al., 2008), and typical PCB losses of 2 to 3% at the Fox River, Grasse River, and Hudson River. The placement losses at the upper harbor CAD cell are predicted to be at least one order of magnitude smaller. Even when considering all of the uncertainties of dredged material placement, the losses from placement are expected to be much smaller than the losses from dredging.

The long-term contaminant losses after capping are insignificant, even during the initial period (3 years) following cap placement when expulsion of pore water from consolidation is the dominant driver for contaminant transport. As long as the cap is stable and isolation is provided, the long-term losses will be negligible for thousands of years. The only uncertainty in the prediction is the assumption of long-term stability and isolation; however, since the dredged material is predicted to consolidate up to fifteen additional feet after capping, the CAD cell should become more and more stable. In addition, the depression formed by this consolidation will provide a sink for additional sediment deposition, which will increase effectively the “cap” thickness and maintain long-term isolation.

The long-term contaminant losses from the CAD cell is very likely to be controlled by the deposition of new sediment onto the CAD cell cap and not by the capped sediments which will have negligible contribution. The new sediment should resemble the background sediment surrounding the CAD cell and it would be expected to have a much higher contaminant concentration than would ever result from diffusion of contaminants from the capped dredged material.

5 — Conclusions

1. The proposed 570-foot by 730-foot rectangular CAD cell excavated 52 ft below the existing sediment surface is sufficient in size to hold the sediments and cap proposed for an upper harbor CAD cell and to contain the lateral spread and collapse of the dredged material discharge during placement.

2. About 2.4 ft of water will be entrained in the dredged material during placement, but all of this water along with 4 to 5 ft of pore water is predicted to be expelled from the consolidating dredged material during the five or ten years of placement.

3. An additional 5.5 to 7 ft of settlement and pore water expulsion is predicted to occur within 40 years after cap placement. Up to 9 ft of additional consolidation is expected beyond 40 years.

4. Dredged material resuspension will occur during placement, resulting in predicted average TSS concentrations ranging from 14 to 54 mg/L for the 5-year scenario and 13 to 38 mg/L for the 10-year scenario, and both dissolved and particulate-associated contaminant release to the water column overlying the CAD cell. The TSS concentrations just below the lip of the CAD cell are predicted to be about 5 mg/L except during the last year of placement when it will increase to about an average of 40 mg/L.

5. The resuspension predictions appear to be a reasonable and conservative representation of the behavior of actual plumes observed during similar dredged material placement in a City of New Bedford CAD cell in 2009.

6. Hydrodynamic modeling yielded only low velocities in the water column above the CAD cell, typically less than 0.1 fps when enclosed in a silt curtain and less than 0.05 fps when enclosed in a sheet pile walls. The velocity is sufficiently great to exchange the water above the CAD cell, typically in three to six hours when enclosed in a silt curtain and in twelve to twenty-four hours when enclosed in a sheet pile walls.

7. The predicted velocities in the CAD cells are sufficiently low to limit mixing below the lip of the CAD cell water, mostly in the top few feet. However, higher resolution hydrodynamic modeling of the CAD cell environ performed using the 3-D EFDC model set up for sediment transport modeling showed the potential to set up a slow vertical eddy in the CAD cell. The eddy could provide slow mixing to a depth of 10 feet below the lip of the CAD cell. The upward currents in the eddy exceed the settling velocities of the suspended solids in only a small fraction of the area, over a shallow depth and only for a small fraction of the time. The extent of the area, depth and time are a function of the enclosure. With a sheet pile wall, the area is about 10%, the depth is about 3 feet, and the time is 13%, while with a silt curtain, the area is about 15%, the

depth is about 6 feet, and the time is 20%. The differential velocities between settling and upflow are 0.1 mm/sec or less for the sheet pile wall enclosure and 0.5 mm/sec or less for the silt curtain enclosure. Therefore, use of silt curtains rather than a sheet pile wall would potentially cause up to ten times as much loss of suspended solids and their associated contaminants, but the loss of suspended solids is restricted to the supply of suspended solids by turbulent diffusion of the discharge plume at the bottom of the CAD cell. The difference in flow through velocity for the two enclosures would yield an increase in suspended solids supply by a factor of two to three.

8. The slow vertical eddy in the CAD cell with either enclosure was predicted to provide slow mixing to a depth of 10 feet below the lip of the CAD cell. Therefore, dissolved contaminants in the top ten feet of the CAD cell were subjected to turbulent diffusion and exchange with the water column above the lip of the CAD cell.

9. Dissolved contaminant concentrations in the CAD cell water (but not the overlying water) during filling will become approximately equal to the sediment pore water being placed in the CAD cell.

10. Short-term contaminant losses were predicted for four mechanisms: entrainment by overlying flow, displacement by placed material, post-placement turbulent diffusion, and thermal overturn. All four mechanisms contribute significantly to PCB losses but their relative contributions are dependent on the placement scenario.

11. PCB entrainment losses (Aroclors 1242, 1248 and 1254) for a sheet pile wall enclosure are predicted to be 5.0 kg and 6.6 kg, respectively, for 5- and 10-year schedules, while PCB losses for a silt curtain enclosure are predicted to be 14.0 kg and 18.7 kg, respectively. Copper entrainment losses for a sheet pile wall enclosure are predicted to be 28.8 kg and 31.9 kg, respectively, for 5- and 10-year schedules, while copper losses for a silt curtain enclosure are predicted to be 81.6 kg and 90.3 kg, respectively.

12. The total predicted displacement losses of PCB (Aroclors 1242, 1248 and 1254) are 12.8 kg and 11.1 kg for the five or ten years of filling schedules, respectively. For the 5-year scenario, the released PCBs are about 87% Aroclor 1242 (mass loss about 0.05% of Aroclor 1242 total mass placed), 7% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 6% Aroclor 1254 (mass loss about 0.012% of Aroclor 1254 total mass placed). Similarly for the 10-year plan, released PCBs are about 86% Aroclor 1242 (mass loss about 0.04% of Aroclor 1242 total mass placed), 8% Aroclor 1248 (mass loss 0.006% of Aroclor 1248 total mass placed) and 7% Aroclor 1254 (mass loss about 0.011% of Aroclor 1254 total mass placed). About 95% of the released PCBs are predicted to be dissolved. The total predicted displacement losses of copper are 20.7 kg and 19.0 kg for the five or ten years of filling schedules, respectively. Copper displacement losses represent about 29% and 19% of the total losses from a sheet pile wall enclosed CAD cell for 5-year and 10-year placement scenarios, respectively. For a CAD cell enclosed by a silt curtain, copper displacement losses represent about 17% and 12% of the total losses for 5-year and 10-year placement scenarios, respectively.

13. Contaminant losses from the CAD cell after placement of the annual lift is driven by turbulent diffusion from the upper ten feet below the lip of the CAD cell (the top 106,600 cubic

yards) to the upper exchangeable water column. Turbulent diffusion losses are insensitive to the enclosure method, but are a function of the bulk sediment contaminant concentration and the number of placement seasons. The total predicted turbulent diffusion losses of PCB (Aroclors 1242, 1248 and 1254) are 10.4 kg and 22.4 kg for the five or ten years of filling schedules, respectively. PCB turbulent diffusion losses represent about 25% of the total losses for a 5-year placement scenario and about 34% of the total losses for a 10-year placement scenario. The total predicted turbulent diffusion losses of copper are 9.2 kg and 23.1 kg for the five or ten years of filling schedules, respectively.

14. An additional potential loss of contaminants independent of the enclosure method is the exchange of CAD cell water in the fall or winter by the cold dense water diving into the CAD cell and thermally overturning the contaminated CAD cell water and subjecting the contaminated water to flow from the CAD site. However, due to the shallow depth of the overlying water column and the mixing that would occur, this mechanism is likely to limit the exchange to no more than 5 feet of water or 65,500 cubic yards in the CAD cell. The total predicted thermal overturn losses of PCB (Aroclors 1242, 1248 and 1254) are 10.2 kg and 20.2 kg for the five or ten years of filling schedules, respectively. The total predicted turbulent diffusion losses of copper are 12.6 kg and 26.6 kg for the five or ten years of filling schedules, respectively.

15. For a sheet-pile enclosed CAD cell, the total losses based on all four processes for the 5-year dredging plan are predicted to be 38.3 kg PCB and 71.2 kg copper, which is 0.087% of the PCB and 0.044% of the copper mass being placed in the CAD cell. About 97% of the PCB losses and 86% of the copper losses are predicted to be dissolved. For the 10-year dredging schedule, the total losses are predicted to be 60.4 kg PCB (0.139% of mass placed) and 100.6 kg copper (0.062%). About 98% of the PCB and 90% of the copper mass loss is predicted to be dissolved.

16. For a silt curtain enclosed CAD cell, the total losses of PCBs are predicted to be 22% greater than the losses for a sheet pile wall enclosed CAD cell. Likewise, the total losses of copper from a silt curtain enclosed CAD cell are predicted to be 66% greater than the losses for a sheet pile wall enclosed CAD cell.

17. The predicted losses of PCBs from a 10-year disposal schedule are predicted to be 55% greater than the predicted losses from a 5-year disposal schedule, while the predicted losses of copper from a 10-year disposal schedule are predicted to be 35% greater than the predicted losses from a 5-year disposal schedule.

18. All combinations of schedules and enclosures have losses that are at least an order of magnitude smaller than typical mechanical dredging losses. The worst combination (silt curtain and 10-year schedule) has losses that are about twice as large as the best combination (sheet pile wall and 5-year schedule). The losses did not consider the potential losses from installation and removal of the enclosures.

19. After capping, the contaminants expelled from the dredged material by consolidation would be contained in the lower foot of the cap by adsorption on the capping media.

20. A stable 3-ft cap would be highly effective in isolating the contaminated dredged material. Without consideration of burial (i.e., the additional sediment deposition that will take place over time into the bowl-shaped CAD cell depression formed by consolidation after the cap is placed), copper is predicted to break through the cap in approximately 820 years, while PCB 1242 is predicted to just barely break through at 6700 years. The breakthrough PCB 1242 concentration is nearly the same as the predicted peak concentration in the cap's bioactive zone. No breakthroughs of PCB Aroclors 1248 and 1254 are predicted. Again, breakthrough, as used here, is defined as the condition when the contaminant flux or bioactive zone pore water concentration increases to levels of 0.01% of the original flux or sediment pore water contaminant concentration. With burial promoted by the estimated 14 to 16 feet of post-capping settlement, the transport of contaminants through the cap and burial material will take tens of thousands of years to achieve the breakthrough.

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Stark, T. D., Choi, H. and Schroeder, P. R. (March 2005). "Settlement of Dredged and Contaminated Material Placement Areas. II: Primary Consolidation, Secondary Compression, and Desiccation of Dredged Fill Input Parameters," Vol. 131, No. 2, ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering, pp. 52-61.

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Figures

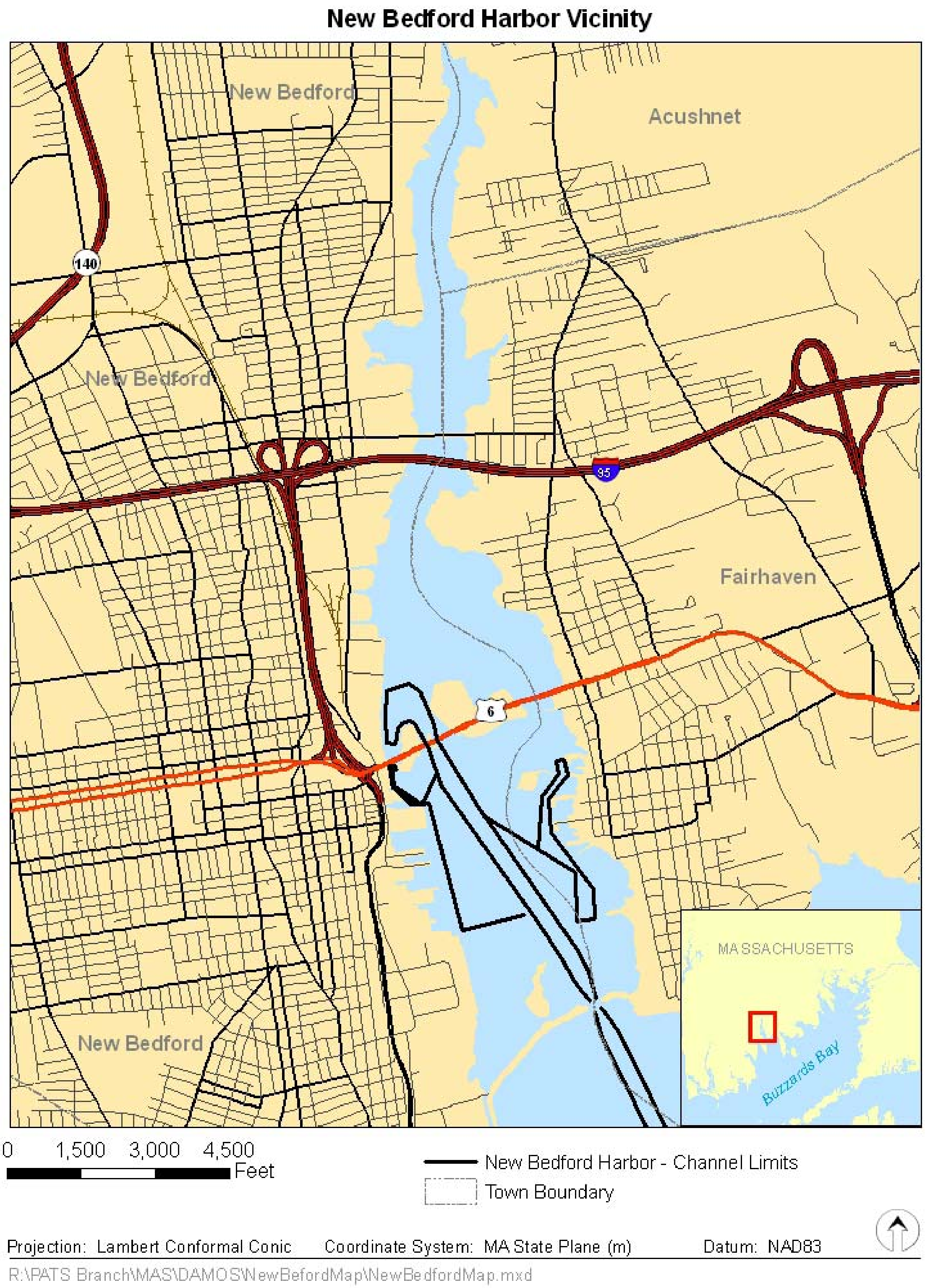


Figure 1. New Bedford Harbor.

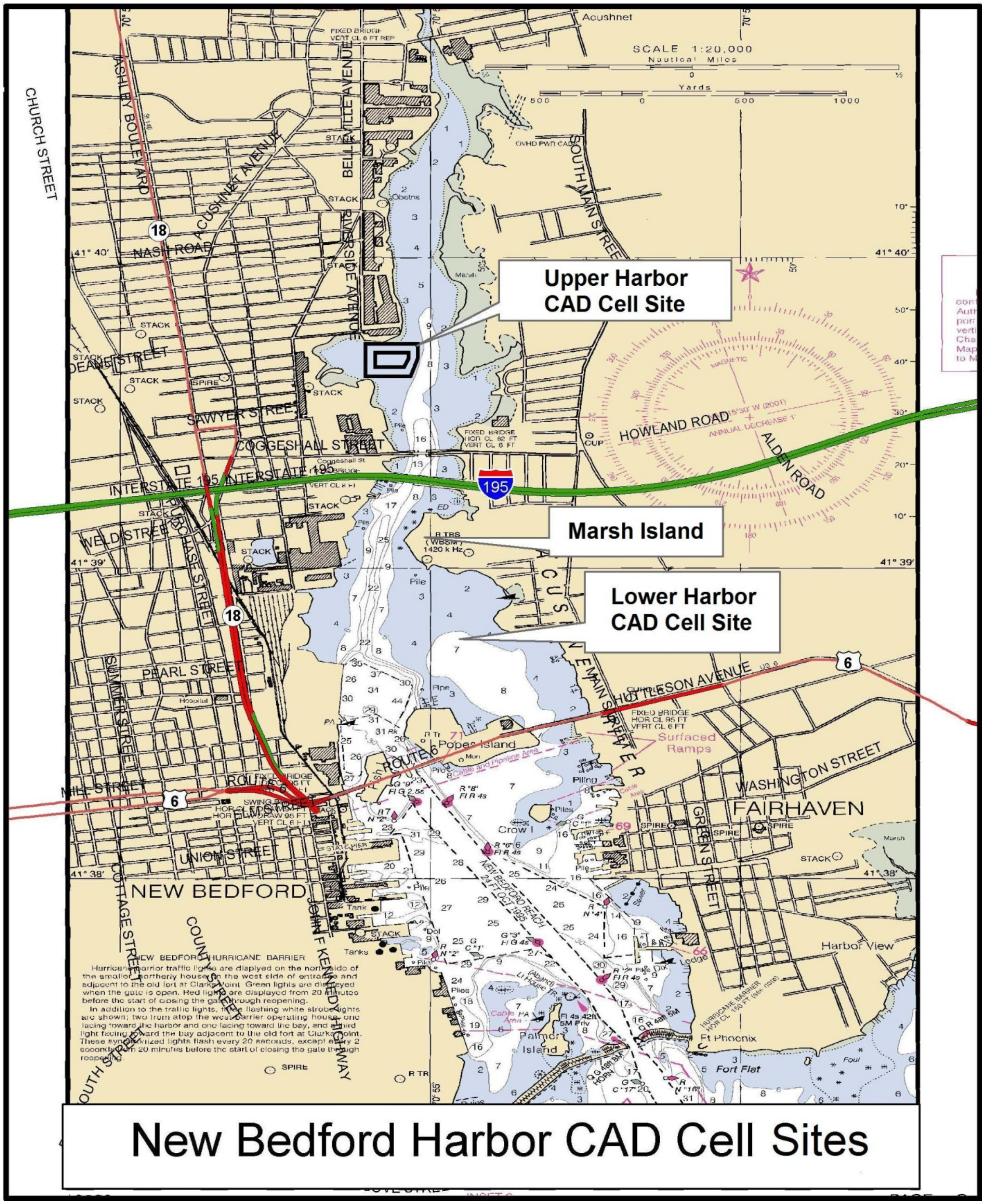


Figure 2. New Bedford Harbor CAD Cell Sites.

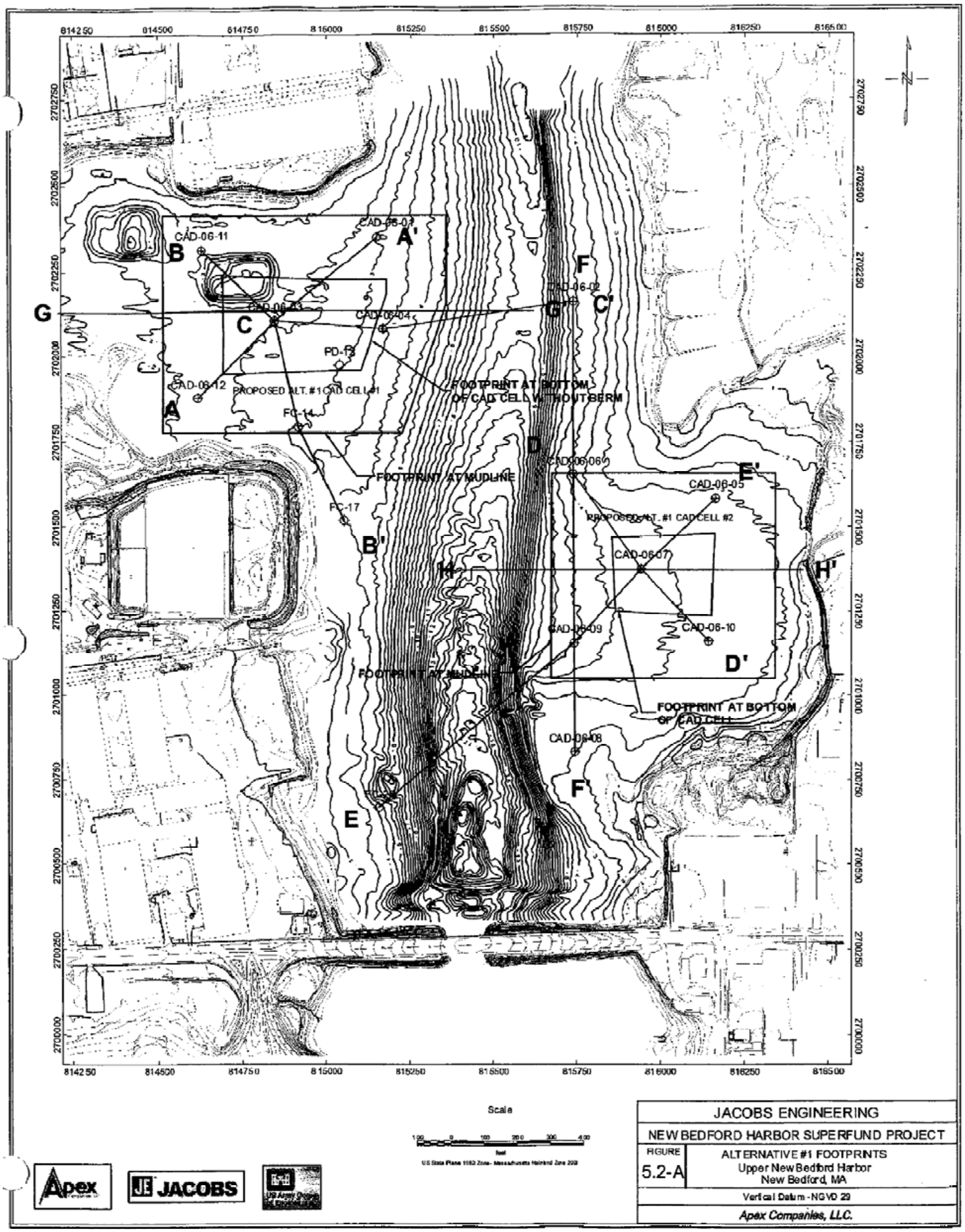


Figure 3. Conceptual NBH CAD Cell Locations Evaluated in 2006.

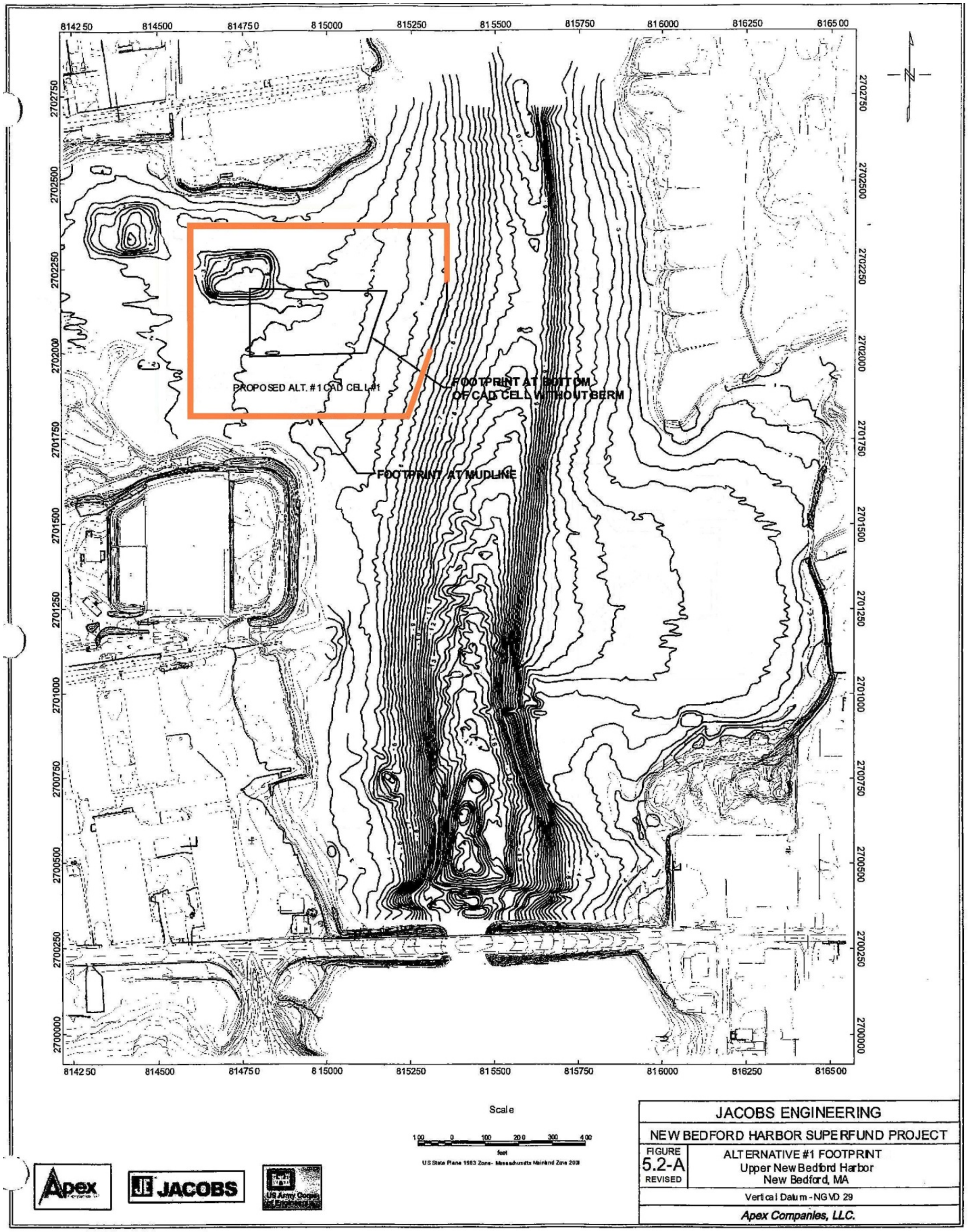


Figure 4. New Bedford Harbor Upper CAD Cell Containment.

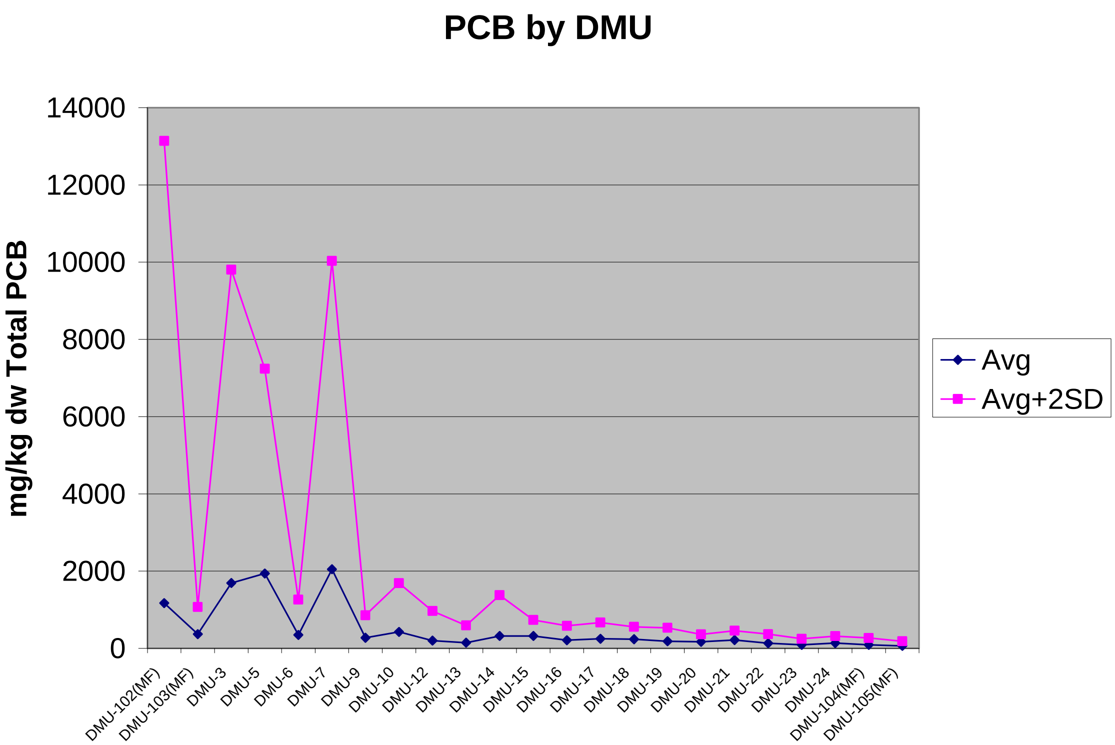


Figure 5. Total PCB Data by DMU.

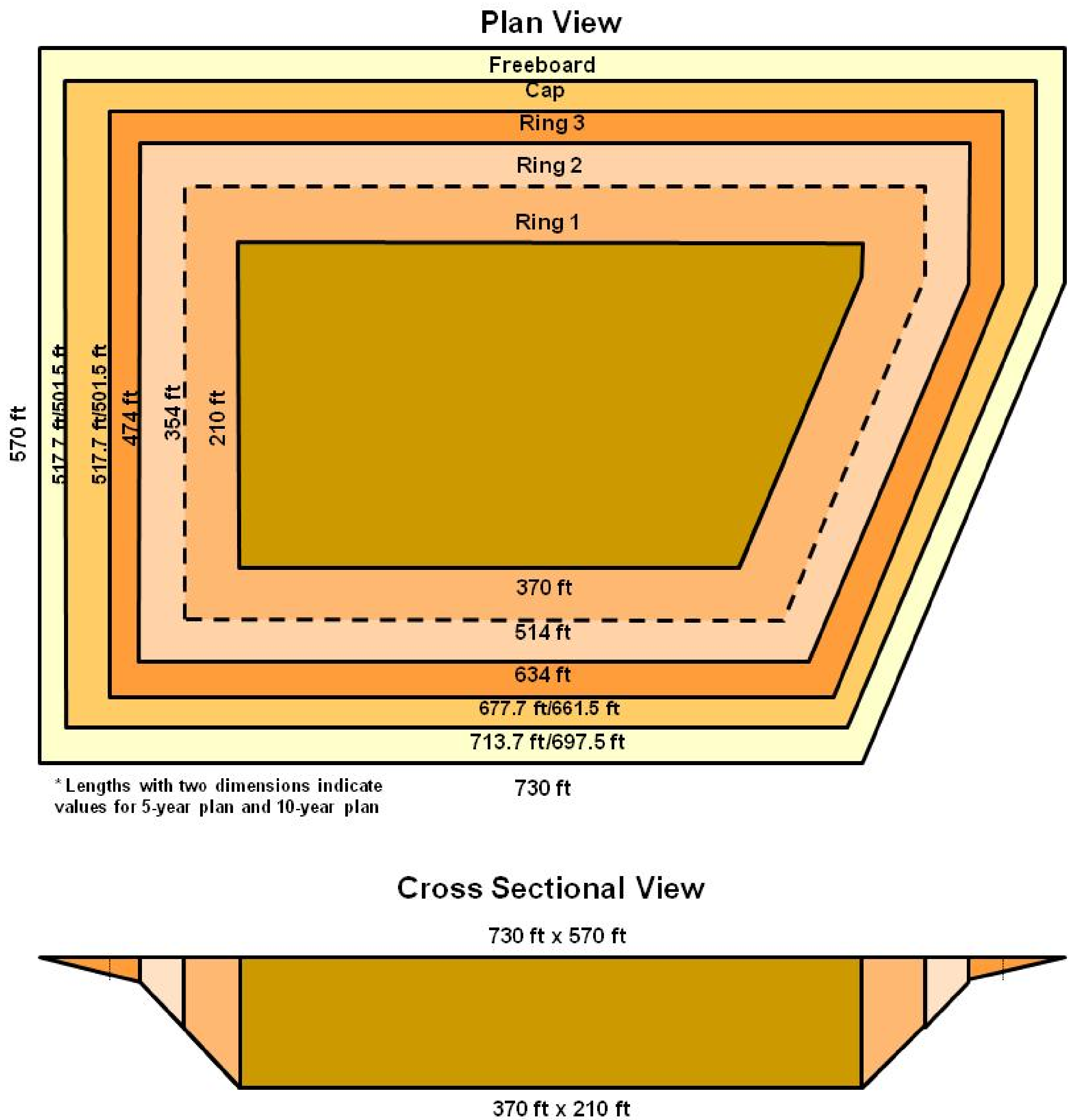


Figure 6. Schematic of CAD Cell Sections for PSDDF and CAP Modeling.

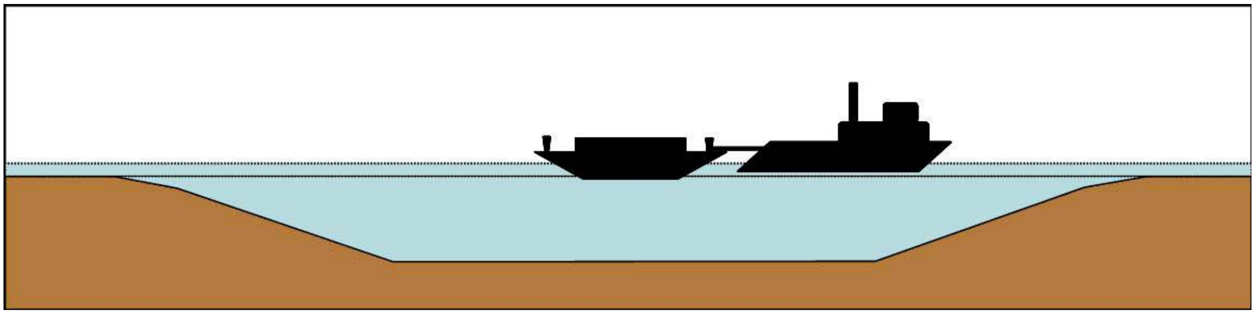
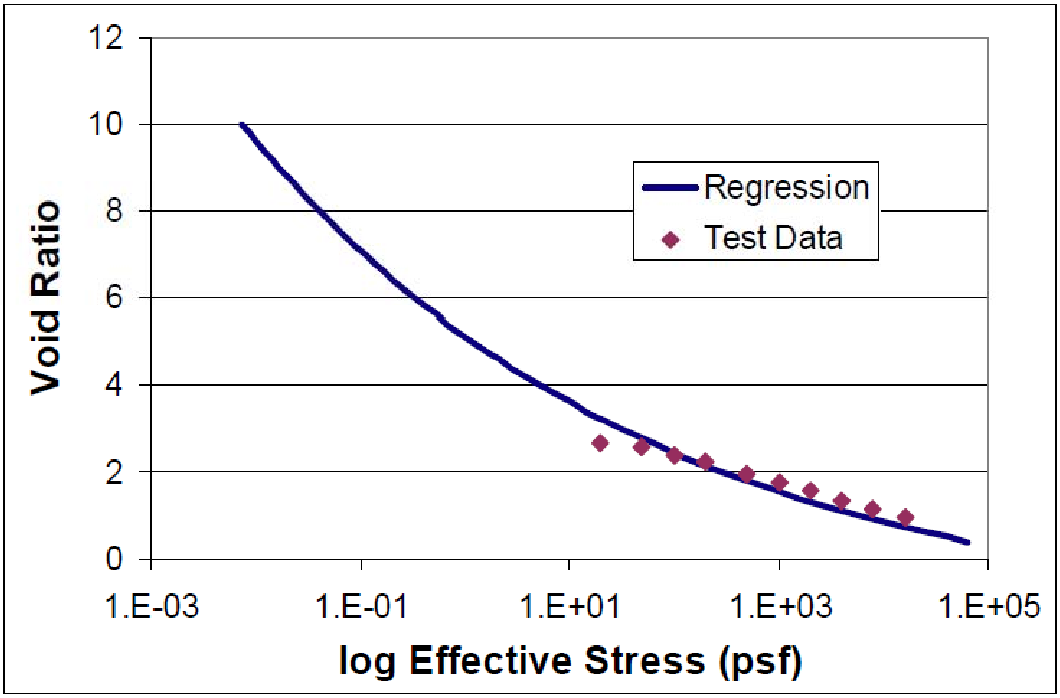


Figure 7. Scaled Graphic of CAD Cell Used for Modeling.

(CAD shown is 570 x 730 feet across the rectangular top and 52 feet deep. The first eight feet of CAD wall has a side slope of 1V:6H and the remainder of the CAD walls are sloped at 1V:3H. The mean water depth surrounding the CAD is eight feet deep and the barge draft is six feet (assumes a deeper access route or high tide entry). The barge hopper length is 60 feet with a total barge length shown of 90 feet.).



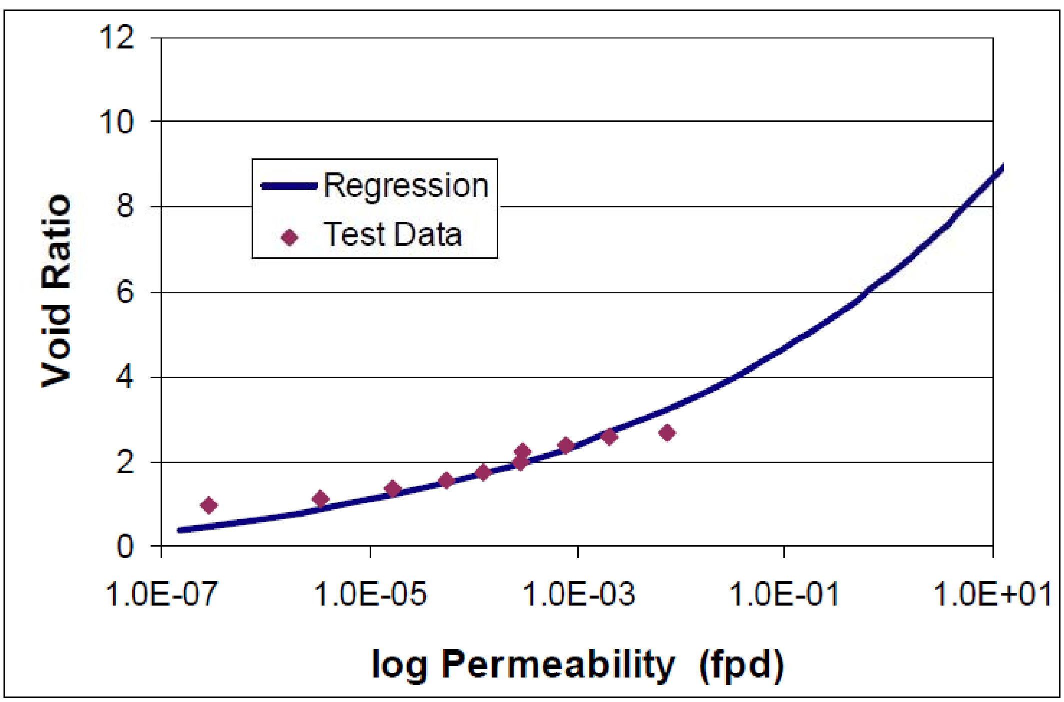


Figure 8. Void Ratio vs. Effective Stress and Void Ratio vs. Permeability Relationships for New Bedford Harbor Sediment Composite 1.

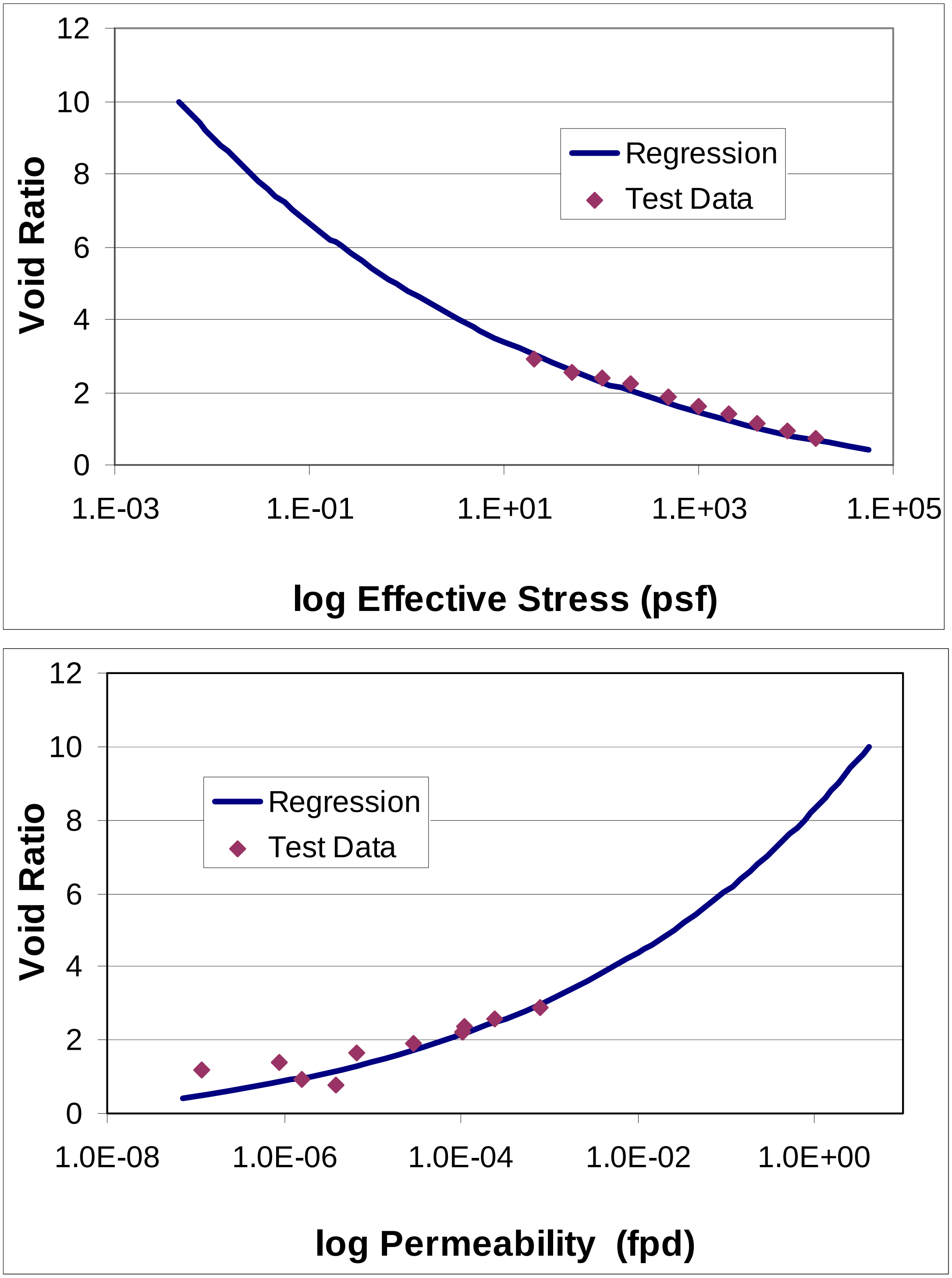
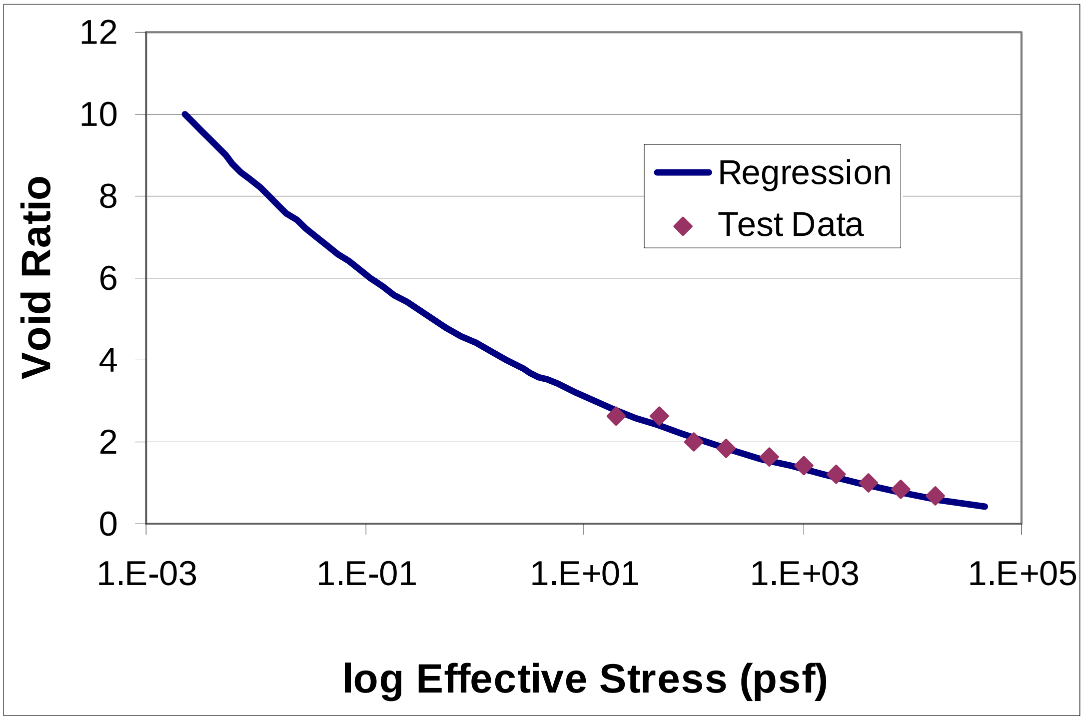


Figure 9. Void Ratio vs. Effective Stress and Void Ratio vs. Permeability Relationships for New Bedford Harbor Sediment Composite 2.



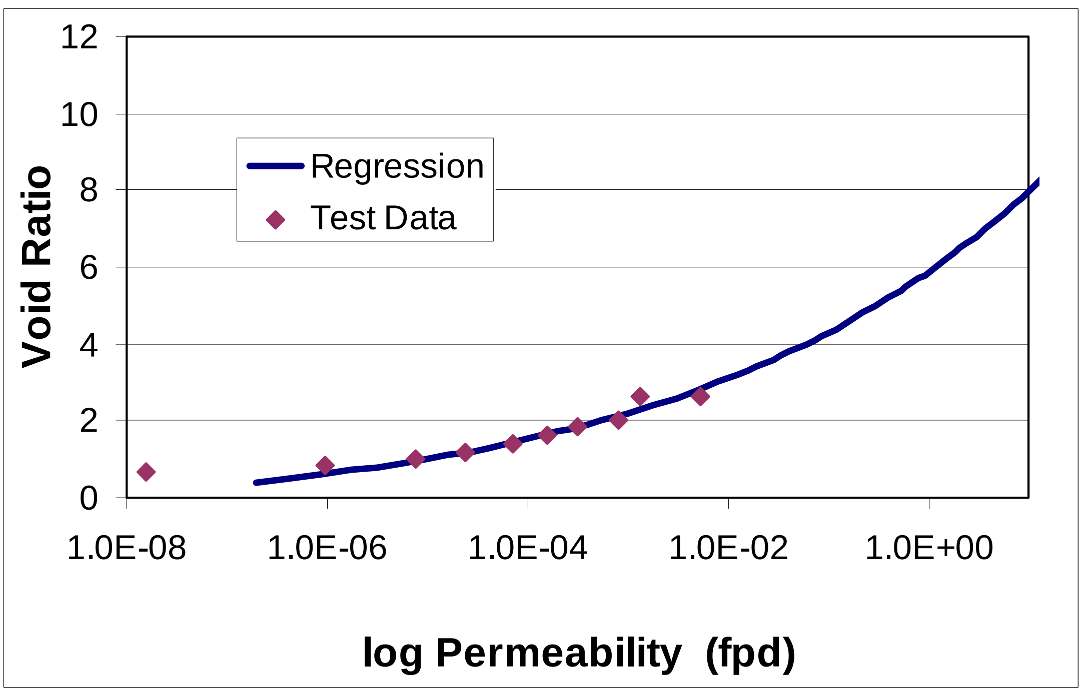


Figure 10. Void Ratio vs. Effective Stress and Void Ratio vs. Permeability Relationships for New Bedford Harbor Sediment Composite 3.

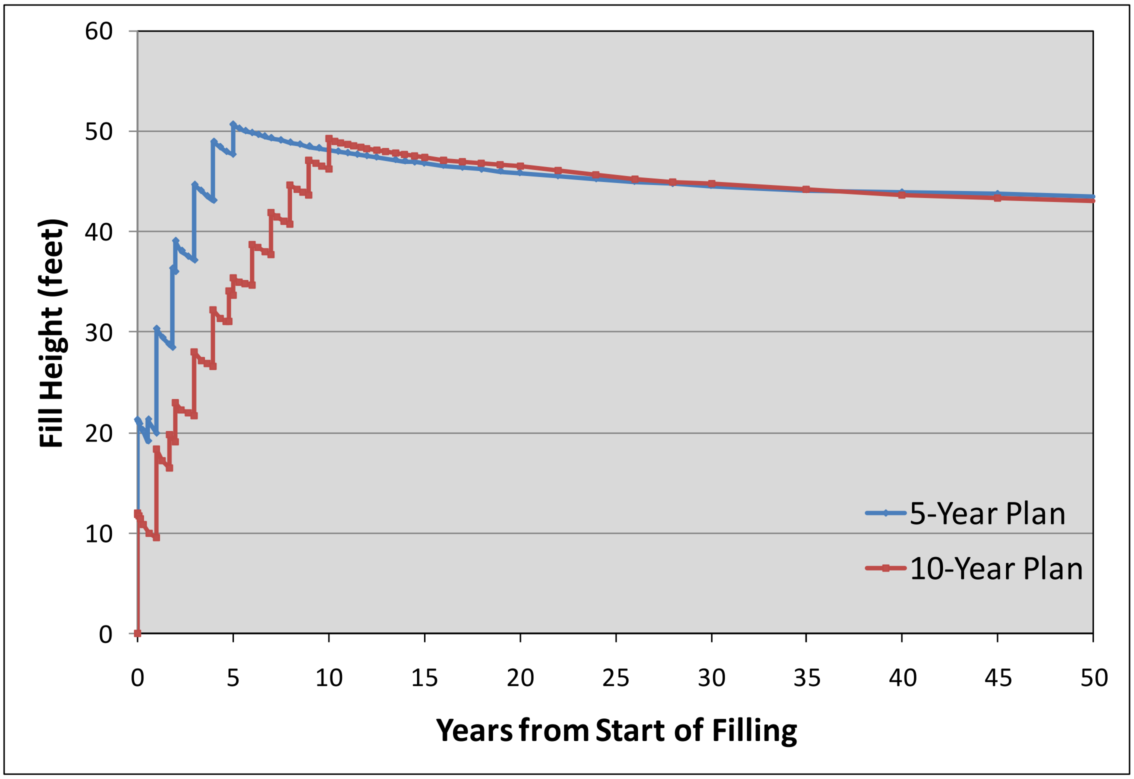


Figure 11. Fill Height History of Center Section of Upper New Bedford Harbor CAD Cell.

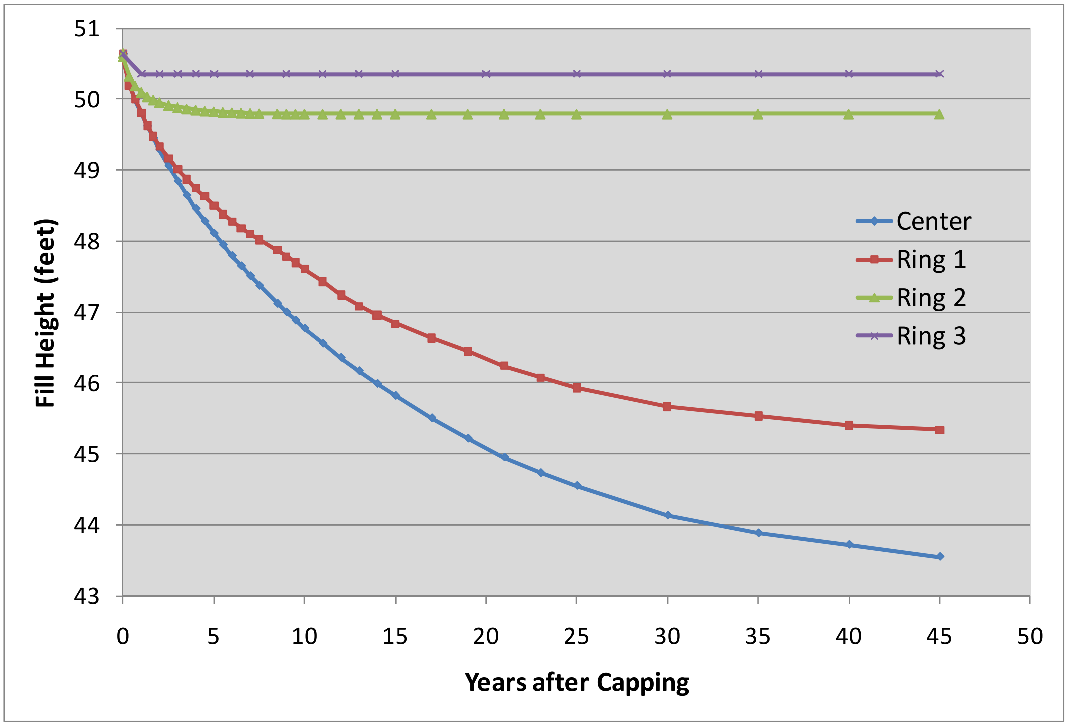


Figure 12a. Fill Height History of Four Sections of CAD Cell after Capping – 5-Year Dredging Plan.

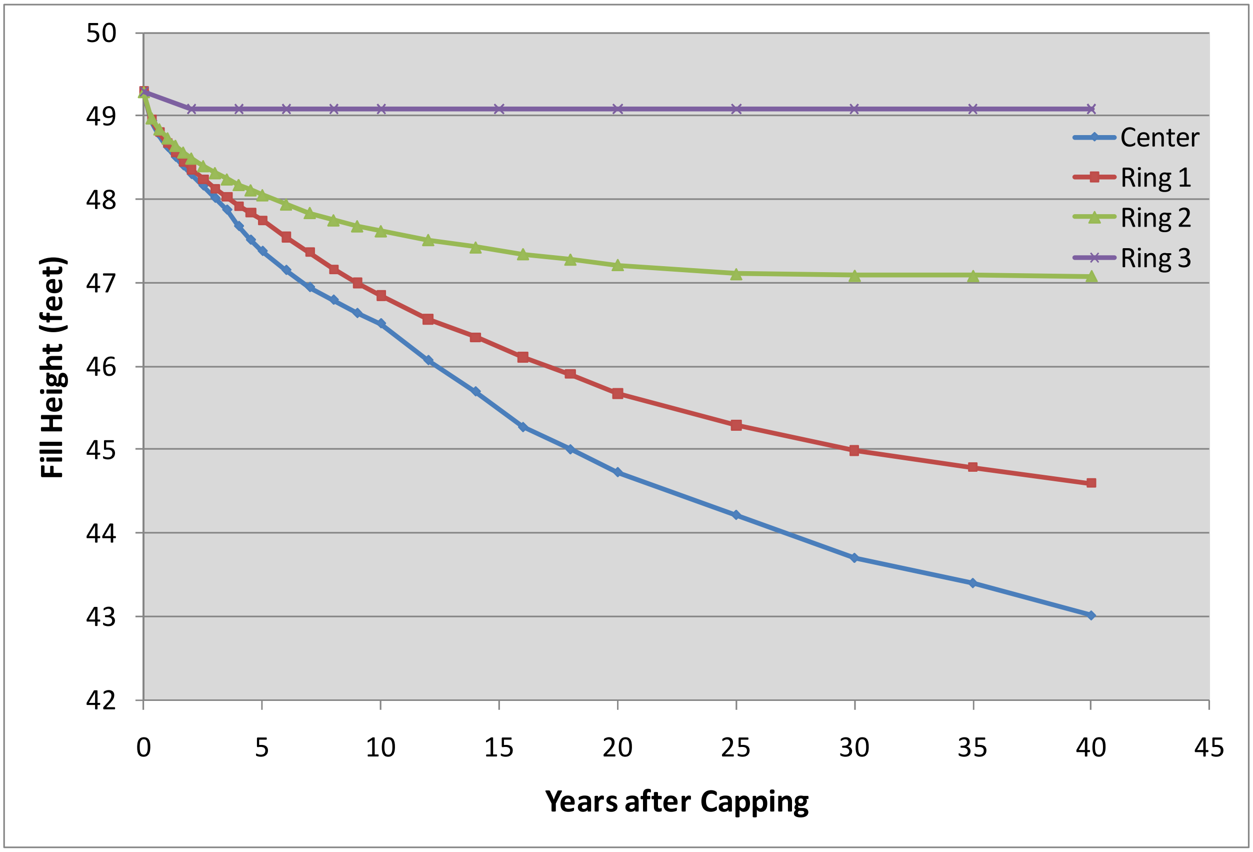


Figure 12b. Fill Height History of Four Sections of CAD Cell after Capping – 10-Year Dredging Plan.

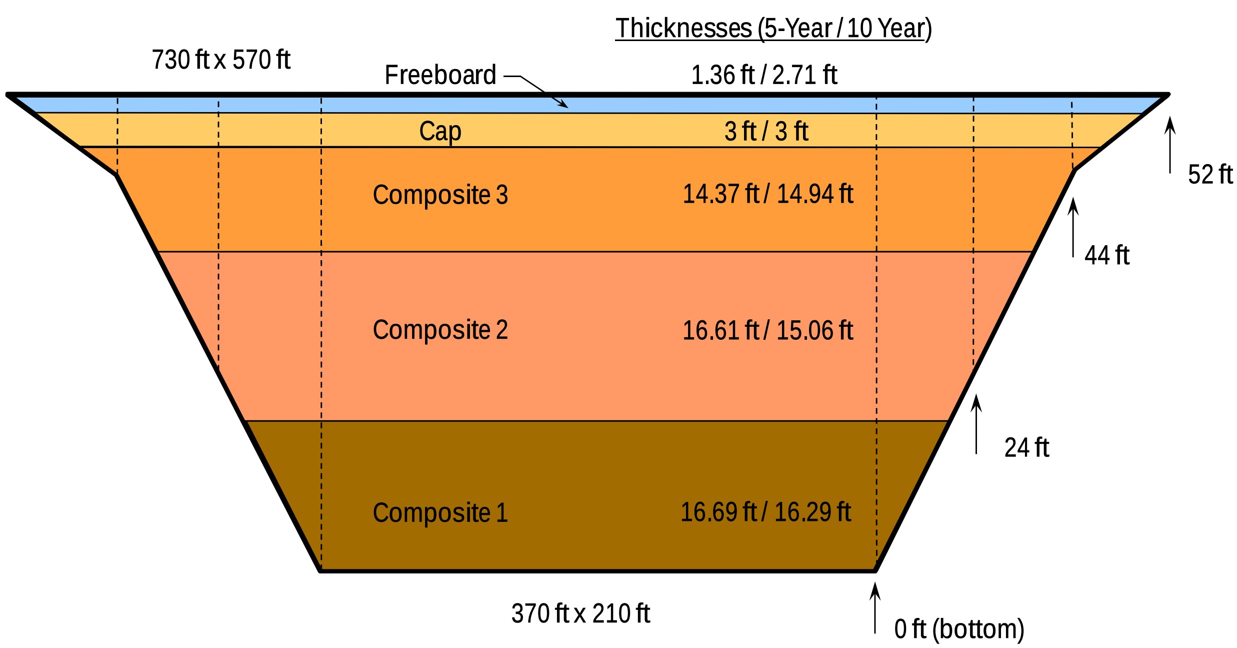


Figure 13. CAD Cell Status Immediately after Cap Placement.

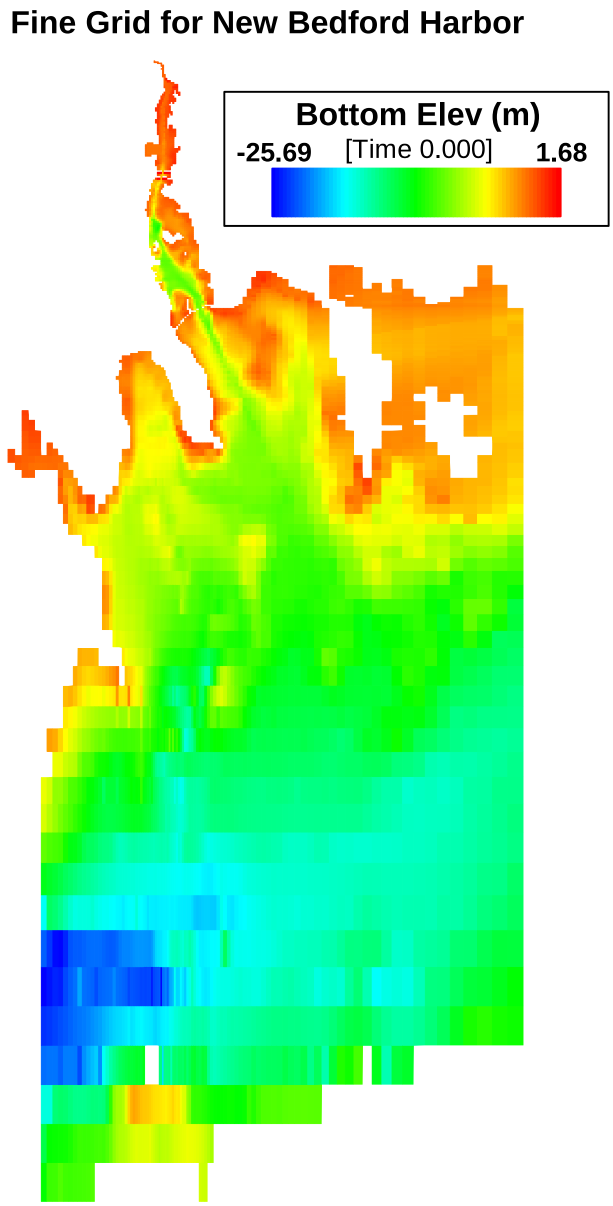


Figure 14. Cartesian Grid for New Bedford Harbor and a Portion of Buzzards Bay.

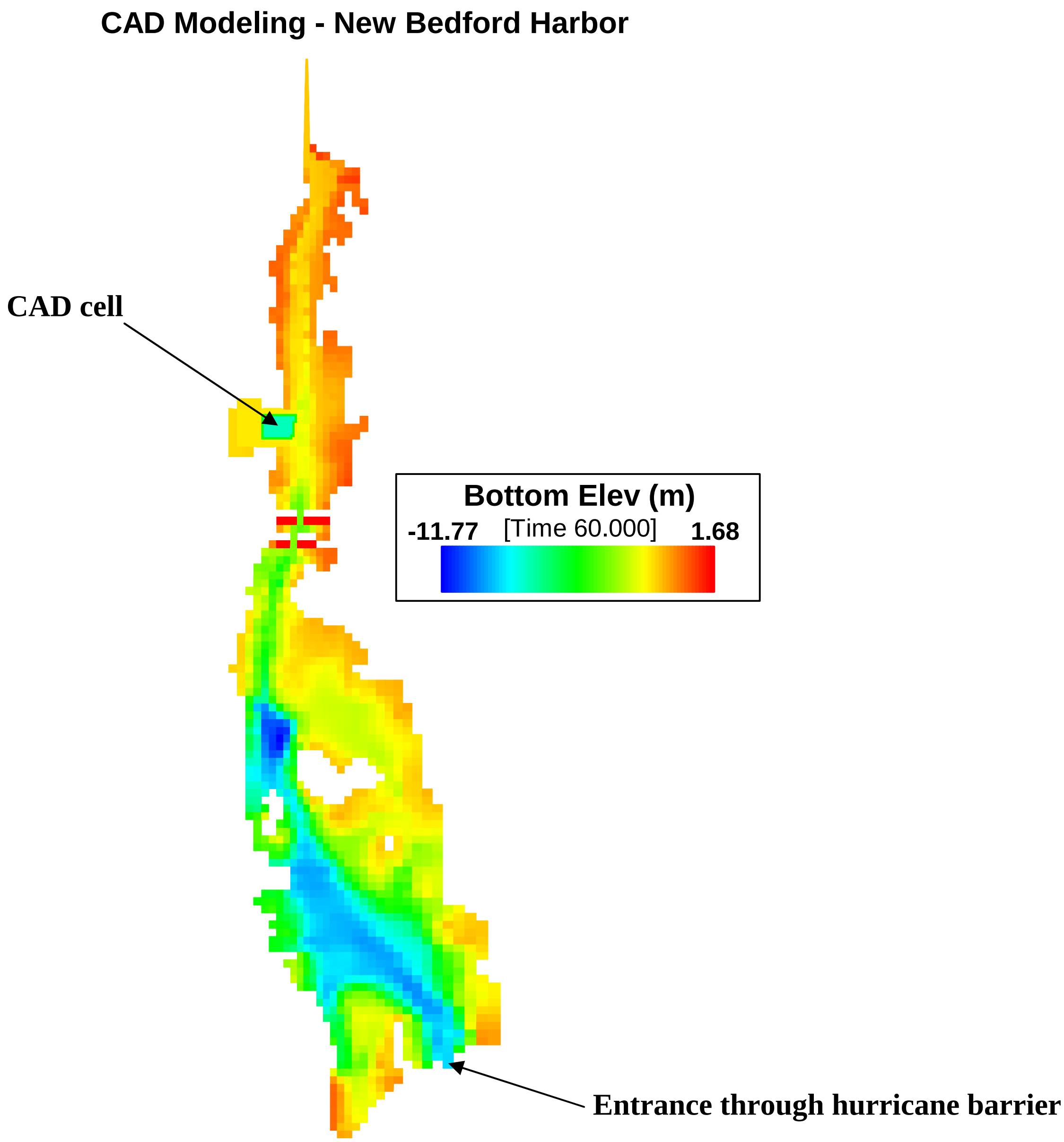


Figure 15. Cartesian Grid for Upper Harbor CAD Cell Model.

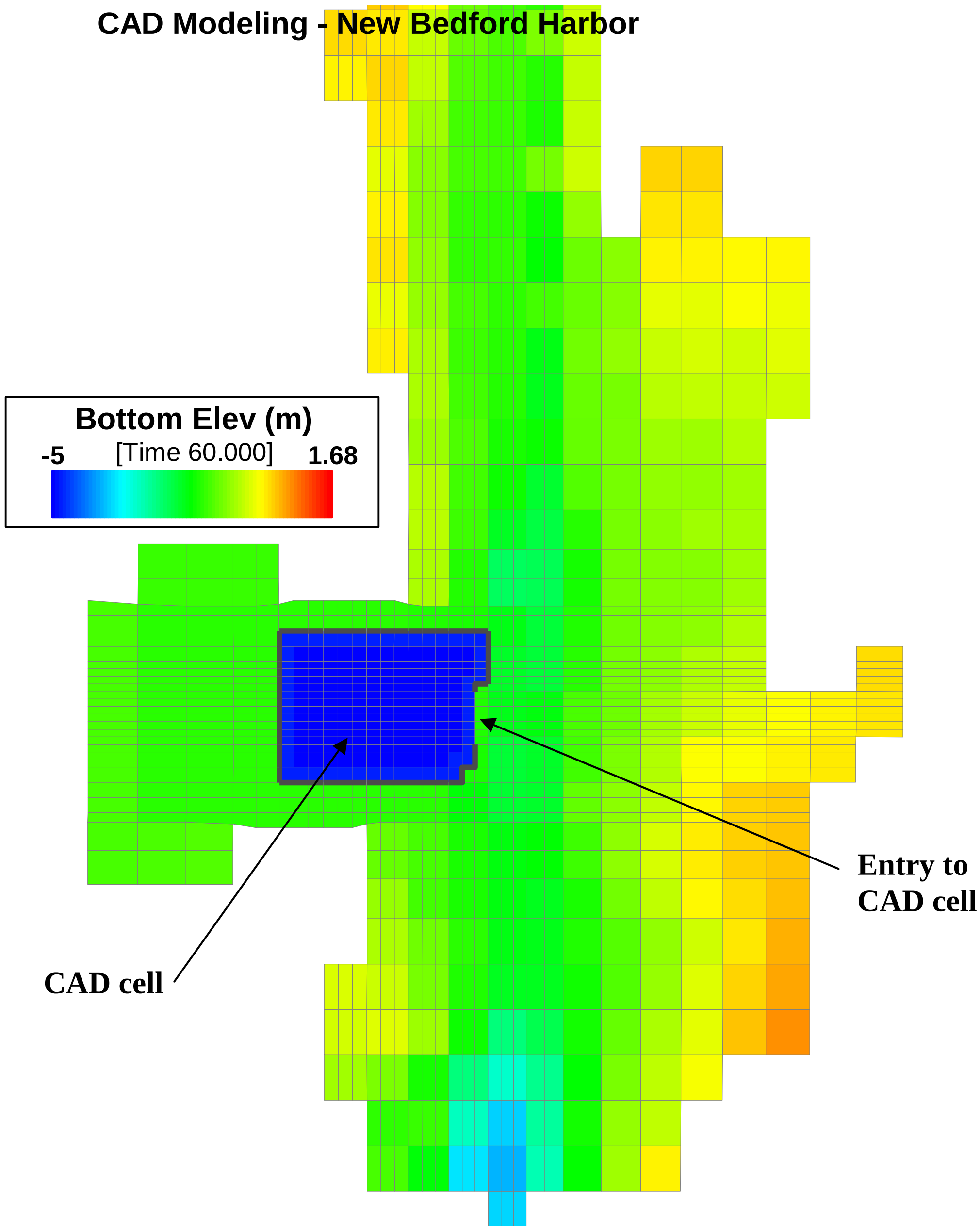


Figure 16. Cartesian Grid in Proximity to the Upper Harbor CAD Cell.

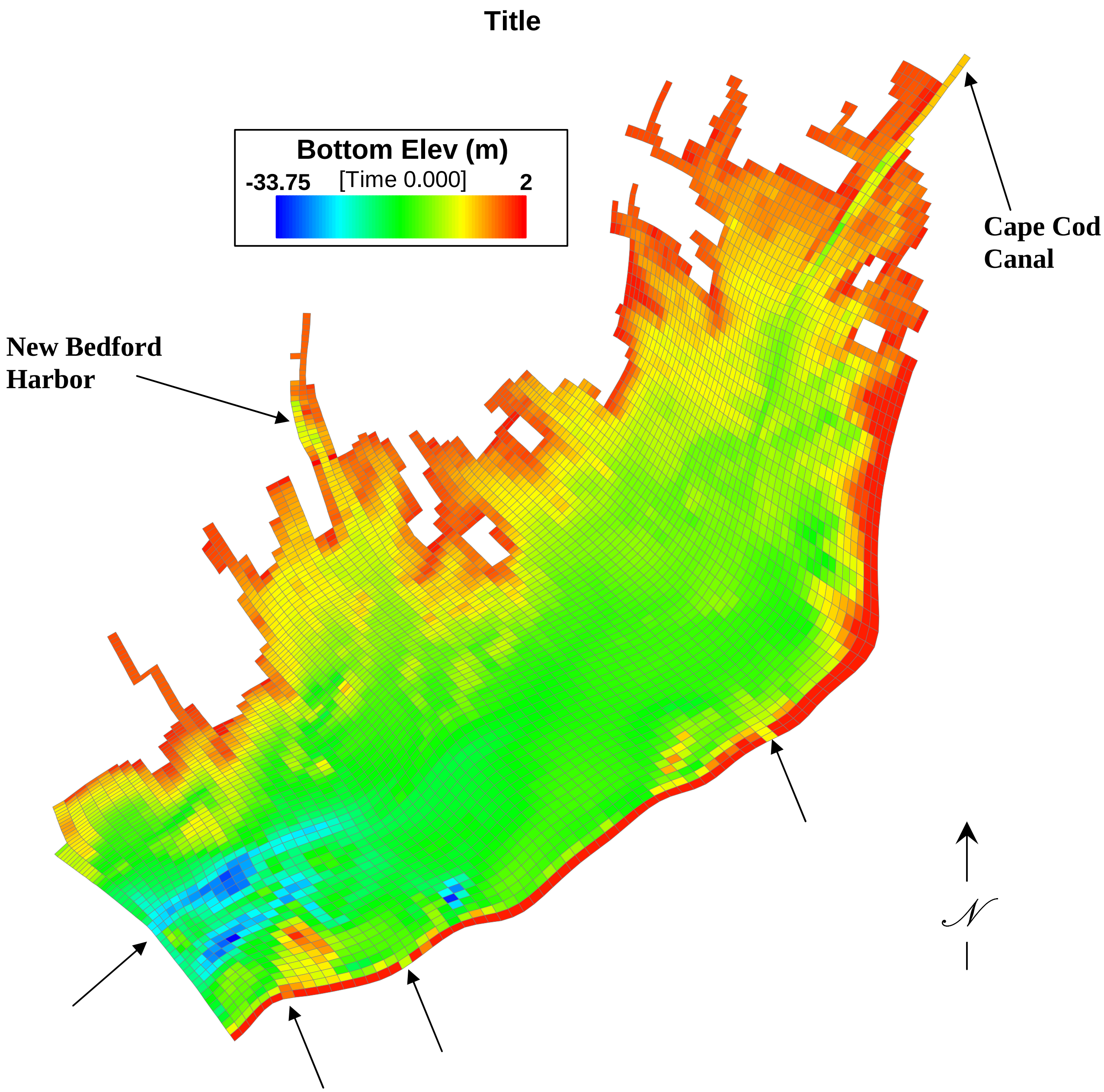


Figure 17. Curvilinear-Orthogonal Grid for the Buzzards Bay EFDC Model. (Unlabeled arrows are locations of open water boundaries.)

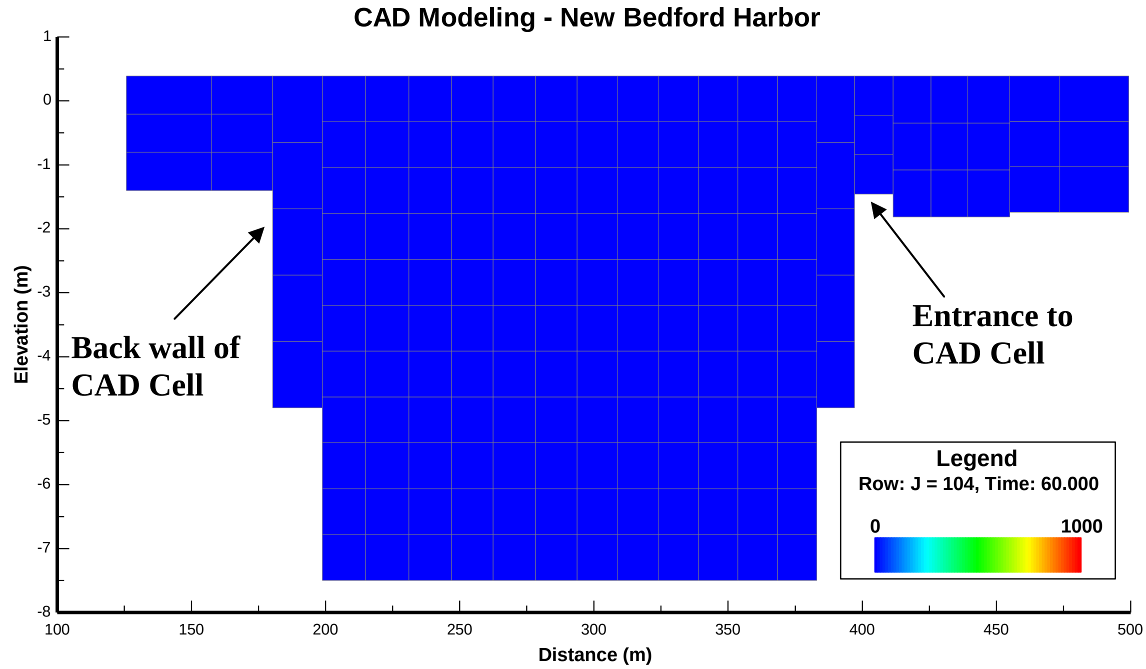


Figure 18. Vertical Slice through the Grid along the East-West Oriented Centerline of the CAD cell Showing the Number of Layers Used in Each Grid Cell.

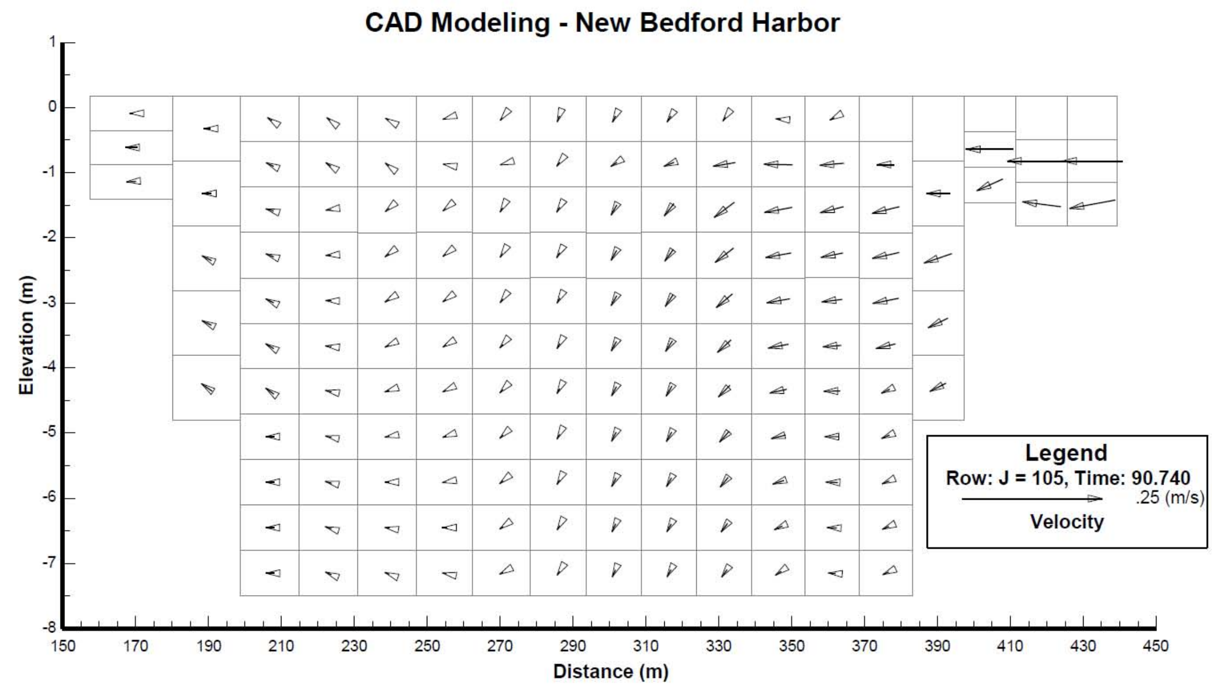


Figure 19. Velocity Vectors at One Time Step during a Flood Tide for the Open CAD Cell. (The north direction is into the page.)

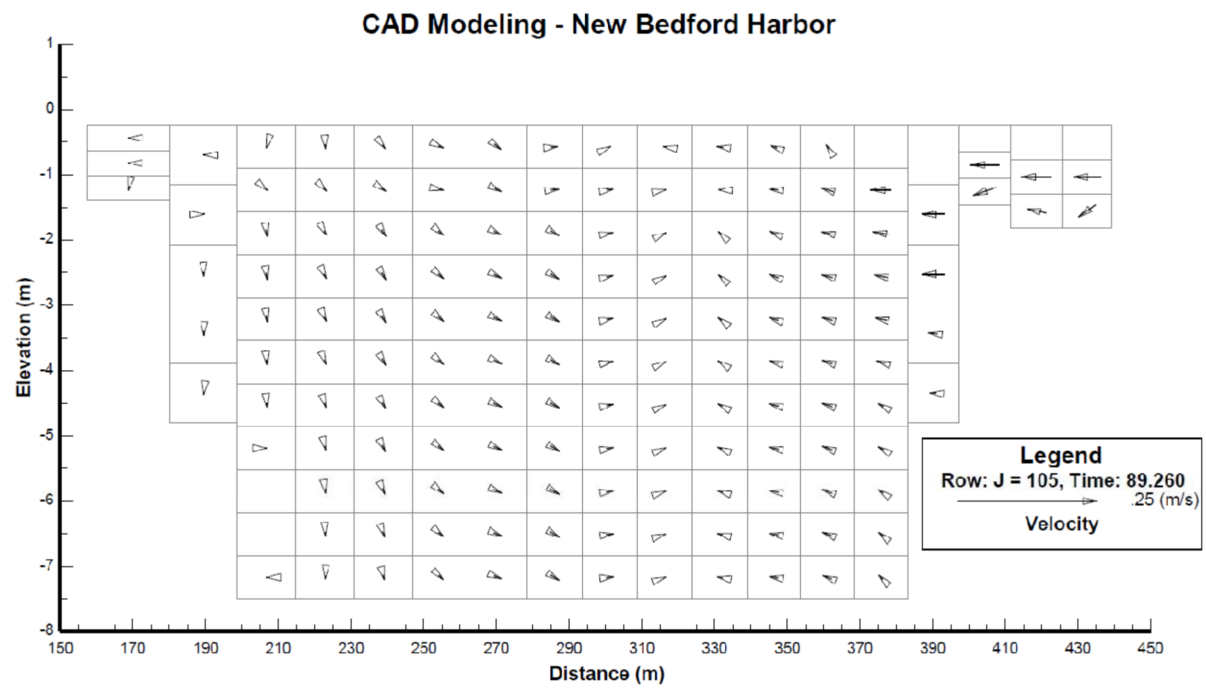


Figure 20. Velocity Vectors at a Different Stage of a Flood Tide for the Open CAD Cell. (The north direction is into the page.)

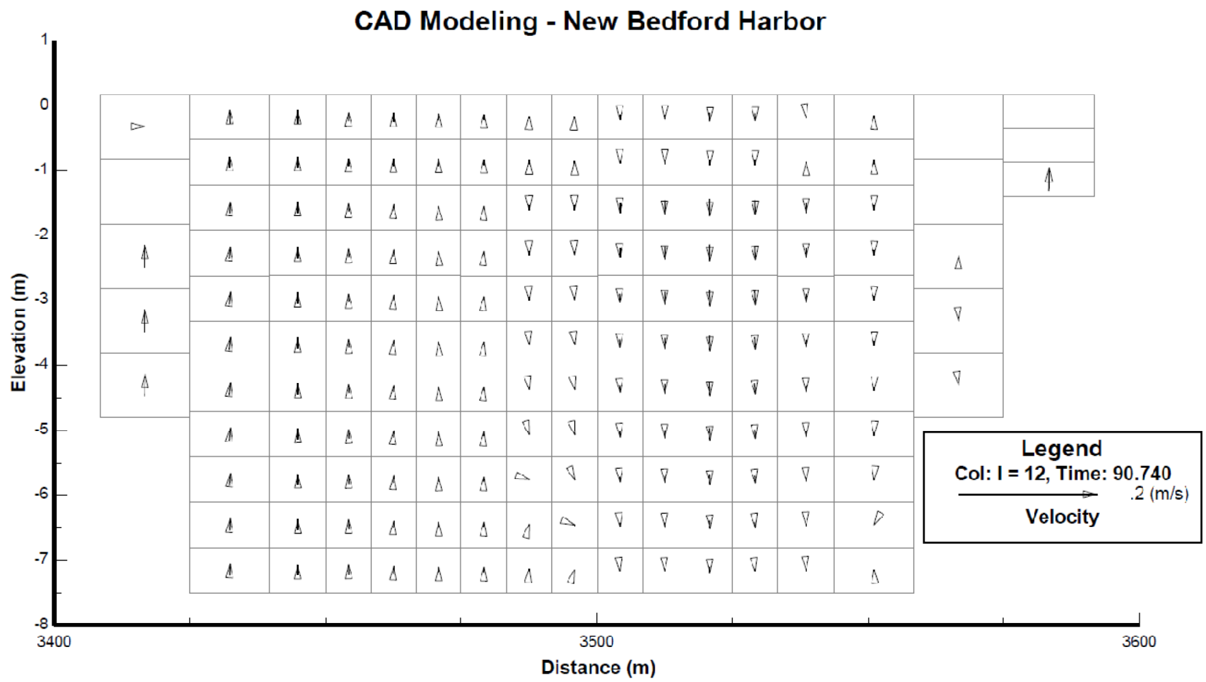


Figure 21. Velocity Vectors in a North-South Oriented Vertical Plane for the Open CAD Cell. North is to the right, south is to the left, and west is into the page.

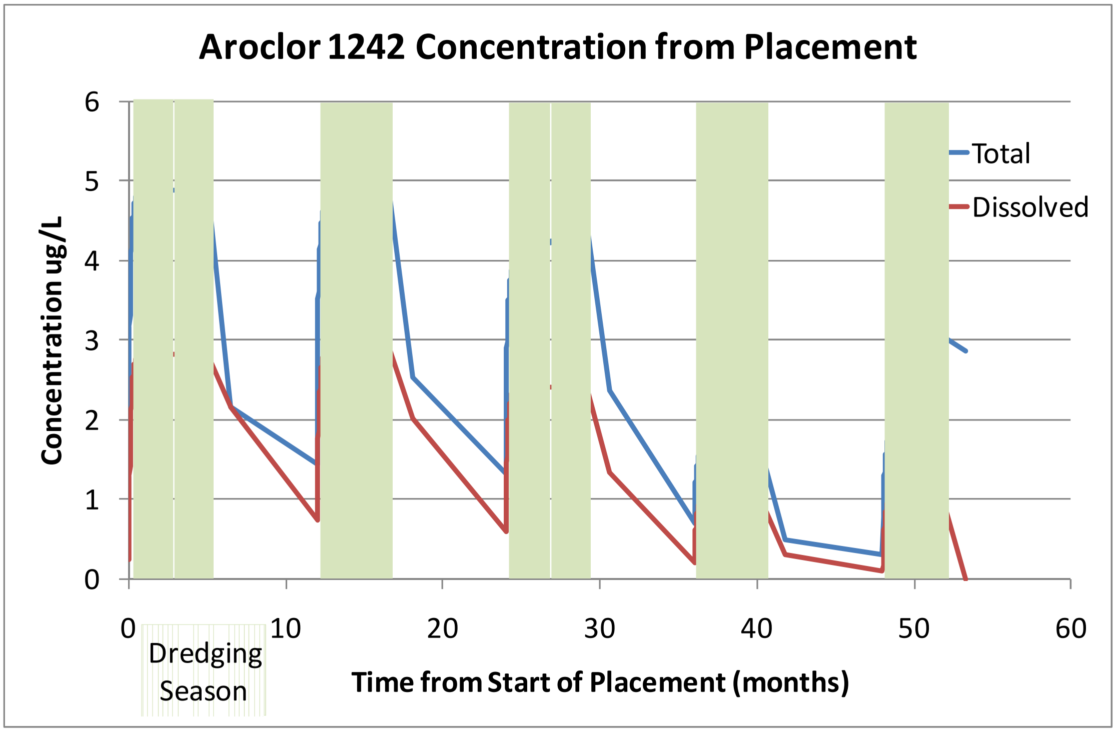


Figure 22a. Concentration of PCBs Aroclor 1242 in CAD Cell Water Prior to Capping – 5-Year Dredging Plan.

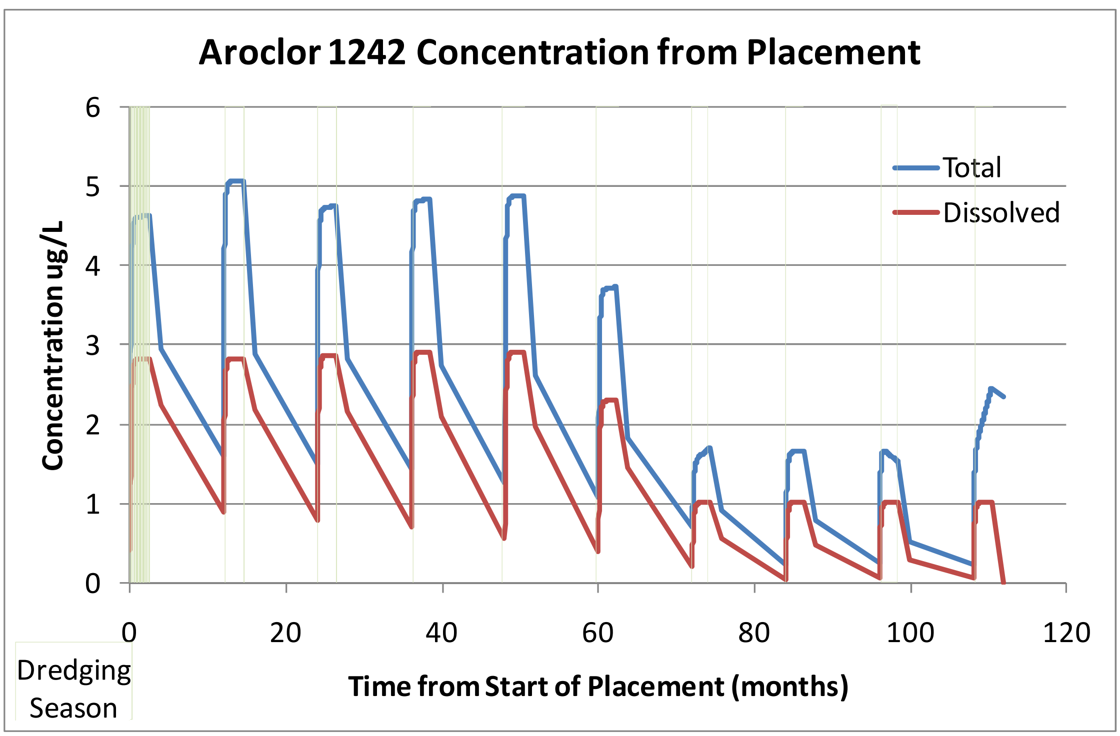


Figure 22b. Concentration of PCBs Aroclor 1242 in CAD Cell Water Prior to Capping – 10-Year Dredging Plan.

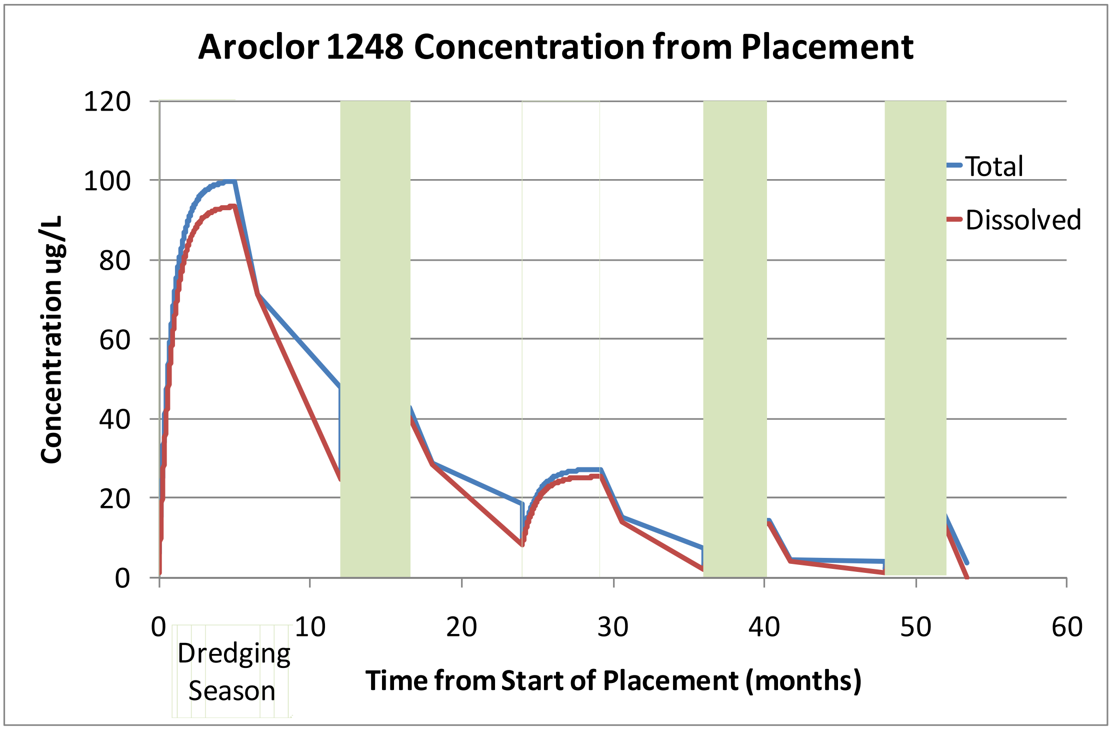


Figure 23a. Concentration of PCBs Aroclor 1248 in CAD Cell Water Prior to Capping – 5-Year Dredging Plan.

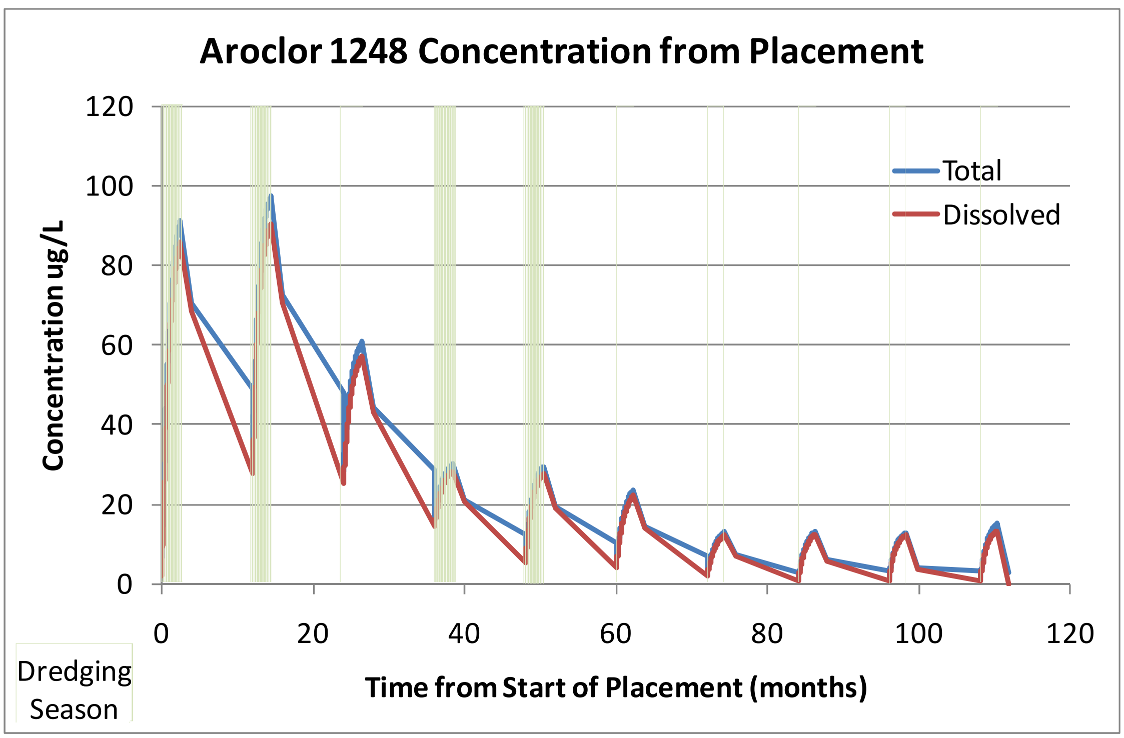


Figure 23b. Concentration of PCBs Aroclor 1248 in CAD Cell Water Prior to Capping – 10-Year Dredging Plan.

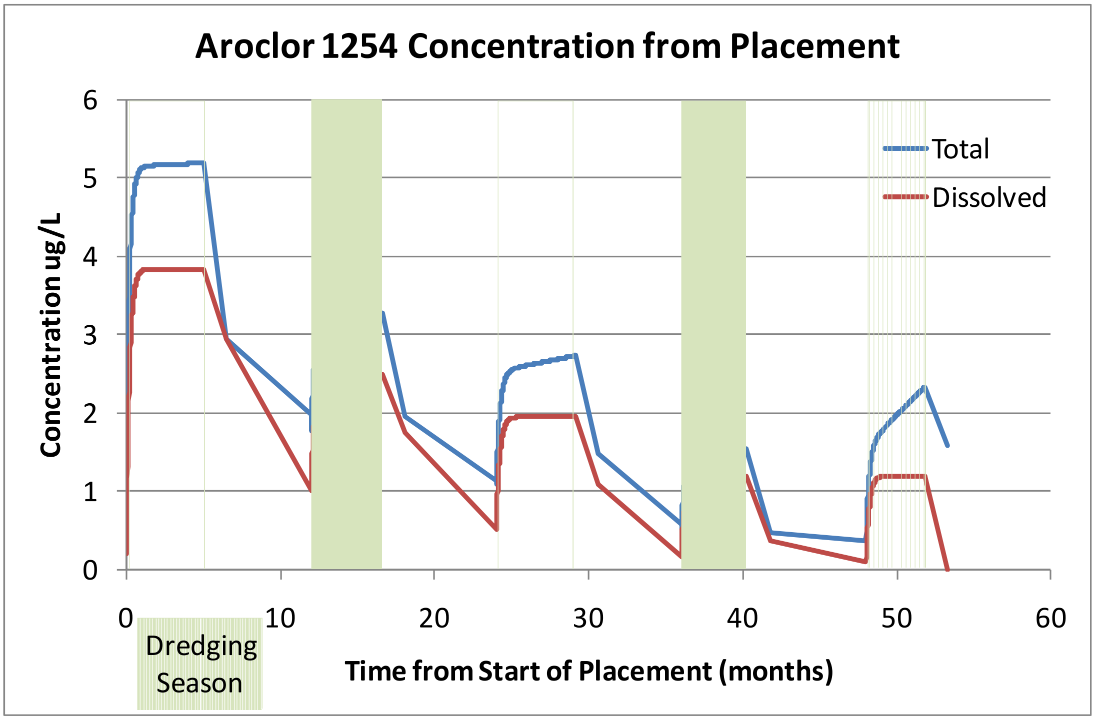


Figure 24a. Concentration of PCBs Aroclor 1254 in CAD Cell Water Prior to Capping – 5-Year Dredging Plan.

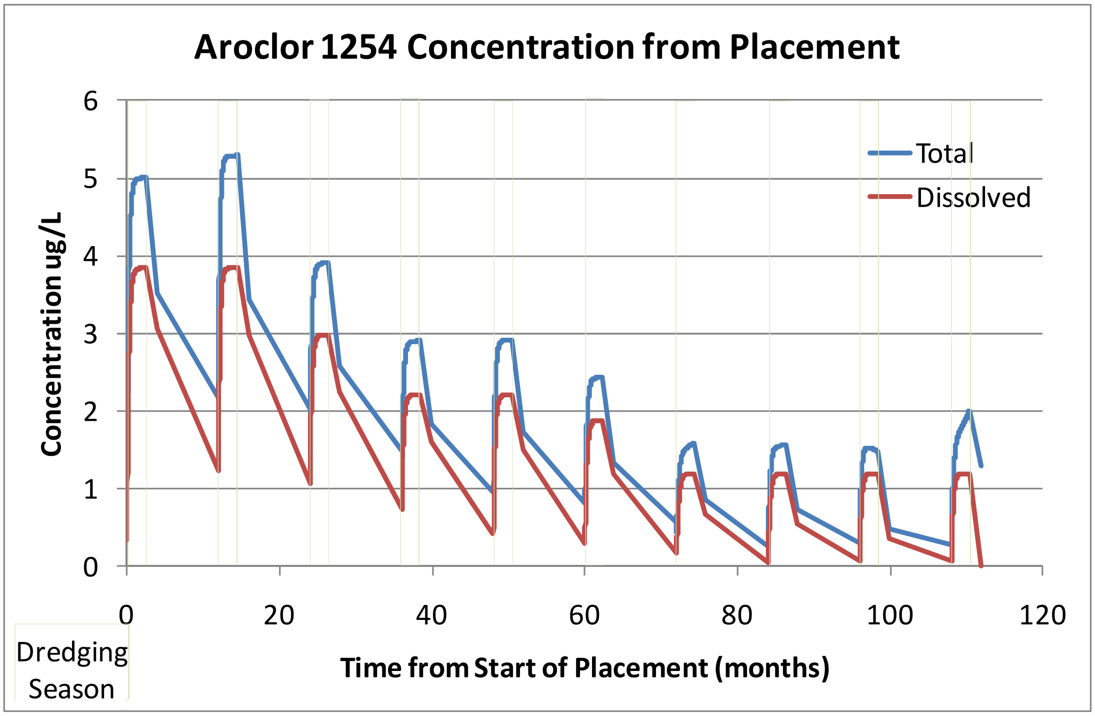


Figure 24b. Concentration of PCBs Aroclor 1254 in CAD Cell Water Prior to Capping – 10-Year Dredging Plan.

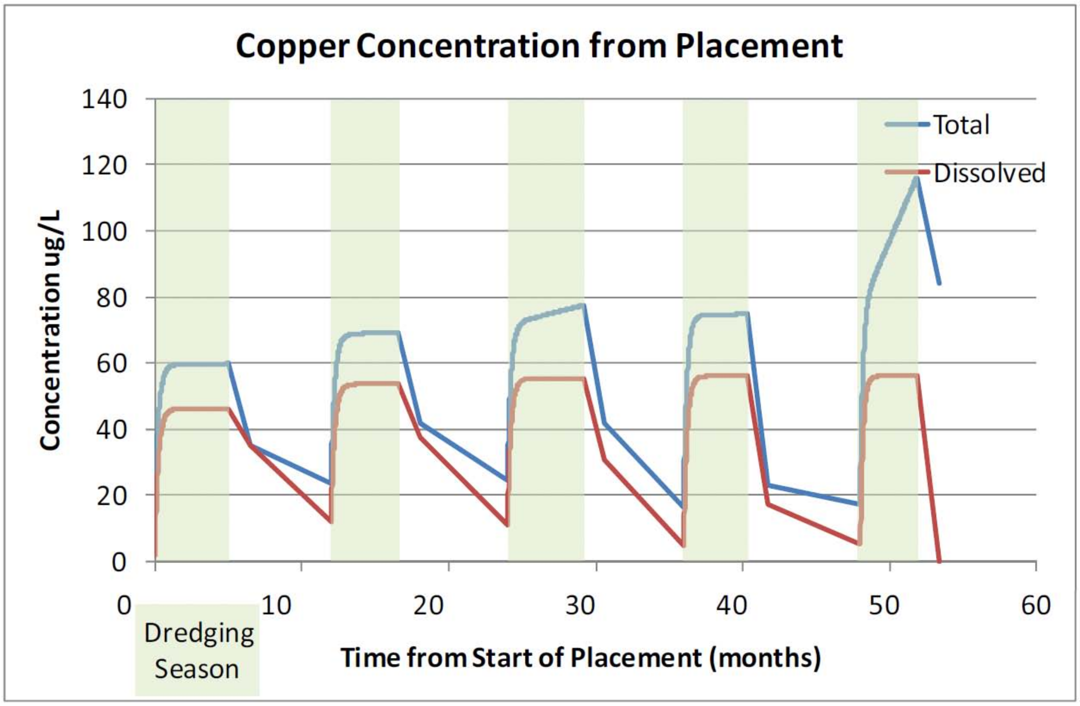


Figure 25a. Concentration of Copper in CAD Cell Water Prior to Capping – 5-Year Dredging Plan.

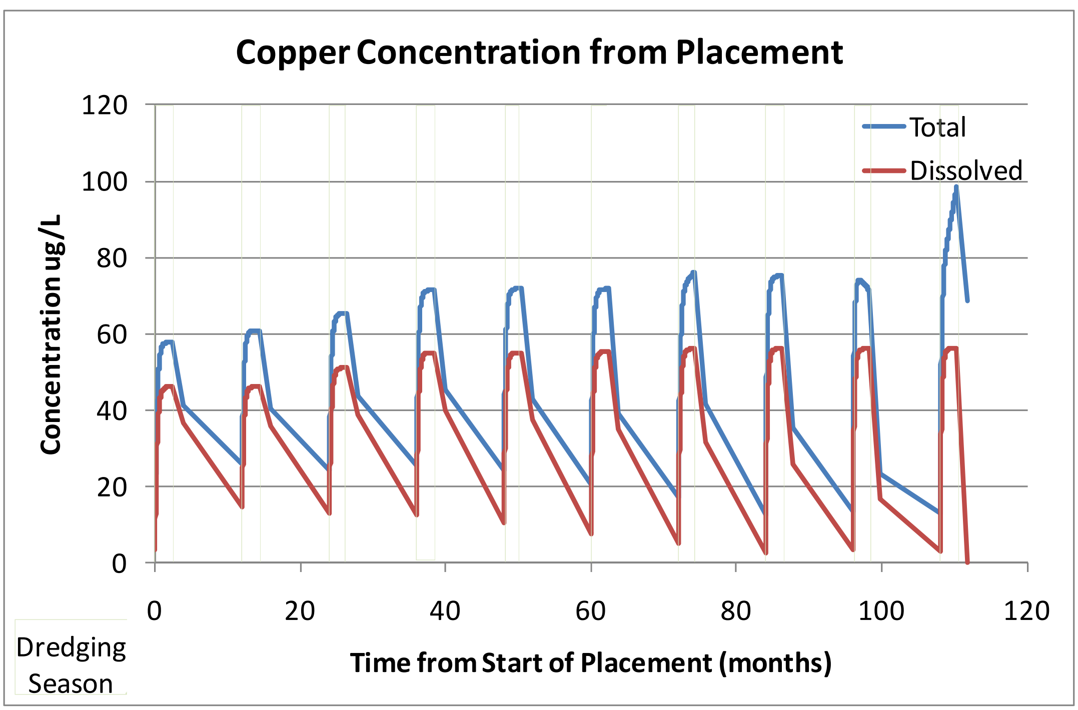


Figure 25b. Concentration of Copper in CAD Cell Water Prior to Capping – 10-Year Dredging Plan.

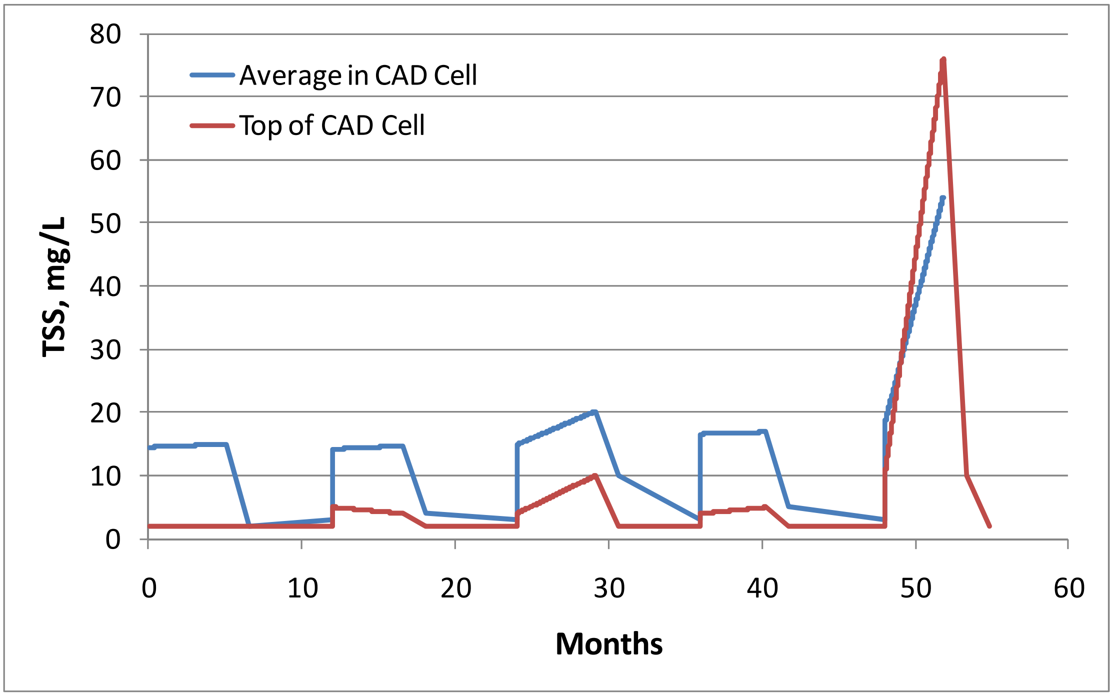


Figure 26a. Total Suspended Solids Concentration in CAD Cell as a Function of Time – 5-Year Dredging Plan.

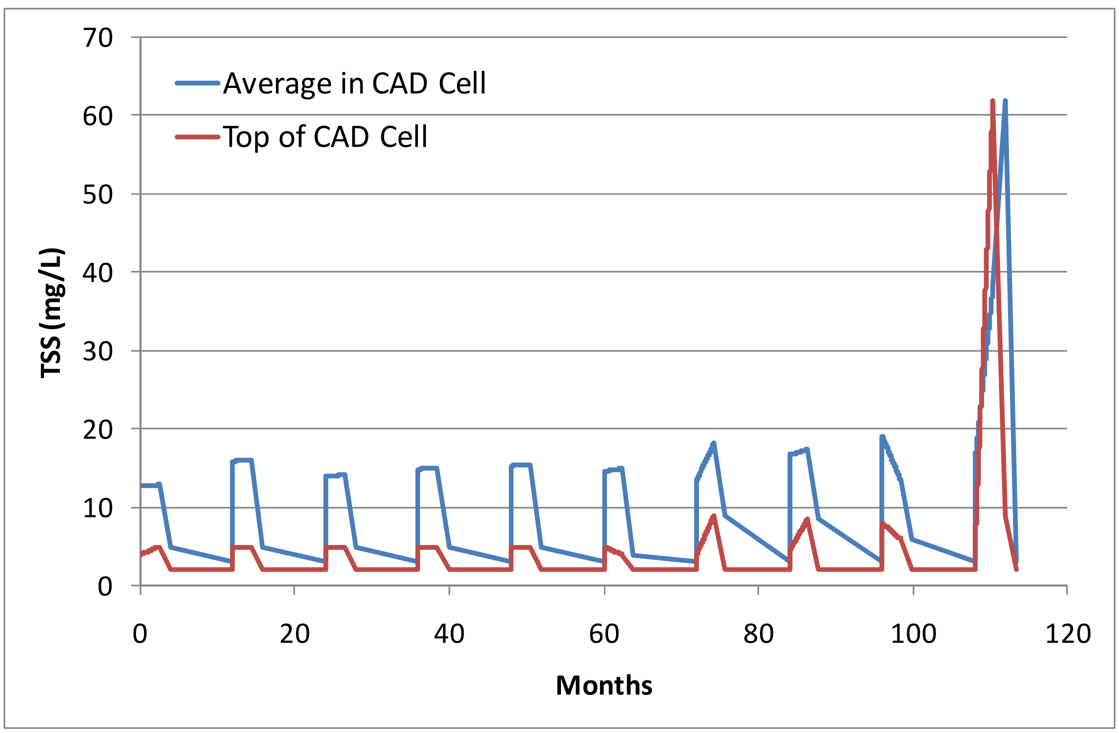


Figure 26b. Total Suspended Solids Concentration in CAD Cell as a Function of Time – 10-Year Dredging Plan.

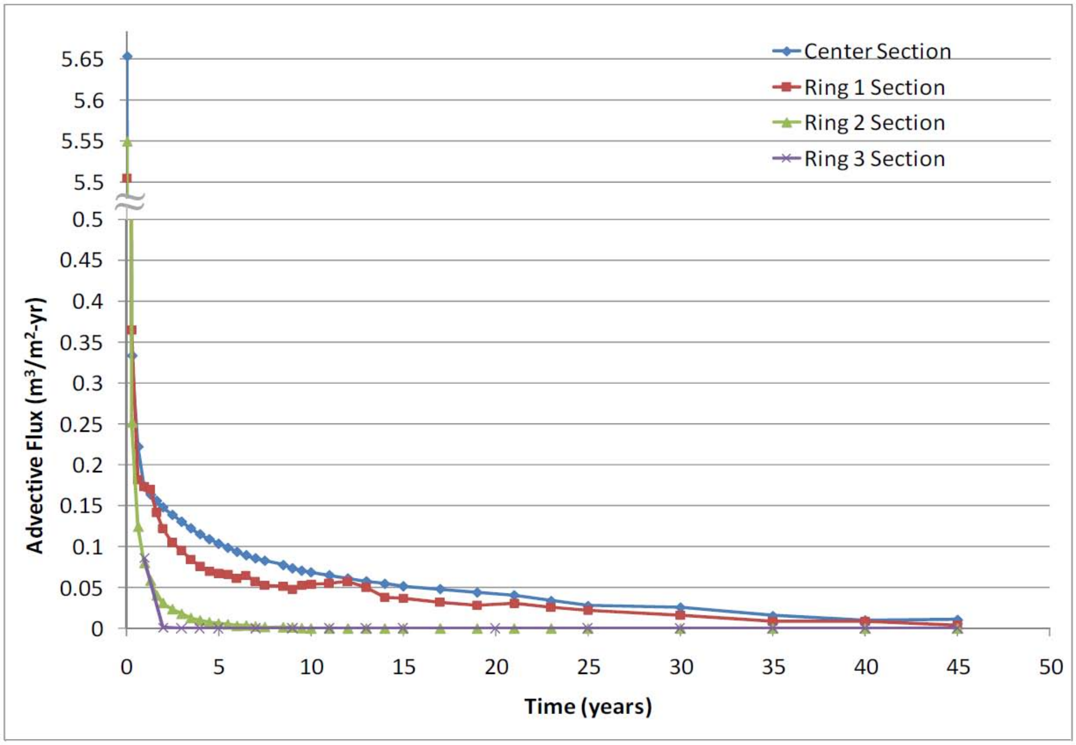


Figure 27a. Water Flux through the Four Sections of the Cap as a Function of Time – 5-Year Dredging Plan.

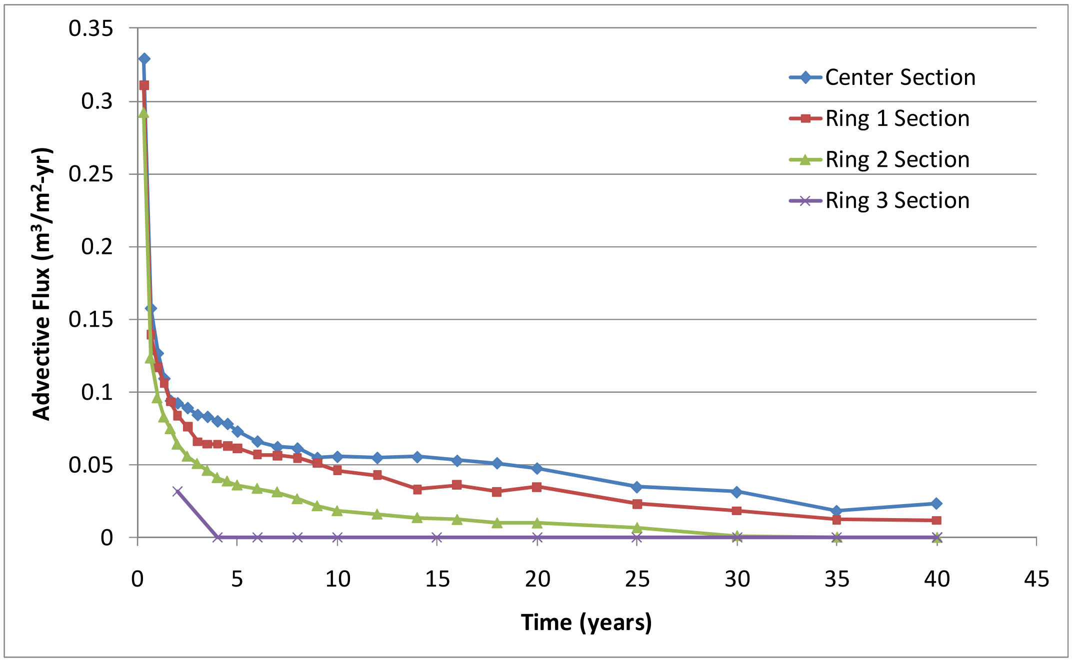


Figure 27b. Water Flux through the Four Sections of the Cap as a Function of Time – 10-Year Dredging Plan.

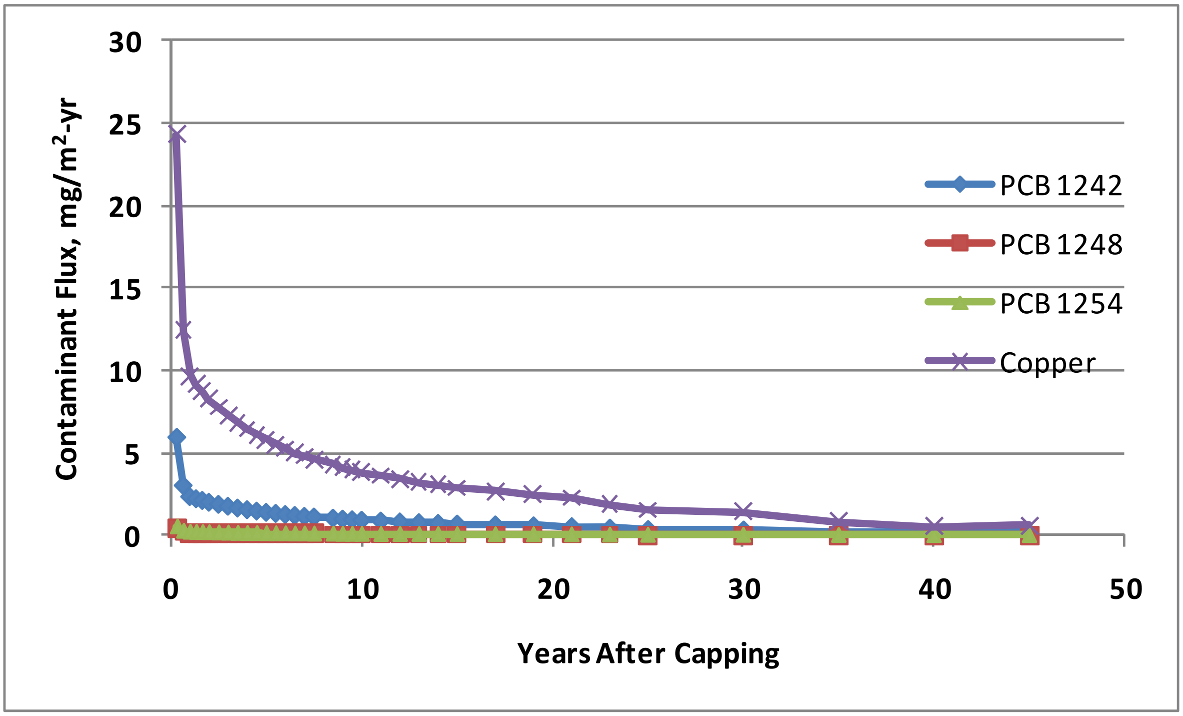


Figure 28a. Predicted Flux of Contaminants into the Cap – 5-Year Dredging Plan.

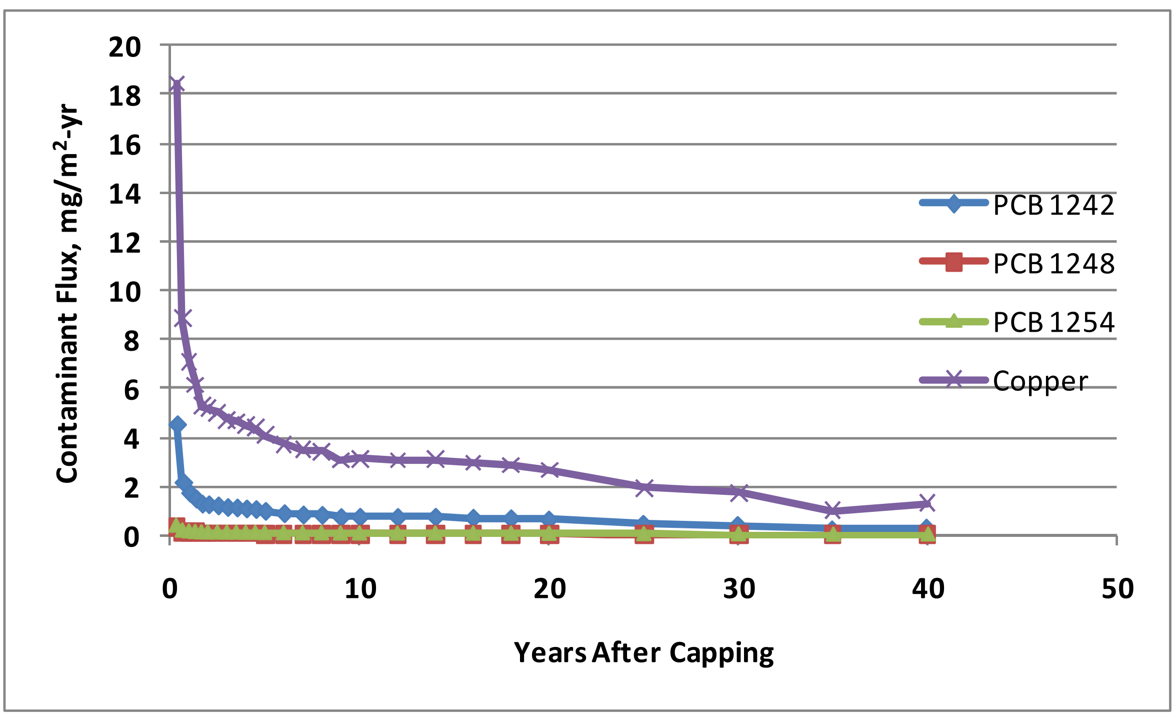


Figure 28b. Predicted Flux of Contaminants into the Cap – 10-Year Dredging Plan.

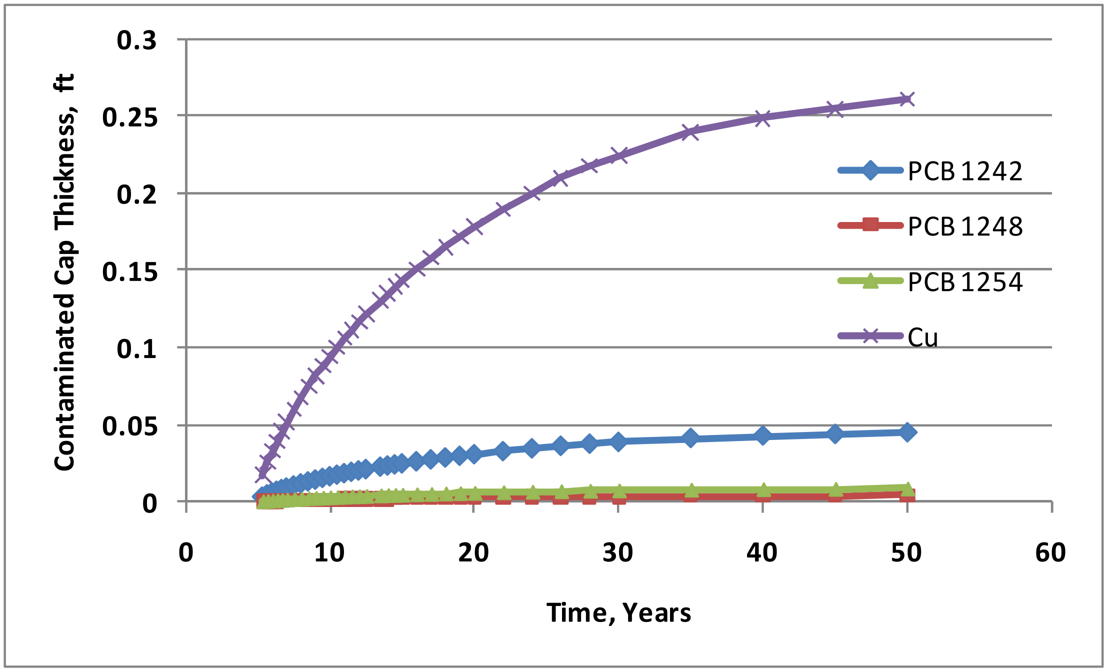


Figure 29a. Predicted Contaminant Migration into Cap – 5-Year Dredging Plan.

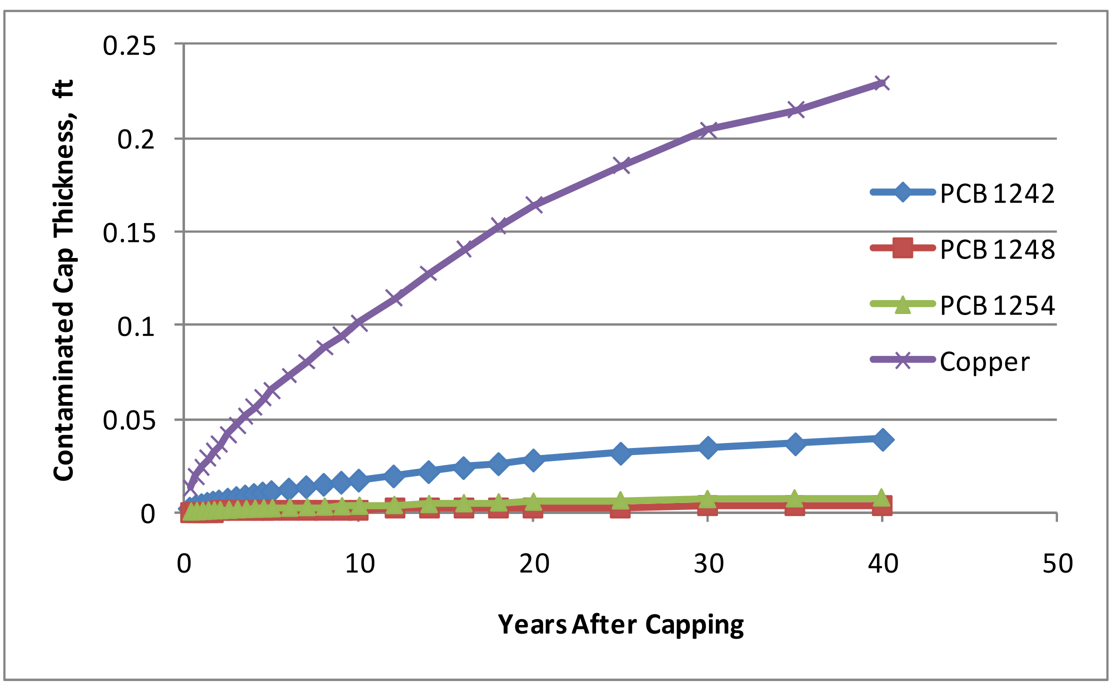


Figure 29b. Predicted Contaminant Migration into Cap – 10-Year Dredging Plan.

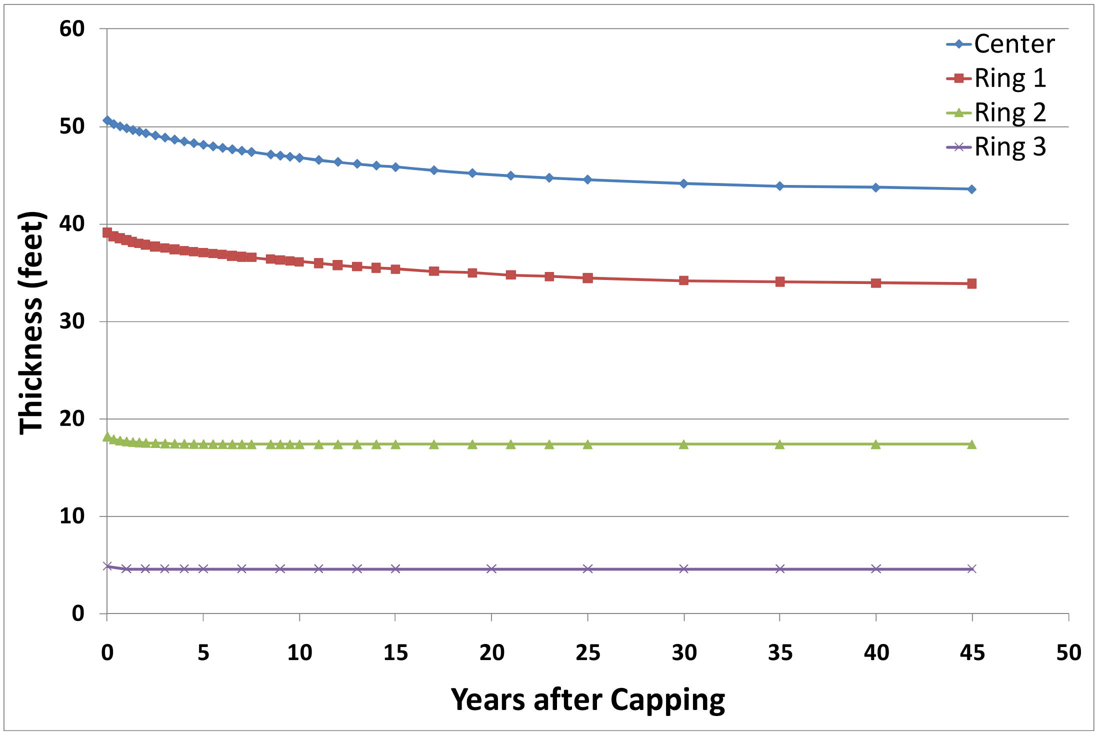


Figure 30a. Thickness History of Four Sections of CAD Cell after Capping – 5-Year Dredging Plan.

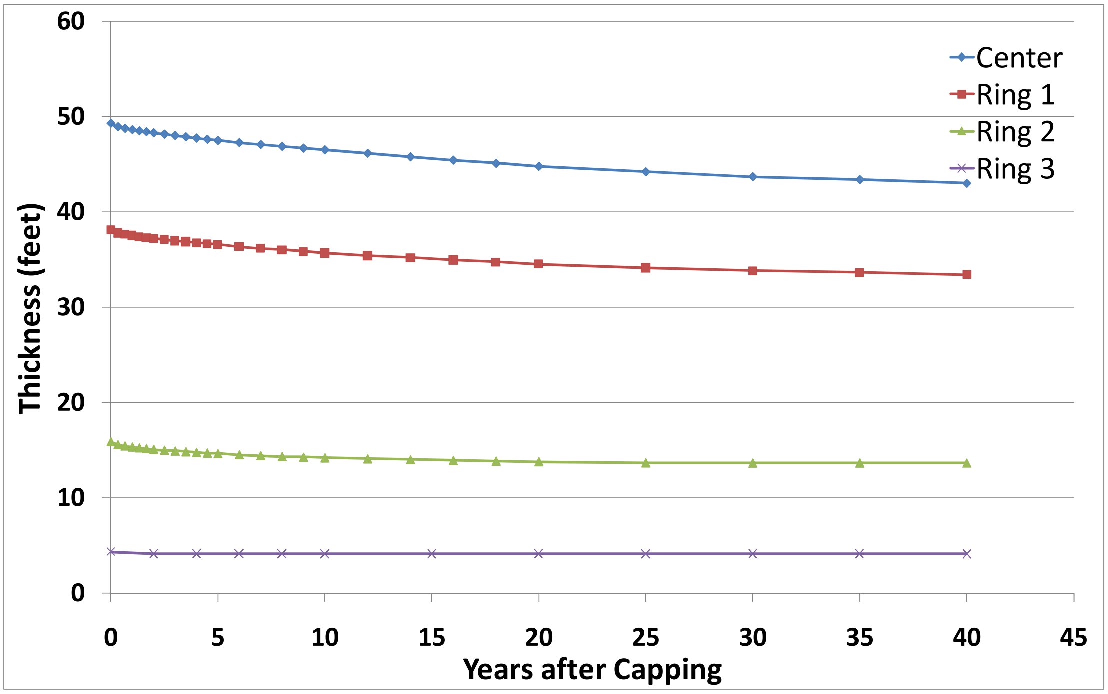


Figure 30b. Thickness History of Four Sections of CAD Cell after Capping – 10-Year Dredging Plan.

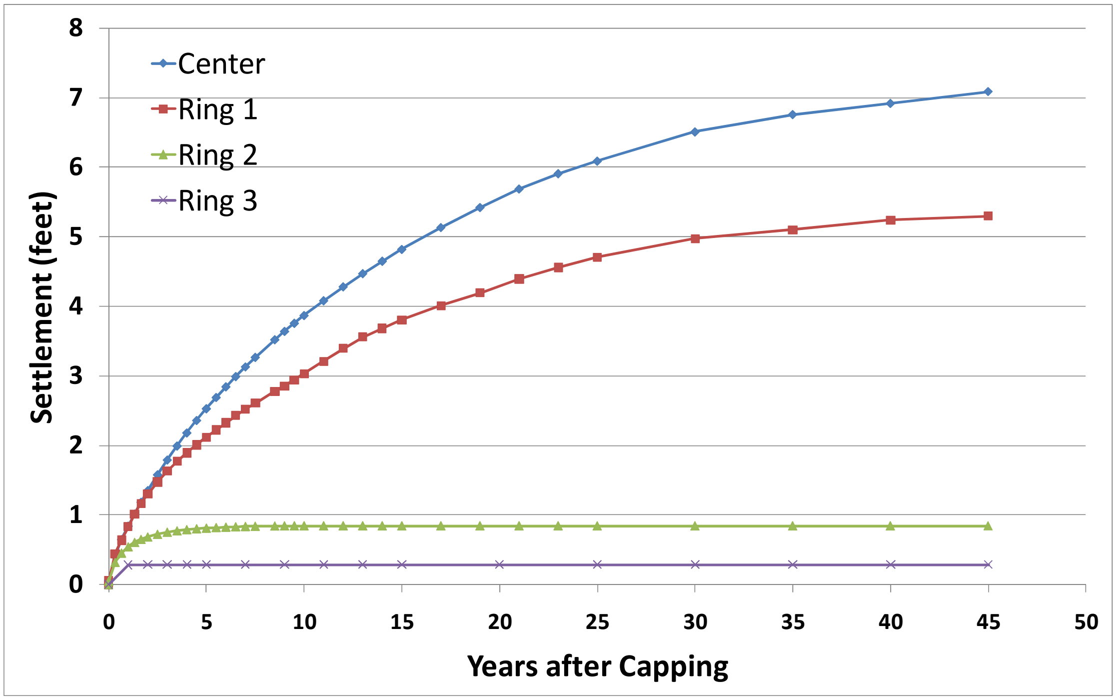


Figure 31a. Settlement History of Four Sections of CAD Cell after Capping – 5-Year Dredging Plan.

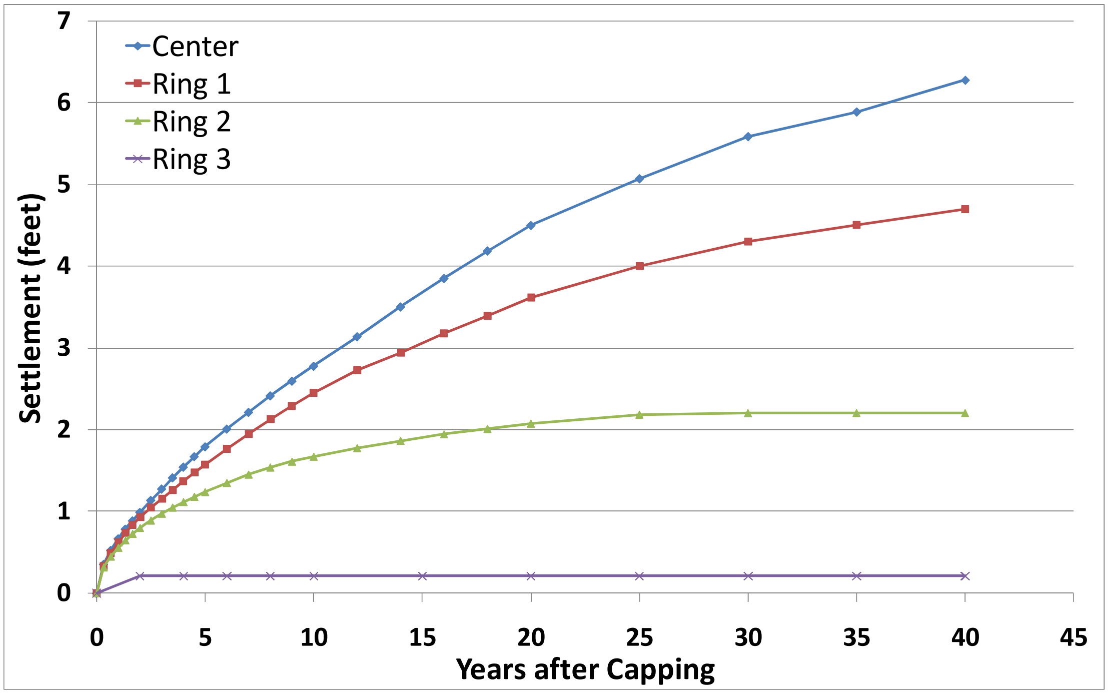


Figure 31b. Settlement History of Four Sections of CAD Cell after Capping – 10-Year Dredging Plan.

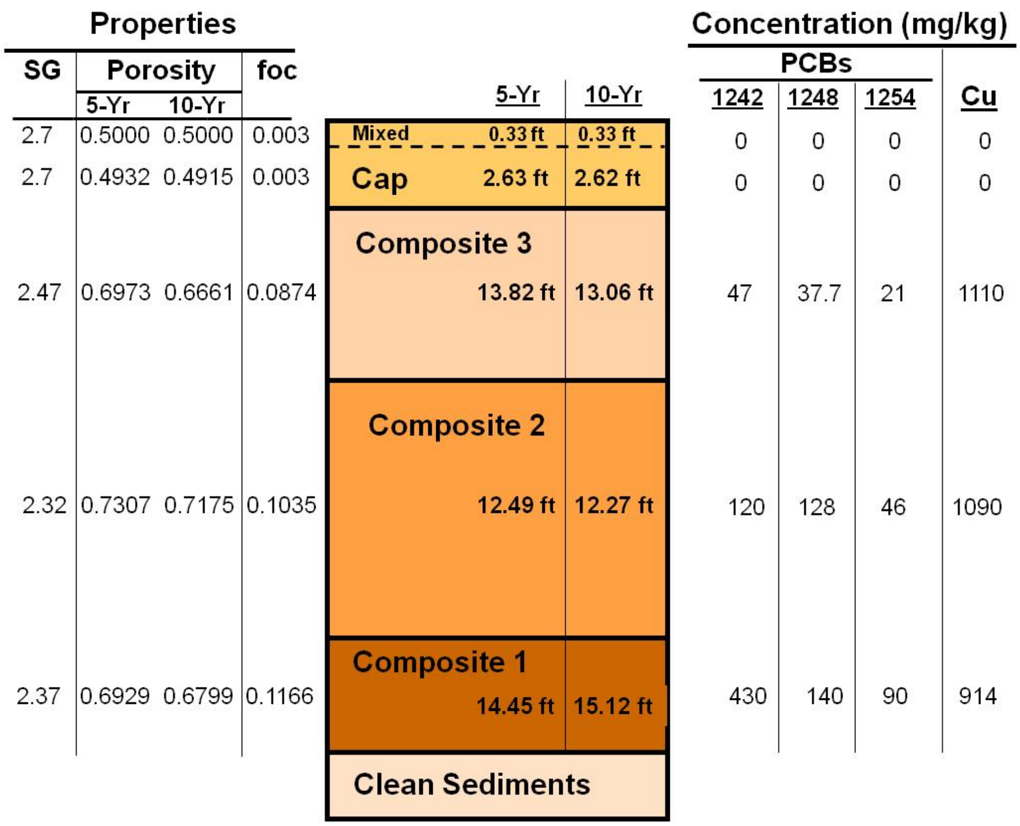


Figure 32. Conceptual Model of the CAD Center Section for PSDDF and CAP Runs.

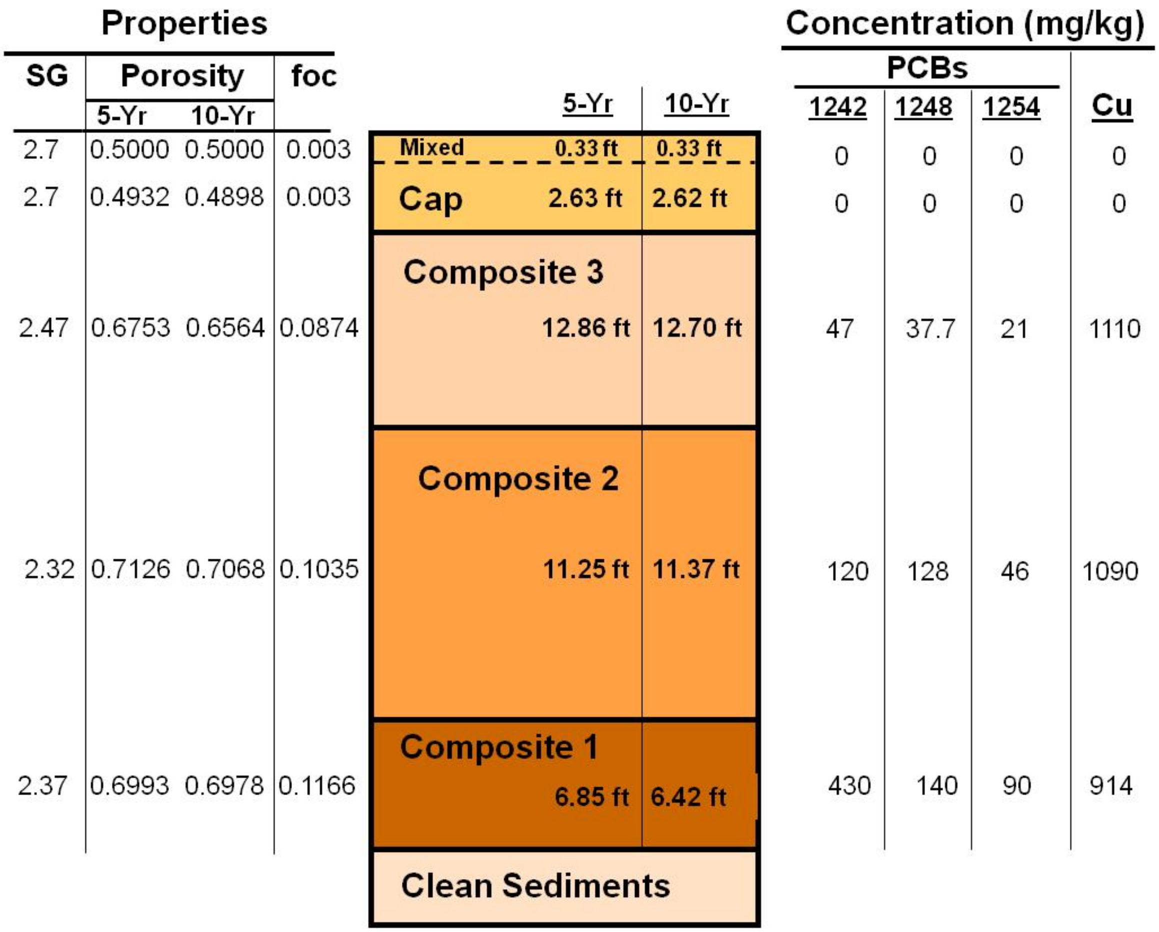


Figure 33. Conceptual Model of the CAD Ring 1 Section for PSDDF and CAP Runs.

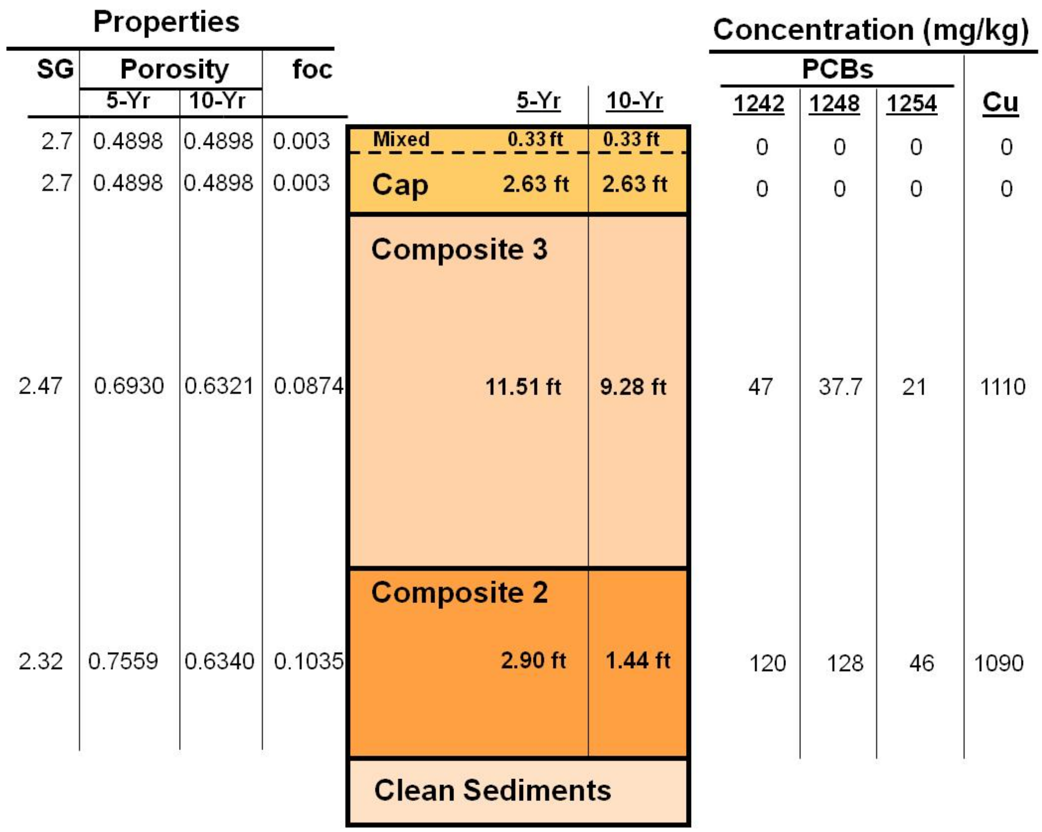


Figure 34. Conceptual Model of the CAD Ring 2 Section for PSDDF and CAP Runs.

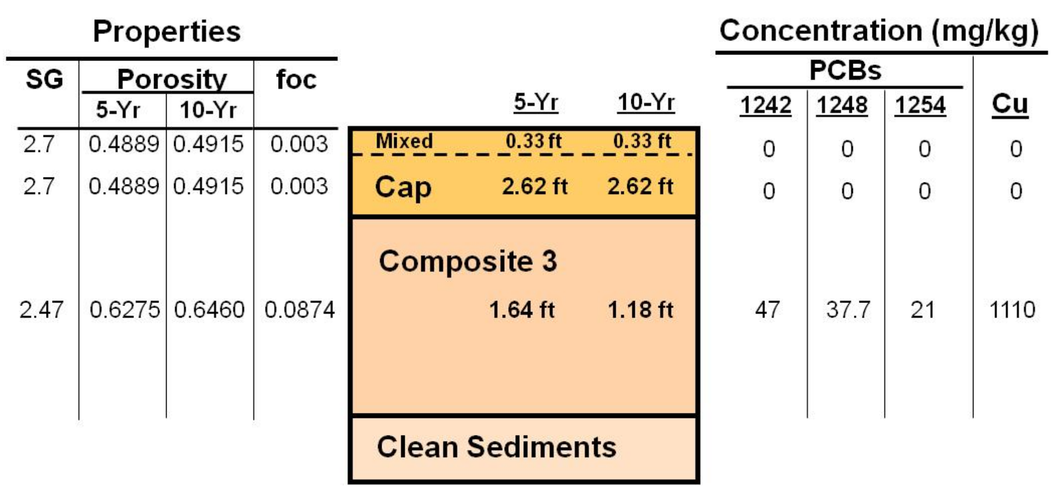


Figure 35. Conceptual Model of the CAD Ring 3 Section for PSDDF and CAP Runs.

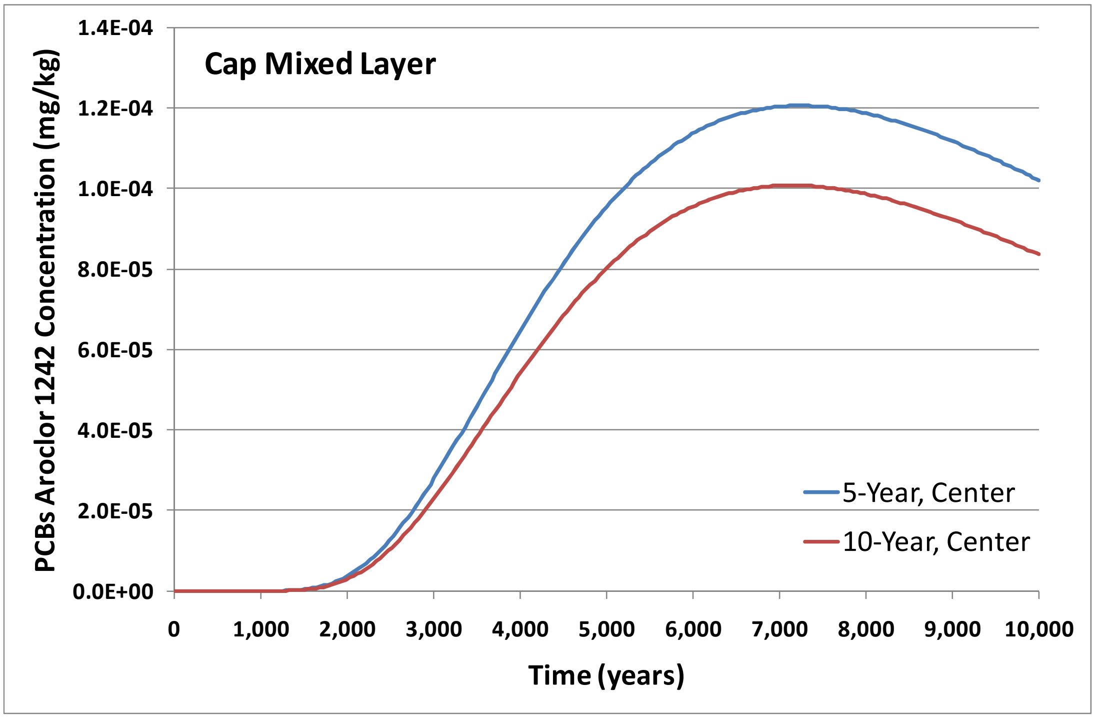


Figure 36. Predicted Long-Term Cap PCBs Aroclor 1242 Concentration for the Lower New Bedford Harbor CAD Cell Bioactive Zone.

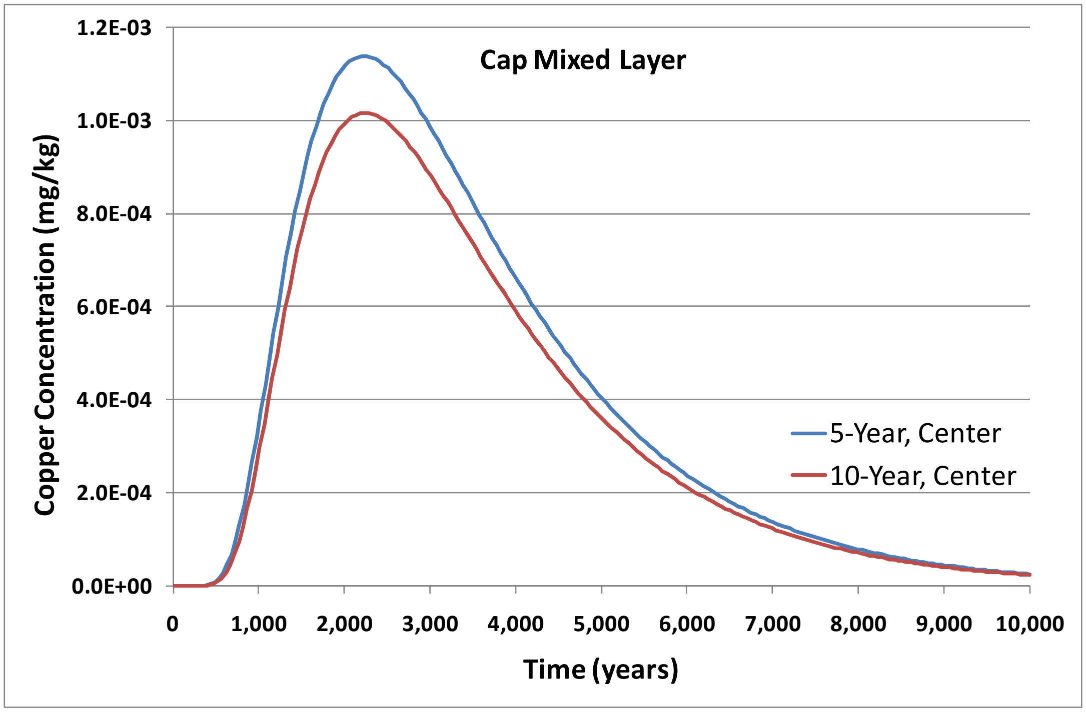


Figure 37. Predicted Long-Term Cap Copper Concentration for the Lower New Bedford Harbor CAD Cell Bioactive Zone.

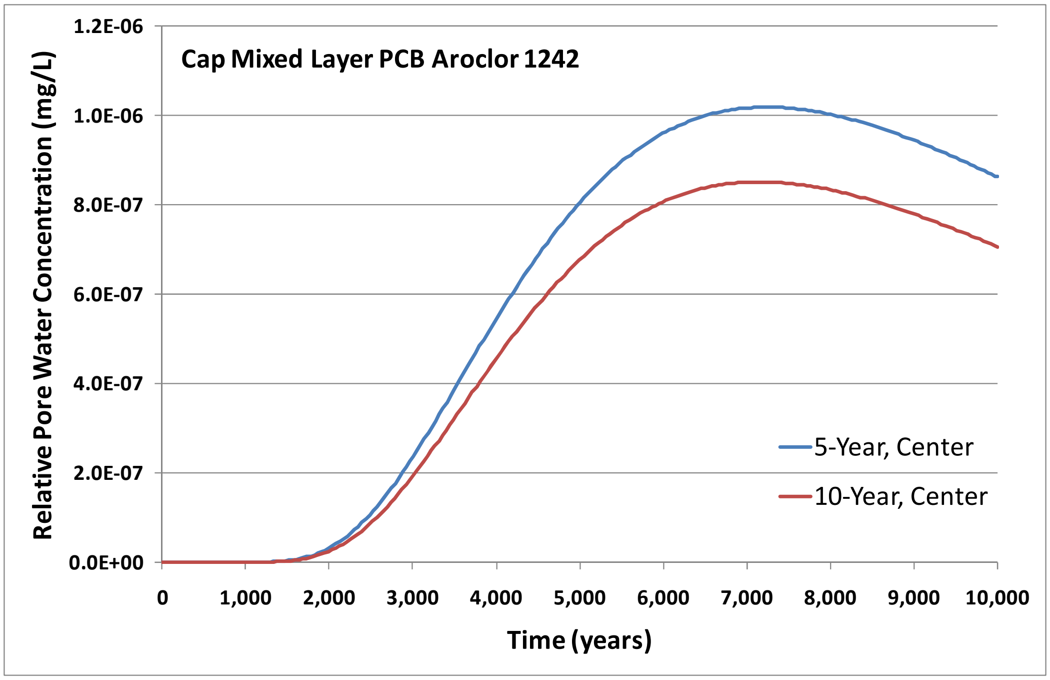


Figure 38. Predicted Cap Bioactive Zone Pore Water PCBs Aroclor 1242 Concentration Relative to the Initial Pore Water Concentration of the Sediment Directly Below the Cap for the Lower New Bedford Harbor CAD Cell.

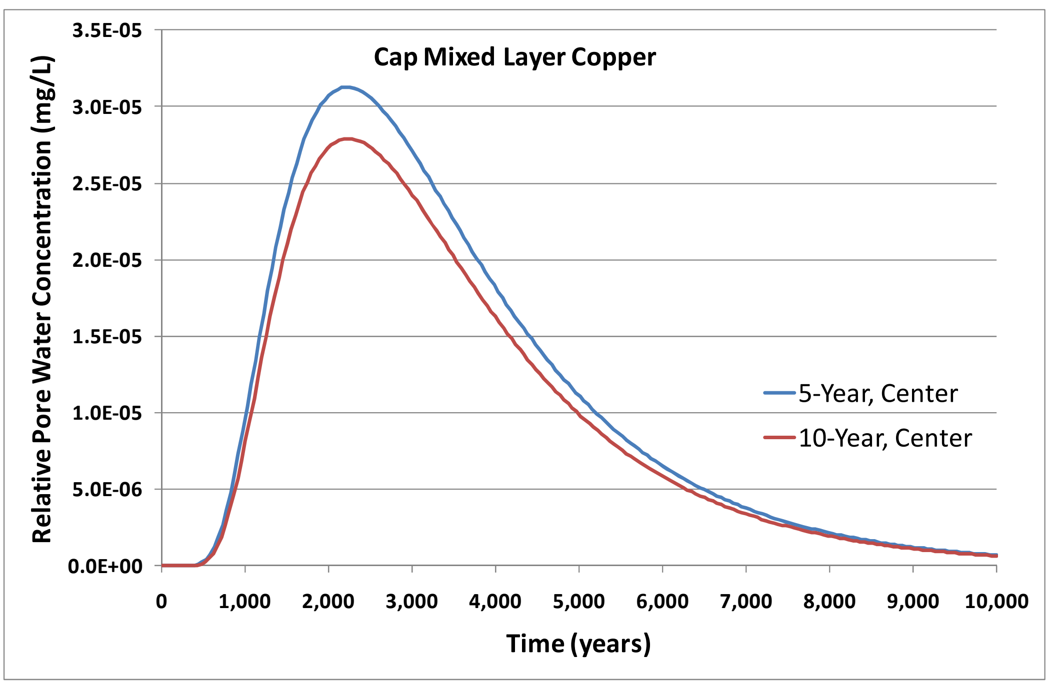


Figure 39. Predicted Cap Bioactive Zone Pore Water Copper Concentration Relative to the Initial Pore Water Concentration of the Sediment Directly Below the Cap for the Lower New Bedford Harbor CAD Cell.

Tables

Table 1. Sediment Properties by Management Unit

ID	Estimated tPCB (mg/kg)*	Mean tPCB (mg/kg)	Estimated Cu (mg/kg)	Mean Cu (mg/kg)	Estimated % S/C	Mean % S/C	Estimated TOC %	Mean TOC %
MU-1								
MU-102 (MF)	1172		598		39.8		7.7	
MU-103 (MF)	368		881		35.3		9	
MU-2		770		740		38		8
MU-3	1691							
MU-4								
MU-5	1940	1,816						
MU-6	347		954		65.6		11.6	
MU-7	2050	1,199	856	905	37	51	10.5	11
MU-8								
MU-9	271		701		13.6		6.2	
MU-10	424	348	932	817		14	7.1	7
MU-11								
MU-12	199		453		5.6		4.4	
MU-13	147	173	1085	769	34.7	20	9.4	7
MU-14	322		1191		46.7		8.8	
MU-15	322	322		1,191		47		9
MU-16	212		941		38.4		7.8	
MU-17	44	228		941		38		8
MU-18	238		757		33		5.1	
MU-19	182							
MU-104 (MF)	91							
MU-105 (MF)	62							
MU-20	166	131	1140	1,120	7.1	33	7.8	8
MU-21	213		1120		2.5		7.2	
MU-22	133	173		1,120		3		7
MU-23	91	170	1199	978	53.3	43	10	8
MU-24	136		1100		58.8		8.8	

Table 2. Sediment Characteristics

Material	Specific Gravity	f_{oc}[3]	Contaminant Concentration, mg/kg			
			PCB 1242[1]	PCB 1248[2]	PCB 1254[1]	Cu[1]
Composite 1	2.37	0.1166	430	140	90	914
Composite 2	2.32	0.1035	120	128	46	1090
Composite 3	2.47	0.0874	47	37.7	21	1110
Cap	2.7	0.003	0	0	0	0

[1]Jacobs Engineering Data

[2]ERDC SBLT Data

[3]Average of Jacobs Engineering data and ERDC data.

Table 3. Assumed Dredging and Placement Groupings for Upper Harbor CAD Cell

ID	Original Inventory CY	Cleanup Inventory CY	Inventory Removed to Date CY	Estimated Inventory Removed 2011 & 2012 CY	Volume to Be Placed in CAD Cell CY	5-Year Groupings CY	10-Year Groupings CY
MU-1	29925	2993	19672	5000	8246		
MU-102 (MF)	44299	4430	23208	15000	10521		
MU-103 (MF)	11185	1119	2933		9371		
MU-2	29842	2984	19668	5000	8158		36295
MU-3	21642	2164	10188	5000	8618		
MU-4	14994	1499	10656		5837		
MU-5	8973	897	2364	5000	2506		
MU-6	21791	2179	0		18970		35932
					5000	77227	
MU-7	26453	2645	3305	15000	10793		
MU-8	9146	915	20		100401		
MU-9	15527	1553	6997		10083		35917
MU-10	34859	3486	11769		26576		
MU-11	17962	1796	17263		2495		
MU-12	15700	1570	6219		7051		36122
					4000	71039	
MU-13	16297	1630	4311		13616		
MU-14	18954	1895	2121		18728		36344
MU-15	19635	1964	0		21599		
MU-16	22462	2246	0		12708		34307
					12000	78651	
MU-17	18948	1895	0		20843		32843
MU-18	17376	1738	2349		16765		
MU-19	15624	1562	8786		8400		
MU-104 (MF)	11462	1146	2967		9641		34806
MU-105 (MF)	8912	891	0		9803	65452	
MU-20	14505	1451	5449		10507		
MU-21	16953	1695	0		14648		34958
					4000		
MU-22	10001	1000	0		11001		
MU-23	18983	1898	14620		6261		
MU-24	20475	2048	9505		13018	59435	34280
Total	532885	53289	184370	50000	351804	351804	351804

Table 4a. Annual Lift Thicknesses and Void Ratios after Annual Placement Operations – 5-Year Dredging Plan

Year	Material	In Situ Void Ratio	Lift Thickness at In Situ Void Ratio, ft			
			Center	**Ring 1**	**Ring 2**	**Ring 3**
1	ERCOMP-1	3.600	19.88	7.45		
2	ERCOMP-1	3.600	1.93	1.63		
2	ERCOMP-2	3.970	9.13	9.01	1.09	
3	ERCOMP-2	3.970	6.60	6.60	3.18	
3	ERCOMP-3	2.589	2.70	2.70	1.94	
4	ERCOMP-3	2.589	6.33	6.33	5.94	0.39
5	ERCOMP-3	2.589	4.65	4.65	4.65	2.77
6	Sand Cap	1	3	3	3	3
Sum of Lift Thicknesses, ft			54.2	41.4	19.8	6.20
Year	**Material**	**As Placed Void Ratio**	**Lift Thickness at As Placed Void Ratio, ft**			
			Center	**Ring 1**	**Ring 2**	**Ring 3**
1	ERCOMP-1	4.060	21.28	8.61		
2	ERCOMP-1	4.060	2.03	1.86		
2	ERCOMP-2	4.466	9.57	9.55	1.79	
3	ERCOMP-2	4.466	6.89	6.89	4.05	
3	ERCOMP-3	2.947	2.81	2.81	2.37	
4	ERCOMP-3	2.947	6.40	6.40	6.35	1.47
5	ERCOMP-3	2.947	4.70	4.70	4.70	4.28
6	Sand Cap	1	3	3	3	3
Sum of Lift Thicknesses, ft			56.7	43.8	22.2	8.80
Average Bottom Elevation, ft			-52	-40	-18	-4

Table 4b. Annual Lift Thicknesses and Void Ratios after Annual Placement Operations – 10-Year Dredging Plan

Year	Material	In Situ Void Ratio	Lift Thickness at In Situ Void Ratio, ft			
			Center	Ring 1	Ring 2	Ring 3
1	ERCOMP-1	3.600	11.18	2.22		
2	ERCOMP-1	3.600	7.77	4.50		
3	ERCOMP-1	3.600	2.87	2.36		
3	ERCOMP-2	3.970	3.32	3.21	0.03	
4	ERCOMP-2	3.970	5.26	5.26	0.89	
5	ERCOMP-2	3.970	4.63	4.63	1.88	
6	ERCOMP-2	3.970	2.51	2.51	1.47	
6	ERCOMP-3	2.589	1.41	1.41	0.97	
7	ERCOMP-3	2.589	3.43	3.43	2.80	
8	ERCOMP-3	2.589	3.33	3.33	3.25	0.17
9	ERCOMP-3	2.589	2.94	2.94	2.94	1.11
10	ERCOMP-3	2.589	2.57	2.57	2.57	1.87
11	Sand Cap	1	3	3	3	3
Sum of Lift Thicknesses, ft			54.2	41.4	19.8	6.2
Year	Material	As Placed Void Ratio	Lift Thickness at As Placed Void Ratio, ft			
			Center	Ring 1	Ring 2	Ring 3
1	ERCOMP-1	4.060	12.07	2.61		
2	ERCOMP-1	4.060	8.22	5.18		
3	ERCOMP-1	4.060	3.02	2.69		
3	ERCOMP-2	4.466	3.49	3.48	0.17	
4	ERCOMP-2	4.466	5.51	5.51	1.39	
5	ERCOMP-2	4.466	4.84	4.84	2.45	
6	ERCOMP-2	4.466	2.62	2.62	1.83	
6	ERCOMP-3	2.947	1.47	1.47	1.18	
7	ERCOMP-3	2.947	3.56	3.56	3.35	0.04
8	ERCOMP-3	2.947	3.32	3.32	3.32	0.97
9	ERCOMP-3	2.947	2.93	2.93	2.93	1.99
10	ERCOMP-3	2.947	2.63	2.63	2.63	2.76
11	Sand Cap	1	3	3	3	3
Sum of Lift Thicknesses, ft			56.7	43.8	22.2	8.80
Average Bottom Elevation, ft			-52	-40	-18	-4

Table 5a. Predicted Resuspension during Dredged Material Placement – 5-Year Dredging Plan

Period	**Load**	**Average TSS mg/L**	**TSS at Top mg/L**	**Mass TSS kg**
Year 1	1	14.5	2	4011
	460	15.0	2	3131
	Average	14.75	2	3571
Year 2	1	14.2	5	3133
	420	14.7	4	2462
	Average	14.45	4.5	2798
Year 3	1	14.9	4	2656
	470	20.2	10	2277
	Average	17.55	7	2467
Year 4	1	16.6	4	2110
	390	16.9	5	1221
	Average	16.75	4.5	1666
Year 5	1	18.2	10	1561
	350	54.1	76	1953
	Average	36.15	43	1757

Table 5b. Predicted Resuspension during Dredged Material Placement – 10-Year Dredging Plan

Period	**Load**	**Average TSS mg/L**	**TSS at Top mg/L**	**Mass TSS kg**
Year 1	1	12.8	4	3549
	220	12.9	5	3183
	Average	12.85	4.5	3366
Year 2	1	15.9	5	4054
	220	16.1	5	3604
	Average	16.0	5	3829
Year 3	1	13.9	5	3225
	220	14.2	5	2910
	Average	14.05	5	3067
Year 4	1	14.9	5	3147
	220	15.1	5	2744
	Average	15.0	5	2945
Year 5	1	15.3	5	2874
	220	15.5	5	2450
	Average	15.4	5	2662
Year 6	1	14.6	5	2386
	210	15.0	4	2031
	Average	14.8	4.5	2208
Year 7	1	13.5	4	1910
	200	18.2	9	2088
	Average	15.85	6.5	1999
Year 8	1	16.7	4.5	2060
	210	17.4	8.5	1618
	Average	17.05	6.5	1839
Year 9	1	19.1	8	1916
	210	13.6	6	970
	Average	16.35	7	1443
Year 10	1	15.9	5	1238
	210	38.3	62	1847
	Average	27.1	33.5	1542

Table 6a. CAD Water Contaminant Concentrations - 5-Year Dredging Plan

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor			Cu	PCBs Aroclor			Cu
			1242	1248	1254		1242	1248	1254	
Year 1										
Initial	0		0	0	0	0	0	0	0	0
1	14.5	2	6.24	2.03	1.31	13.25	1.17	0.24	0.19	2.06
6	14.5		11.94	3.03	2.19	22.68	6.80	1.15	1.03	11.06
11	14.5		17.30	3.67	2.87	30.18	12.09	1.74	1.67	18.22
21	14.5		27.07	4.36	3.79	40.91	21.73	2.37	2.55	28.47
31	14.5		35.69	4.65	4.34	47.72	30.24	2.63	3.08	34.96
46	14.5		46.76	4.80	4.78	53.55	41.17	2.77	3.49	40.52
61	14.6		55.93	4.84	4.98	56.50	50.22	2.81	3.68	43.32
81	14.6		65.77	4.86	5.10	58.30	59.93	2.82	3.79	45.02
101	14.6		73.42	4.86	5.14	59.04	67.48	2.82	3.82	45.71
126	14.6		80.65	4.87	5.15	59.39	74.60	2.82	3.84	46.01
151	14.7		85.93	4.87	5.16	59.51	79.80	2.82	3.84	46.11
176	14.7		89.78	4.88	5.16	59.57	83.59	2.82	3.84	46.14
201	14.7		92.59	4.88	5.17	59.61	86.36	2.82	3.84	46.15
226	14.7		94.65	4.88	5.17	59.63	88.38	2.82	3.84	46.16
251	14.8		96.15	4.89	5.17	59.66	89.84	2.82	3.84	46.16
276	14.8		97.24	4.89	5.17	59.68	90.91	2.82	3.84	46.16
301	14.8		98.04	4.89	5.18	59.71	91.69	2.82	3.84	46.16
326	14.9		98.62	4.90	5.18	59.73	92.26	2.82	3.84	46.16
351	14.9		99.05	4.90	5.18	59.76	92.67	2.82	3.84	46.16
376	14.9		99.37	4.91	5.18	59.78	92.96	2.82	3.84	46.16
401	14.9		99.60	4.91	5.19	59.81	93.18	2.82	3.84	46.16
426	15.0		99.77	4.91	5.19	59.83	93.34	2.82	3.84	46.16
451	15.0		99.89	4.92	5.19	59.86	93.45	2.82	3.84	46.16
460	15.0	2	99.93	4.92	5.19	59.87	93.49	2.82	3.84	46.16
Average	14.75		83.89	4.81	5.00	57.39	77.75	2.75	3.69	44.01
Upper Avg.		2	78.58	3.03	3.86	45.83	77.75	2.75	3.69	44.01
(continued)										

Table 6a. CAD Water Contaminant Concentrations - 5-Year Dredging Plan (continued)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor			Cu	PCBs Aroclor			Cu
			1242	1248	1254		1242	1248	1254	
Year 2										
Initial	0.0		47.96	1.45	1.97	23.68	24.61	0.74	1.01	12.14
1	14.2	5	27.00	2.59	1.76	27.23	24.78	0.91	1.08	13.97
6	14.2		27.87	3.30	2.07	35.58	25.64	1.57	1.38	21.95
11	14.2		28.69	3.78	2.32	42.26	26.46	2.01	1.61	28.32
21	14.2		30.21	4.31	2.67	51.86	27.96	2.50	1.95	37.49
31	14.2		31.57	4.55	2.89	58.00	29.30	2.71	2.15	43.35
46	14.3		33.34	4.68	3.07	63.31	31.04	2.84	2.33	48.41
61	14.3		34.84	4.72	3.16	66.02	32.52	2.87	2.41	50.98
81	14.3		36.48	4.74	3.22	67.71	34.15	2.88	2.46	52.57
101	14.3		37.80	4.75	3.24	68.41	35.45	2.89	2.48	53.22
126	14.3		39.08	4.75	3.25	68.75	36.71	2.89	2.49	53.51
151	14.4		40.05	4.76	3.25	68.88	37.66	2.89	2.49	53.61
201	14.4		41.34	4.76	3.26	68.99	38.92	2.89	2.49	53.65
251	14.5		42.07	4.77	3.26	69.06	39.64	2.89	2.49	53.65
301	14.6		42.50	4.78	3.26	69.12	40.05	2.89	2.49	53.66
351	14.6		42.74	4.79	3.27	69.19	40.28	2.89	2.49	53.66
401	14.7		42.88	4.79	3.27	69.25	40.41	2.89	2.49	53.66
420	14.7	4	42.92	4.80	3.27	69.27	40.44	2.89	2.49	53.66
Average	14.5		39.67	4.69	3.18	66.66	37.22	2.82	2.42	51.41
Upper Avg.		4.5	37.98	3.40	2.65	56.16	37.22	2.82	2.42	51.41
(continued)										

Table 6a. CAD Water Contaminant Concentrations - 5-Year Dredging Plan (continued)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor			Cu	PCBs Aroclor			Cu
			1242	1248	1254		1242	1248	1254	
Year 3										
Initial	0.0		18.46	1.32	1.14	24.47	8.42	0.60	0.52	11.16
1	14.9	4	9.90	2.12	1.10	27.49	8.61	0.74	0.58	13.17
6	15.0		10.81	2.73	1.40	36.75	9.51	1.30	0.87	21.96
16	15.1		12.51	3.41	1.83	49.97	11.18	1.92	1.28	34.46
31	15.2		14.76	3.81	2.19	61.26	13.39	2.27	1.62	45.06
51	15.5		17.25	3.96	2.42	68.14	15.83	2.39	1.82	51.39
76	15.7		19.70	4.02	2.52	71.36	18.23	2.42	1.91	54.16
101	16.0		21.58	4.05	2.56	72.54	20.06	2.42	1.94	54.99
131	16.4		23.24	4.09	2.58	73.19	21.67	2.42	1.95	55.26
161	16.7		24.44	4.12	2.60	73.63	22.82	2.42	1.95	55.32
201	17.2		25.52	4.17	2.62	74.14	23.84	2.42	1.95	55.34
251	17.7		26.33	4.23	2.64	74.76	24.59	2.42	1.95	55.34
301	18.3		26.80	4.28	2.66	75.38	24.99	2.42	1.95	55.34
351	18.9		27.07	4.34	2.68	76.00	25.20	2.42	1.95	55.34
401	19.4		27.23	4.40	2.70	76.62	25.32	2.42	1.95	55.34
451	20.0		27.35	4.46	2.73	77.24	25.37	2.42	1.95	55.34
470	20.2	10	27.38	4.48	2.73	77.47	25.38	2.42	1.95	55.34
Average	17.6		24.03	4.15	2.56	72.43	22.32	2.37	1.89	53.30
Upper Avg.		7	23.00	3.08	2.16	60.93	22.32	2.37	1.89	53.30
(continued)										

Table 6a. CAD Water Contaminant Concentrations - 5-Year Dredging Plan (continued)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor			Cu	PCBs Aroclor			Cu
			1242	1248	1254		1242	1248	1254	
Year 4										
Initial	0.0		7.40	0.70	0.57	16.11	2.15	0.21	0.17	4.69
1	16.6	4	2.93	0.83	0.51	23.12	2.28	0.27	0.21	7.23
6	16.6		3.54	1.10	0.73	34.63	2.88	0.51	0.41	18.17
16	16.6		4.67	1.39	1.03	50.51	3.99	0.79	0.70	33.25
31	16.6		6.14	1.56	1.29	63.31	5.45	0.94	0.95	45.41
51	16.6		7.76	1.62	1.44	70.47	7.05	1.00	1.10	52.20
76	16.7		9.36	1.64	1.51	73.41	8.63	1.01	1.16	54.98
101	16.7		10.57	1.64	1.54	74.25	9.83	1.01	1.19	55.75
131	16.7		11.66	1.64	1.54	74.52	10.90	1.01	1.19	55.99
161	16.7		12.44	1.64	1.55	74.60	11.67	1.01	1.19	56.04
201	16.8		13.15	1.64	1.55	74.65	12.38	1.01	1.20	56.05
251	16.8		13.70	1.65	1.55	74.70	12.92	1.01	1.20	56.06
301	16.8		14.02	1.65	1.55	74.74	13.24	1.01	1.20	56.06
351	16.9		14.21	1.65	1.55	74.78	13.42	1.01	1.20	56.06
390	16.9	5	14.30	1.65	1.55	74.82	13.50	1.01	1.20	56.06
Average	16.75		11.76	1.61	1.49	71.85	10.99	0.99	1.14	53.40
Upper Avg.		4.5	11.19	1.15	1.23	58.36	10.99	0.99	1.14	53.40
(continued)										

Table 6a. CAD Water Contaminant Concentrations - 5-Year Dredging Plan (concluded)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor			Cu	PCBs Aroclor			Cu
			1242	1248	1254		1242	1248	1254	
Year 5										
Initial	0.0		4.11	0.31	0.36	16.97	1.25	0.09	0.11	5.14
1	18.2	10	2.11	0.78	0.49	25.34	1.40	0.17	0.16	7.84
6	18.7		2.85	1.12	0.74	38.13	2.12	0.46	0.39	19.45
16	19.7		4.27	1.50	1.11	56.00	3.48	0.78	0.72	35.32
31	21.3		6.20	1.75	1.42	70.67	5.32	0.95	0.98	47.58
51	23.3		8.41	1.88	1.62	79.42	7.41	1.00	1.13	53.67
76	25.9		10.59	1.99	1.72	84.35	9.45	1.01	1.18	55.62
101	28.5		12.21	2.09	1.79	87.60	10.93	1.01	1.19	55.99
131	31.6		13.57	2.20	1.86	91.09	12.11	1.01	1.20	56.05
161	34.7		14.44	2.32	1.92	94.53	12.83	1.01	1.20	56.06
201	38.8		15.14	2.47	2.01	99.09	13.33	1.01	1.20	56.06
251	43.9		15.63	2.67	2.12	104.80	13.57	1.01	1.20	56.06
301	49.1		15.95	2.86	2.23	110.51	13.64	1.01	1.20	56.06
350	54.1	76	16.20	3.05	2.33	116.11	13.66	1.01	1.20	56.06
Average	36.15		13.00	2.34	1.89	93.38	11.33	0.98	1.14	53.48
Upper Avg.		43	13.31	2.59	2.03	100.94	11.33	0.98	1.14	53.48
(concluded)										

Table 6b. CAD Water Contaminant Concentrations - 10-Year Dredging Plan

	Average	Upper	Total Concentration, ug/L				Dissolved Concentration, ug/L			
	TSS	TSS	PCBs Aroclor				PCBs Aroclor			
Load	mg/L	mg/L	1242	1248	1254	Cu	1242	1248	1254	Cu
Year 1										
Initial	0		0	0	0	0	0	0	0	0
1	12.8	4	5.50	1.79	1.15	11.70	1.04	0.22	0.18	1.87
6	12.8		10.59	2.73	1.96	20.31	6.07	1.08	0.95	10.13
11	12.8		15.40	3.36	2.60	27.32	10.83	1.66	1.56	16.85
21	12.8		24.26	4.05	3.50	37.66	19.58	2.30	2.42	26.77
36	12.8		35.82	4.45	4.26	47.00	31.02	2.67	3.14	35.72
51	12.8		45.61	4.56	4.63	52.03	40.69	2.77	3.50	40.54
71	12.8		56.36	4.61	4.86	55.33	51.32	2.81	3.71	43.70
91	12.8		64.96	4.61	4.94	56.78	59.82	2.82	3.79	45.09
116	12.9		73.34	4.62	4.98	57.51	68.10	2.82	3.83	45.78
141	12.9		79.68	4.62	4.99	57.77	74.37	2.82	3.84	46.02
171	12.9		85.29	4.62	5.00	57.89	79.90	2.82	3.84	46.12
201	12.9		89.29	4.62	5.00	57.93	83.86	2.82	3.84	46.15
220	12.9	5	91.22	4.62	5.00	57.94	85.76	2.82	3.84	46.15
Average	12.9		64.21	4.45	4.62	52.72	59.07	2.67	3.48	41.18
Top Avg.		4.5	60.87	3.29	3.88	45.22	59.07	2.67	3.48	41.18
Year 2										
Initial	0.0		48.66	1.59	2.17	26.06	27.61	0.90	1.22	14.71
1	15.9	5	34.45	3.12	2.66	29.24	28.51	1.07	1.37	16.22
6	15.9		38.83	3.84	3.29	36.09	32.83	1.72	1.97	22.73
11	15.9		42.92	4.28	3.78	41.45	36.86	2.12	2.43	27.83
21	15.9		50.30	4.74	4.42	48.93	44.14	2.54	3.03	34.94
36	15.9		59.66	4.97	4.91	55.08	53.36	2.75	3.49	40.79
51	15.9		67.28	5.03	5.12	58.04	60.87	2.80	3.69	43.59
71	16.0		75.29	5.05	5.23	59.74	68.77	2.82	3.79	45.20
91	16.0		81.38	5.06	5.26	60.39	74.77	2.82	3.83	45.80
116	16.0		86.99	5.06	5.28	60.68	80.30	2.82	3.84	46.05
141	16.0		90.98	5.06	5.28	60.78	84.22	2.82	3.84	46.13
171	16.1		94.27	5.07	5.29	60.83	87.45	2.82	3.84	46.15
201	16.1		96.45	5.07	5.29	60.86	89.59	2.82	3.84	46.16
220	16.1	5	97.43	5.07	5.29	60.87	90.55	2.82	3.84	46.16
Average	16.0		79.51	4.94	5.05	57.66	72.85	2.72	3.62	43.19
Top Avg.		5	74.94	3.42	4.07	47.71	72.85	2.72	3.62	43.19

(continued)

Table 6b. CAD Water Contaminant Concentrations - 10-Year Dredging Plan (continued)

	Average	Upper	Total Concentration, ug/L				Dissolved Concentration, ug/L			
	TSS	TSS	PCBs Aroclor				PCBs Aroclor			
Load	mg/L	mg/L	1242	1248	1254	Cu	1242	1248	1254	Cu
Year 3										
Initial	0.0		47.87	1.49	2.03	24.35	25.31	0.78	1.07	12.85
1	13.9	5	28.89	2.64	1.98	26.91	25.70	0.95	1.16	14.50
6	13.9		30.80	3.34	2.39	34.50	27.58	1.59	1.55	21.75
11	13.9		32.60	3.80	2.71	40.58	29.37	2.02	1.85	27.56
21	13.9		35.91	4.31	3.16	49.38	32.64	2.49	2.28	35.97
36	13.9		40.24	4.60	3.54	57.07	36.91	2.75	2.64	43.31
51	14.0		43.89	4.69	3.72	61.05	40.51	2.83	2.82	47.09
71	14.0		47.88	4.72	3.83	63.54	44.46	2.86	2.92	49.45
91	14.0		51.07	4.73	3.88	64.59	47.60	2.86	2.96	50.43
116	14.1		54.17	4.74	3.90	65.10	50.65	2.86	2.97	50.88
141	14.1		56.50	4.74	3.90	65.29	52.95	2.86	2.98	51.03
171	14.1		58.55	4.75	3.91	65.39	54.97	2.86	2.98	51.09
201	14.2		60.00	4.75	3.91	65.45	56.40	2.86	2.98	51.10
220	14.2	5	60.70	4.76	3.91	65.48	57.08	2.86	2.98	51.11
Average	14.1		50.74	4.60	3.71	61.14	47.18	2.74	2.80	47.10
Top Avg.		5	48.44	3.40	3.12	52.10	47.18	2.74	2.80	47.10
Year 4										
Initial	0.0		28.57	1.43	1.49	25.47	14.30	0.71	0.74	12.69
1	14.9	5	16.09	2.62	1.43	28.94	14.47	0.88	0.81	14.62
6	14.9		16.94	3.36	1.74	37.75	15.31	1.57	1.11	23.03
11	14.9		17.74	3.85	1.99	44.73	16.10	2.02	1.35	29.69
21	14.9		19.21	4.39	2.34	54.65	17.56	2.52	1.68	39.15
36	14.9		21.12	4.69	2.63	63.05	19.45	2.79	1.95	47.16
51	14.9		22.73	4.78	2.77	67.24	21.04	2.87	2.09	51.13
71	15.0		24.49	4.81	2.85	69.75	22.78	2.90	2.16	53.51
91	15.0		25.89	4.82	2.88	70.75	24.16	2.90	2.19	54.44
116	15.0		27.24	4.82	2.90	71.21	25.49	2.90	2.21	54.86
141	15.0		28.26	4.83	2.90	71.37	26.49	2.90	2.21	54.99
171	15.1		29.15	4.83	2.90	71.44	27.36	2.90	2.21	55.03
201	15.1		29.77	4.83	2.90	71.48	27.98	2.90	2.21	55.04
220	15.1	5	30.07	4.83	2.91	71.50	28.28	2.90	2.21	55.05
Average	15.0		25.74	4.68	2.75	66.99	23.95	2.78	2.07	50.84
Top Avg.		5	24.55	3.41	2.30	56.23	23.95	2.78	2.07	50.84

(continued)

Table 6b. CAD Water Contaminant Concentrations - 10-Year Dredging Plan (continued)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor				PCBs Aroclor			
			1242	1248	1254	Cu	1242	1248	1254	Cu
Year 5										
Initial	0.0		12.44	1.27	0.97	24.12	5.47	0.56	0.42	10.57
1	15.3	5	7.30	2.52	1.13	27.24	5.75	0.75	0.51	12.63
6	15.3		8.68	3.32	1.52	36.67	7.11	1.49	0.88	21.62
11	15.3		9.98	3.85	1.83	44.11	8.39	1.97	1.17	28.71
21	15.3		12.35	4.43	2.25	54.59	10.74	2.50	1.58	38.69
36	15.3		15.43	4.74	2.60	63.37	13.78	2.79	1.91	47.05
51	15.3		18.02	4.83	2.77	67.67	16.33	2.87	2.07	51.14
71	15.4		20.82	4.86	2.86	70.22	19.10	2.90	2.16	53.54
91	15.4		23.04	4.87	2.90	71.21	21.29	2.90	2.19	54.47
116	15.4		25.16	4.87	2.91	71.65	23.39	2.90	2.21	54.87
141	15.4		26.75	4.88	2.92	71.81	24.95	2.90	2.21	54.99
171	15.5		28.12	4.88	2.92	71.88	26.30	2.90	2.21	55.03
201	15.5		29.08	4.88	2.92	71.92	27.25	2.90	2.21	55.04
220	15.5	5	29.54	4.89	2.92	71.94	27.70	2.90	2.21	55.05
Average	15.4		22.68	4.73	2.74	67.29	20.91	2.77	2.04	50.72
Top Avg.		5	21.49	3.41	2.27	56.10	20.91	2.77	2.04	50.72
Year 6										
Initial	0.0		10.41	1.08	0.83	20.54	3.92	0.40	0.31	7.67
1	14.6	5	5.28	1.80	0.85	23.69	4.13	0.55	0.38	9.81
6	14.6		6.35	2.42	1.17	33.49	5.19	1.12	0.69	19.16
71	14.7		16.12	3.70	2.37	69.68	14.84	2.29	1.82	53.60
21	14.6		9.23	3.30	1.79	52.42	8.04	1.93	1.28	37.22
36	14.7		11.69	3.58	2.11	61.95	10.47	2.18	1.58	46.29
51	14.7		13.79	3.66	2.27	66.75	12.54	2.26	1.73	50.84
71	14.7		16.12	3.70	2.37	69.68	14.84	2.29	1.82	53.60
91	14.8		18.00	3.71	2.41	70.87	16.69	2.29	1.86	54.69
91	14.8		18.00	3.71	2.41	70.87	16.69	2.29	1.86	54.69
141	14.9		21.26	3.72	2.43	71.65	19.92	2.30	1.88	55.34
171	14.9		22.53	3.72	2.44	71.77	21.17	2.30	1.88	55.39
201	15.0		23.45	3.73	2.44	71.84	22.07	2.30	1.88	55.41
210	15.0	4	23.67	3.73	2.44	71.87	22.29	2.30	1.88	55.41
Average	14.8		17.59	3.58	2.26	66.37	16.26	2.18	1.72	50.38
Top Avg.		4.5	16.67	2.60	1.88	55.24	16.26	2.18	1.72	50.38
(continued)										

Table 6b. CAD Water Contaminant Concentrations - 10-Year Dredging Plan (continued)

Load	Average TSS mg/L	Upper TSS mg/L	Total Concentration, ug/L				Dissolved Concentration, ug/L			
			PCBs Aroclor				PCBs Aroclor			
			1242	1248	1254	Cu	1242	1248	1254	Cu
Year 7										
Initial	0.0		6.94	0.70	0.58	16.98	2.16	0.22	0.18	5.20
1	13.5	4	2.80	0.72	0.46	20.19	2.26	0.27	0.22	7.35
6	13.6		3.31	0.96	0.64	30.20	2.76	0.49	0.39	16.83
71	15.2		8.43	1.58	1.46	70.72	7.78	1.01	1.14	54.00
21	14.0		4.73	1.34	1.03	50.34	4.16	0.83	0.75	35.75
36	14.3		5.99	1.49	1.25	61.11	5.40	0.95	0.95	45.68
51	14.7		7.12	1.54	1.37	66.88	6.50	0.99	1.07	50.83
71	15.2		8.43	1.58	1.46	70.72	7.78	1.01	1.14	54.00
91	15.6		9.54	1.60	1.50	72.57	8.86	1.01	1.17	55.27
116	16.2		10.68	1.62	1.53	73.81	9.96	1.01	1.19	55.83
141	16.8		11.60	1.65	1.55	74.64	10.84	1.01	1.19	55.99
171	17.5		12.45	1.67	1.56	75.48	11.65	1.01	1.19	56.04
200	18.2	9	13.06	1.70	1.58	76.26	12.23	1.01	1.20	56.05
Average	15.9		9.30	1.55	1.40	67.54	8.59	0.95	1.07	50.23
Top Avg.		6.5	8.88	1.20	1.20	57.33	8.59	0.95	1.07	50.23
Year 8										
Initial	0.0		2.82	0.23	0.27	12.53	0.65	0.05	0.06	2.80
1	16.7	4.5	1.44	0.68	0.41	21.34	0.79	0.12	0.11	5.45
6	16.7		2.13	1.00	0.65	33.34	1.48	0.42	0.34	16.84
71	16.9		8.43	1.65	1.51	73.38	7.70	1.01	1.15	54.66
21	16.8		4.00	1.45	1.10	55.49	3.32	0.83	0.77	37.83
36	16.8		5.59	1.59	1.33	65.82	4.89	0.96	0.98	47.60
51	16.9		6.94	1.63	1.44	70.66	6.23	1.00	1.09	52.14
71	16.9		8.43	1.65	1.51	73.38	7.70	1.01	1.15	54.66
91	17.0		9.64	1.65	1.54	74.40	8.89	1.01	1.18	55.56
116	17.1		10.81	1.66	1.55	74.88	10.05	1.01	1.19	55.92
141	17.2		11.71	1.66	1.55	75.07	10.93	1.01	1.19	56.02
171	17.3		12.50	1.66	1.56	75.22	11.71	1.01	1.20	56.05
201	17.4		13.08	1.67	1.56	75.34	12.28	1.01	1.20	56.06
210	17.4	8.5	13.21	1.67	1.56	75.37	12.41	1.01	1.20	56.06
Average	17.1		9.35	1.59	1.43	69.62	8.59	0.95	1.08	50.99
Top Avg.		6.5	8.88	1.20	1.21	58.10	8.59	0.95	1.08	50.99

(continued)

Table 6b. CAD Water Contaminant Concentrations - 10-Year Dredging Plan (concluded)

	Average	Upper	Total Concentration, ug/L				Dissolved Concentration, ug/L			
	TSS	TSS	PCBs Aroclor				PCBs Aroclor			
Load	mg/L	mg/L	1242	1248	1254	Cu	1242	1248	1254	Cu
Year 9										
Initial	0.0		3.11	0.25	0.29	13.57	0.78	0.06	0.07	3.29
1	19.1	8	1.68	0.78	0.47	24.49	0.94	0.14	0.13	6.18
51	17.8		7.43	1.67	1.48	72.43	6.68	1.00	1.11	52.86
11	18.8		3.16	1.32	0.92	46.88	2.41	0.64	0.56	27.60
21	18.6		4.45	1.54	1.18	59.42	3.70	0.86	0.81	39.73
36	18.2		6.09	1.65	1.39	68.66	5.34	0.97	1.01	48.88
51	17.8		7.43	1.67	1.48	72.43	6.68	1.00	1.11	52.86
71	17.3		8.85	1.66	1.52	74.04	8.11	1.01	1.16	54.95
91	16.7		9.95	1.64	1.53	74.21	9.21	1.01	1.18	55.66
116	16.1		10.98	1.62	1.53	73.78	10.26	1.01	1.19	55.94
141	15.4		11.73	1.59	1.52	73.13	11.03	1.01	1.19	56.02
171	14.6		12.38	1.56	1.50	72.28	11.71	1.01	1.20	56.05
201	13.8		12.82	1.53	1.49	71.41	12.19	1.01	1.20	56.05
210	13.6	6	12.93	1.52	1.48	71.15	12.30	1.01	1.20	56.06
Average	16.4		9.52	1.57	1.42	69.28	8.80	0.96	1.09	51.42
Top Avg.		7	9.11	1.22	1.23	59.06	8.80	0.96	1.09	51.42
Year 10										
Initial	0.0		3.03	0.24	0.28	13.17	0.75	0.06	0.07	3.10
1	15.9	5	1.50	0.66	0.40	20.74	0.88	0.13	0.12	5.63
51	21.3		7.59	1.80	1.55	76.29	6.69	1.00	1.11	52.89
11	17.0		2.86	1.22	0.84	42.84	2.19	0.61	0.51	25.62
21	18.0		4.16	1.50	1.13	57.17	3.43	0.84	0.77	38.14
36	19.7		5.97	1.70	1.40	69.67	5.15	0.96	1.00	48.32
51	21.3		7.59	1.80	1.55	76.29	6.69	1.00	1.11	52.89
71	23.4		9.46	1.89	1.66	81.08	8.43	1.01	1.17	55.16
91	25.5		10.98	1.97	1.72	84.17	9.84	1.01	1.19	55.83
116	28.2		12.45	2.08	1.79	87.35	11.17	1.01	1.19	56.02
141	30.9		13.52	2.18	1.84	90.35	12.10	1.01	1.20	56.05
171	34.1		14.40	2.30	1.91	93.93	12.82	1.01	1.20	56.06
201	37.3		14.97	2.42	1.98	97.50	13.23	1.01	1.20	56.06
210	38.3	62	15.10	2.46	2.00	98.57	13.31	1.01	1.20	56.06
Average	27.1		10.61	1.97	1.65	80.95	9.39	0.95	1.08	51.22
Top Avg.		33.5	10.90	2.21	1.78	87.98	9.39	0.95	1.08	51.22
(concluded)										

Table 7a. Sheet Pile Enclosed CAD Cell Contaminant Mass Losses - 5-Year Dredging Plan

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 1							
Entrainment by Flow	655,000		0.969	0.316	0.203	1.488	2.060
CAD Water Displacement	44,000	0.121	5.526	0.213	0.272	6.011	3.223
Turbulent Diffusion	106,600	0.330	5.822	0.176	0.239	6.236	2.874
Thermal Overturn	65,500	0.203	4.680	0.141	0.192	5.014	2.311
Total Losses from Year 1			16.997	0.845	0.906	18.749	10.468
Year 2							
Entrainment by Flow	612,000		0.355	0.273	0.111	0.739	2.235
CAD Water Displacement	44,000	0.136	2.439	0.219	0.170	2.828	3.606
Turbulent Diffusion	106,600	0.363	2.310	0.165	0.142	2.618	3.065
Thermal Overturn	65,500	0.223	2.025	0.145	0.125	2.294	2.686
Total Losses from Year 2			7.128	0.801	0.549	8.478	11.593
Year 3							
Entrainment by Flow	699,000		0.291	0.299	0.114	0.704	3.220
CAD Water Displacement	44,000	0.150	1.653	0.221	0.155	2.029	4.378
Turbulent Diffusion	106,600	0.399	1.152	0.110	0.089	1.351	2.512
Thermal Overturn	65,500	0.245	1.271	0.121	0.098	1.490	2.771
Total Losses from Year 3			4.366	0.752	0.455	5.573	12.881
Year 4							
Entrainment by Flow	568,000		0.092	0.074	0.041	0.206	2.168
CAD Water Displacement	44,000	0.165	0.667	0.069	0.073	0.810	3.479
Turbulent Diffusion	106,600	0.450	0.171	0.013	0.015	0.199	0.710
Thermal Overturn	65,500	0.277	0.676	0.051	0.060	0.787	2.807
Total Losses from Year 4			1.606	0.206	0.189	2.002	9.165
Year 5							
Entrainment by Flow	524,000		0.810	0.650	0.362	1.821	19.127
CAD Water Displacement	44,000	0.186	0.712	0.139	0.109	0.960	5.401
Turbulent Diffusion	106,600	0.517	0.000	0.000	0.000	0.000	0.000
Thermal Overturn	65,500	0.318	0.487	0.036	0.043	0.566	2.001
Total Losses from Year 5			2.010	0.825	0.513	3.348	26.529
(continued)							

Table 7a. Sheet Pile Enclosed CAD Cell Contaminant Mass Losses - 5-Year Dredging Plan (continued)

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 6							
Capping Displacement Losses	38128	0.817	0.138	0.01	0.012	0.16	0.566
Summary							
Total Contaminant Losses, kg			32.246	3.439	2.625	38.31	71.201
Contaminant Mass Dredged, kg			23693	13365	6730	43788	163409
Percent Loss, %			0.136%	0.026%	0.039%	0.087%	0.044%
(concluded)							

Table 7b. Sheet Pile Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 1							
Entrainment by Flow	480,500		0.711	0.231	0.149	1.091	1.511
CAD Water Displacement	44,000	0.121	2.047	0.111	0.130	2.288	1.521
Turbulent Diffusion	106,600	0.330	5.571	0.183	0.250	6.003	2.998
Thermal Overturn	65,500	0.203	4.294	0.141	0.192	4.627	2.311
Total Losses from Year 1			12.622	0.666	0.721	14.010	8.340
Year 2							
Entrainment by Flow	480,500		0.790	0.257	0.165	1.212	1.679
CAD Water Displacement	44,000	0.136	2.520	0.115	0.137	2.772	1.605
Turbulent Diffusion	106,600	0.363	5.731	0.178	0.243	6.152	2.921
Thermal Overturn	65,500	0.223	4.534	0.141	0.192	4.867	2.311
Total Losses from Year 2			13.574	0.691	0.738	15.003	8.515
(continued)							

Table 7b. Sheet Pile Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan (continued)

Loss Mechanism	**Volume Exchanged cy**	**Remaining CAD Water Mass Fraction**	**Contaminant Mass Loss, kg**				
			PCB Aroclors				**Cu**
			1242	**1248**	**1254**	**Sum**	
Year 3							
Entrainment by Flow	480,500		0.473	0.245	0.120	0.838	1.859
CAD Water Displacement	44,000	0.150	1.629	0.114	0.105	1.849	1.752
Turbulent Diffusion	106,600	0.399	3.512	0.176	0.183	3.871	3.144
Thermal Overturn	65,500	0.245	2.858	0.143	0.149	3.150	2.559
Total Losses from Year 3			8.471	0.679	0.558	9.708	9.314
Year 4							
Entrainment by Flow	480,500		0.220	0.235	0.084	0.540	2.002
CAD Water Displacement	44,000	0.165	0.826	0.115	0.077	1.018	1.891
Turbulent Diffusion	106,600	0.363	1.667	0.171	0.130	1.968	3.244
Thermal Overturn	65,500	0.223	1.416	0.145	0.111	1.672	2.756
Total Losses from Year 4			4.128	0.666	0.403	5.197	9.893
Year 5							
Entrainment by Flow	480,500		0.220	0.235	0.084	0.540	2.002
CAD Water Displacement	44,000	0.186	0.723	0.115	0.076	0.914	1.887
Turbulent Diffusion	106,600	0.517	1.540	0.161	0.123	1.825	3.061
Thermal Overturn	65,500	0.318	1.387	0.145	0.111	1.643	2.756
Total Losses from Year 5			3.870	0.656	0.395	4.921	9.705
Year 6							
Entrainment by Flow	459,000		0.148	0.151	0.058	0.357	1.731
CAD Water Displacement	44,000	0.204	0.535	0.084	0.060	0.679	1.773
Turbulent Diffusion	106,600	0.599	1.147	0.118	0.097	1.362	2.852
Thermal Overturn	65,500	0.368	1.116	0.115	0.094	1.325	2.774
Total Losses from Year 6			2.946	0.468	0.310	3.724	9.131
Year 7							
Entrainment by Flow	437,000		0.102	0.082	0.046	0.229	2.409
CAD Water Displacement	44,000	0.225	0.271	0.037	0.037	0.345	1.753
Turbulent Diffusion	106,600	0.711	0.561	0.046	0.055	0.662	2.572
Thermal Overturn	65,500	0.437	0.612	0.051	0.060	0.723	2.806
Total Losses from Year 7			1.547	0.216	0.197	1.959	9.541
(continued)							

Table 7b. Sheet Pile Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan (continued)

Loss Mechanism	**Volume Exchanged cy**	**Remaining CAD Water Mass Fraction**	**Contaminant Mass Loss, kg**				
			PCB Aroclors				**Cu**
			1242	**1248**	**1254**	**Sum**	
Year 8							
Entrainment by Flow	459,000		0.107	0.086	0.048	0.241	2.530
CAD Water Displacement	42,000	0.280	0.285	0.038	0.039	0.362	1.865
Turbulent Diffusion	81,552	0.666	0.360	0.029	0.035	0.424	1.625
Thermal Overturn	65,500	0.535	0.621	0.051	0.060	0.732	2.806
Total Losses from Year 8			1.373	0.204	0.181	1.759	8.827
Year 9							
Entrainment by Flow	459,000		0.132	0.106	0.059	0.297	3.114
CAD Water Displacement	42,000	0.343	0.293	0.039	0.040	0.371	1.896
Turbulent Diffusion	52,198	0.561	0.146	0.012	0.014	0.172	0.663
Thermal Overturn	65,500	0.703	0.616	0.051	0.060	0.726	2.806
Total Losses from Year 9			1.186	0.208	0.172	1.566	8.480
Year 10							
Entrainment by Flow	459,000		0.552	0.443	0.247	1.242	13.039
CAD Water Displacement	42,000	0.451	0.350	0.071	0.057	0.478	2.824
Turbulent Diffusion	22,741	0.357	0.000	0.000	0.000	0.000	0.000
Thermal Overturn	63,653	1	0.648	0.049	0.058	0.755	2.727
Total Losses from Year 10			1.549	0.563	0.362	2.474	18.590
Year 11							
Capping Displacement Losses	36778	0.578	0.057	0.004	0.005	0.066	0.233
Summary							
Total Contaminant Losses, kg			51.325	5.021	4.042	60.388	100.570
Contaminant Mass Dredged, kg			23517	13169	6672	43358	163463
Percent Loss, %			0.218%	0.038%	0.061%	0.139%	0.062%
(concluded)							

Table 8a. Silt Curtain Enclosed CAD Cell Contaminant Mass Losses - 5-Year Dredging Plan

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 1							
Entrainment by Flow	655,000		2.744	0.894	0.574	4.212	5.833
CAD Water Displacement	44,000	0.121	5.526	0.213	0.272	6.011	3.223
Turbulent Diffusion	106,600	0.330	5.822	0.176	0.239	6.236	2.874
Thermal Overturn	65,500	0.203	4.680	0.141	0.192	5.014	2.311
Total Losses from Year 1			18.772	1.423	1.278	21.473	14.241
Year 2							
Entrainment by Flow	612,000		1.004	0.774	0.315	2.093	6.329
CAD Water Displacement	44,000	0.136	2.439	0.219	0.170	2.828	3.606
Turbulent Diffusion	106,600	0.363	2.310	0.165	0.142	2.618	3.065
Thermal Overturn	65,500	0.223	2.025	0.145	0.125	2.294	2.686
Total Losses from Year 2			7.777	1.302	0.753	9.832	15.686
Year 3							
Entrainment by Flow	699,000		0.823	0.848	0.323	1.993	9.117
CAD Water Displacement	44,000	0.150	1.653	0.221	0.155	2.029	4.378
Turbulent Diffusion	106,600	0.399	1.152	0.110	0.089	1.351	2.512
Thermal Overturn	65,500	0.245	1.271	0.121	0.098	1.490	2.771
Total Losses from Year 3			4.899	1.300	0.664	6.862	18.778
Year 4							
Entrainment by Flow	568,000		0.260	0.209	0.116	0.585	6.140
CAD Water Displacement	44,000	0.165	0.667	0.069	0.073	0.810	3.479
Turbulent Diffusion	106,600	0.450	0.171	0.013	0.015	0.199	0.710
Thermal Overturn	65,500	0.277	0.676	0.051	0.060	0.787	2.807
Total Losses from Year 4			1.775	0.341	0.265	2.380	13.136
Year 5							
Entrainment by Flow	524,000		2.293	1.839	1.025	5.157	54.155
CAD Water Displacement	44,000	0.186	0.712	0.139	0.109	0.960	5.401
Turbulent Diffusion	106,600	0.517	0.000	0.000	0.000	0.000	0.000
Thermal Overturn	65,500	0.318	0.487	0.036	0.043	0.566	2.001
Total Losses from Year 5			3.493	2.014	1.176	6.683	61.557
(continued)							

Table 8a. Silt Curtain Enclosed CAD Cell Contaminant Mass Losses - 5-Year Dredging Plan (continued)

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 6							
Capping Displacement Losses	38128	0.817	0.138	0.01	0.012	0.16	0.566
Summary							
Total Contaminant Losses, kg			36.854	6.390	4.147	47.391	123.964
Contaminant Mass Dredged, kg			23693	13365	6730	43788	163409
Percent Loss, %			0.156%	0.048%	0.062%	0.108%	0.076%
(concluded)							

Table 8b. Silt Curtain Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 1							
Entrainment by Flow	480,500		2.013	0.655	0.421	3.089	4.278
CAD Water Displacement	44,000	0.121	2.047	0.111	0.130	2.288	1.521
Turbulent Diffusion	106,600	0.330	5.571	0.183	0.250	6.003	2.998
Thermal Overturn	65,500	0.203	4.294	0.141	0.192	4.627	2.311
Total Losses from Year 1			13.924	1.090	0.994	16.008	11.107
Year 2							
Entrainment by Flow	480,500		2.236	0.728	0.468	3.432	4.753
CAD Water Displacement	44,000	0.136	2.520	0.115	0.137	2.772	1.605
Turbulent Diffusion	106,600	0.363	5.731	0.178	0.243	6.152	2.921
Thermal Overturn	65,500	0.223	4.534	0.141	0.192	4.867	2.311
Total Losses from Year 2			15.021	1.162	1.040	17.223	11.590
(continued)							

Table 8b. Silt Curtain Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan (continued)

Loss Mechanism	Volume Exchanged cy	Remaining CAD Water Mass Fraction	Contaminant Mass Loss, kg				
			PCB Aroclors				Cu
			1242	1248	1254	Sum	
Year 3							
Entrainment by Flow	480,500		1.339	0.693	0.341	2.372	5.263
CAD Water Displacement	44,000	0.150	1.629	0.114	0.105	1.849	1.752
Turbulent Diffusion	106,600	0.399	3.512	0.176	0.183	3.871	3.144
Thermal Overturn	65,500	0.245	2.858	0.143	0.149	3.150	2.559
Total Losses from Year 3			9.337	1.127	0.778	11.243	12.718
Year 4							
Entrainment by Flow	480,500		0.624	0.666	0.239	1.529	5.668
CAD Water Displacement	44,000	0.165	0.826	0.115	0.077	1.018	1.891
Turbulent Diffusion	106,600	0.363	1.667	0.171	0.130	1.968	3.244
Thermal Overturn	65,500	0.223	1.416	0.145	0.111	1.672	2.756
Total Losses from Year 4			4.532	1.097	0.558	6.186	13.560
Year 5							
Entrainment by Flow	480,500		0.624	0.666	0.239	1.529	5.668
CAD Water Displacement	44,000	0.186	0.723	0.115	0.076	0.914	1.887
Turbulent Diffusion	106,600	0.517	1.540	0.161	0.123	1.825	3.061
Thermal Overturn	65,500	0.318	1.387	0.145	0.111	1.643	2.756
Total Losses from Year 5			4.274	1.087	0.549	5.910	13.372
Year 6							
Entrainment by Flow	459,000		0.419	0.427	0.165	1.011	4.902
CAD Water Displacement	44,000	0.204	0.535	0.084	0.060	0.679	1.773
Turbulent Diffusion	106,600	0.599	1.147	0.118	0.097	1.362	2.852
Thermal Overturn	65,500	0.368	1.116	0.115	0.094	1.325	2.774
Total Losses from Year 6			3.217	0.744	0.417	4.378	12.301
Year 7							
Entrainment by Flow	437,000		0.289	0.232	0.129	0.650	6.822
CAD Water Displacement	44,000	0.225	0.271	0.037	0.037	0.345	1.753
Turbulent Diffusion	106,600	0.711	0.561	0.046	0.055	0.662	2.572
Thermal Overturn	65,500	0.437	0.612	0.051	0.060	0.723	2.806
Total Losses from Year 7			1.733	0.365	0.281	2.379	13.953
(continued)							

Table 8b. Silt Curtain Enclosed CAD Cell Contaminant Mass Losses - 10-Year Dredging Plan (continued)

Loss Mechanism	**Volume Exchanged cy**	**Remaining CAD Water Mass Fraction**	**Contaminant Mass Loss, kg**				
			PCB Aroclors				**Cu**
			1242	**1248**	**1254**	**Sum**	
Year 8							
Entrainment by Flow	459,000		0.303	0.243	0.136	0.682	7.163
CAD Water Displacement	42,000	0.280	0.285	0.038	0.039	0.362	1.865
Turbulent Diffusion	81,552	0.666	0.360	0.029	0.035	0.424	1.625
Thermal Overturn	65,500	0.535	0.621	0.051	0.060	0.732	2.806
Total Losses from Year 8			1.570	0.362	0.269	2.200	13.460
Year 9							
Entrainment by Flow	459,000		0.373	0.299	0.167	0.839	8.816
CAD Water Displacement	42,000	0.343	0.293	0.039	0.040	0.371	1.896
Turbulent Diffusion	52,198	0.561	0.146	0.012	0.014	0.172	0.663
Thermal Overturn	65,500	0.703	0.616	0.051	0.060	0.726	2.806
Total Losses from Year 9			1.427	0.401	0.280	2.109	14.182
Year 10							
Entrainment by Flow	459,000		1.563	1.254	0.698	3.515	36.917
CAD Water Displacement	42,000	0.451	0.350	0.071	0.057	0.478	2.824
Turbulent Diffusion	22,741	0.357	0.000	0.000	0.000	0.000	0.000
Thermal Overturn	63,653	1	0.648	0.049	0.058	0.755	2.727
Total Losses from Year 10			2.561	1.374	0.814	4.748	42.468
Year 11							
Capping Displacement Losses	36778	0.578					
Summary							
Total Contaminant Losses, kg			57.653	8.813	5.985	72.451	158.944
Contaminant Mass Dredged, kg			23517	13169	6672	43358	163463
Percent Loss, %			0.245%	0.067%	0.090%	0.167%	0.097%
(concluded)							

Table 9. Predicted Losses by Mechanism and Placement Scenario

Loss Mechanism	Contaminant Mass Loss, kg (percent of total losses)				
	PCB Aroclors				Cu
	1242	1248	1254	Sum	
Sheet Pile Enclosed CAD Cell - 5-Year Dredging Plan					
Entrainment by Flow	2.52	1.61	0.83	4.96 (12.9%)	28.81 (40.5%)
CAD Water Displacement	11.14	0.87	0.79	12.80 (33.4%)	20.65 (29.0%)
Turbulent Diffusion	9.46	0.46	0.49	10.40 (27.2%)	9.16 (12.9%)
Thermal Overturn	9.14	0.49	0.52	10.15 (26.5%)	12.58 (17.7%)
Total Short-term Losses	32.25	3.44	2.62	38.31	71.20
Sheet Pile Enclosed CAD Cell - 10-Year Dredging Plan					
Entrainment by Flow	3.46	2.07	1.06	6.59 (10.9%)	31.88 (31.7%)
CAD Water Displacement	9.54	0.84	0.76	11.14 (18.5%)	19.00 (18.9%)
Turbulent Diffusion	20.24	1.07	1.13	22.44 (37.2%)	23.08 (22.9%)
Thermal Overturn	18.10	1.03	1.09	20.22 (33.5%)	26.61 (26.5%)
Total Short-term Losses	51.32	5.02	4.04	60.39	100.57
Silt Curtain Enclosed CAD Cell - 5-Year Dredging Plan					
Entrainment by Flow	7.12	4.56	2.35	14.04 (29.6%)	81.57 (65.8%)
CAD Water Displacement	11.14	0.87	0.79	12.80 (27.0%)	20.65 (16.7%)
Turbulent Diffusion	9.46	0.46	0.49	10.40 (22.0%)	9.16 (7.4%)
Thermal Overturn	9.14	0.49	0.52	10.15 (21.4%)	12.58 (10.1%)
Total Short-term Losses	36.85	6.39	4.15	47.39	123.96
Silt Curtain Enclosed CAD Cell - 10-Year Dredging Plan					
Entrainment by Flow	9.78	5.86	3.00	18.65 (25.7%)	90.25 (56.8%)
CAD Water Displacement	9.54	0.84	0.76	11.14 (15.4%)	19.00 (12.0%)
Turbulent Diffusion	20.24	1.07	1.13	22.44 (31.0%)	23.08 (14.5%)
Thermal Overturn	18.10	1.03	1.09	20.22 (27.9%)	26.61 (16.7%)
Total Short-term Losses	57.65	8.81	5.99	72.45	158.94

Table 10. Comparison of Disposal Scenarios

Enclosure Scenario		Overall Placement Losses				
		PCB 1242	PCB 1248	PCB 1254	PCBs	Copper
5-Year Schedule						
Sheet Pile Wall	kg	32.246	3.439	2.625	38.310	71.201
	percent	0.136%	0.026%	0.039%	0.087%	0.044%
Silt Curtain	kg	36.854	6.390	4.147	47.391	123.964
	percent	0.156%	0.048%	0.062%	0.108%	0.076%
10-Year Schedule						
Sheet Pile Wall	kg	51.325	5.021	4.042	60.388	100.570
	percent	0.218%	0.038%	0.061%	0.139%	0.062%
Silt Curtain	kg	57.653	8.813	5.985	72.451	158.944
	percent	0.245%	0.067%	0.090%	0.167%	0.097%
Increase in losses due to increase in schedule duration		55% PCBs 35% Copper				
Increase in losses due to use of silt curtain instead of sheet pile wall		22% PCBs 66% Copper				

Table 11. Partitioning Data for Model Simulations

Parameter	Partitioning Coefficients, L/kg			
	PCBs Aroclor			Copper
	1242	1248	1254	
Koc from SBLT results	-	550,000	210,000	18,200 (Kd)
Koc from pore water analysis	39,400	-	202,000	21,400 (Kd)
Koc for Model Simulations	39,352	426,162	201,019	-
Kd for ERCOMP-1	4,587	49,669	23,429	20,000
Kd for ERCOMP-2	4,073	44,108	20,805	20,000
Kd for ERCOMP-3	3,439	37,247	17,569	20,000
Kd for Sand Cap	118	1,278	603	36