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Los Angeles District

Feasibility Report

UPPER NEWPORT BAY

Orange County, California

UPPER NEWPORT BAY NUMERICAL MODEL DEVELOPMENT

BASELINE CONDITIONS ANALYSIS

July 1998

EXECUTIVE SUMMARY

A numerical model of the Upper Newport Bay estuary is being developed in support of the Upper Newport Bay Feasibility Study undertaken by the U.S. Army Corps of Engineers, Los Angeles District, and its local sponsor, the County of Orange. When completed, the model will be used to evaluate the impacts of alternative dredging strategies with regard to circulation, sediment deposition, and water quality relative to future without project conditions. This report describes the baseline conditions analysis of Phase 2 of numerical model development. During Phase 1 of model development the RMA2 hydrodynamic model and RMA11 sediment transport model were configured and calibrated for the Upper Newport Bay. During Phase 2 several improvements were made to the model formulation. The finite element representation of the Upper Newport Bay was extended to include additional marsh areas. The model calibration was updated. A simulation was performed representing the December 1997 storm event. And the 50-year without project simulation was re-run with the updated models.

The RMA2 hydrodynamic and RMA11 sediment transport models were reconfigured so that bed elevations are updated at every time step during wet weather simulation. The artificial limit on bed elevation used in Phase 1 has been removed. A new calibration simulation was completed. Simulation of sedimentation resulting from representative peak storm flows followed by resuspension and redistribution by tidal circulation has produced deposition patterns that reasonably match the observed changes in bed elevation. The model predicted the total volume of deposited sediments in the Upper Bay between 1985 and 1997 within 2% of the observed change in bathymetry.

The December 1997 storm event was simulated. Scour and deposition patterns predicted by the model reasonably match those observed in the estuary. Scour was underestimated in some areas of the main channel. The model may overestimate the water surface elevation in Unit I for several hours near peak flood because the current sediment model formulation does not permit overtopping of the salt dike. This limitation does not affect the long-term simulations because the flows in the wet weather periods are not sufficient to overtop the salt dike.

The 50-year without project simulation has been completed. An analysis of the sediment deposition at 5-year intervals through year 50 is presented. Over the course of the 50 years, the model predicts that the Unit I and Unit II basin fill to an equilibrium state while an increasing volume of sediment deposits in the Lower Bay. The model predicted sediment deposition of approximately 3 million cubic yards in the Upper Bay and 3 ¾ million cubic yards in the Lower Bay. Since the model has not been calibrated for deposition in the Lower Bay, the result should be considered as an indication of potential deposition.

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UPPER NEWPORT BAY NUMERICAL MODEL DEVELOPMENT
BASELINE CONDITIONS ANALYSIS

July 1998

Prepared by
Resource Management Associates, Inc.

1. INTRODUCTION

1.1 Background

Hydrodynamic and sediment transport models for the Upper Newport Bay have been constructed in support of the Upper Newport Bay Feasibility Study conducted by the U.S. Army Corps of Engineers. The models will ultimately be used to assess the impacts of several alternative dredging plans on circulation, sediment deposition, and water quality relative to the future without project condition. These results will provide information to other teams to aid in evaluating impacts on vegetative and biological species counts, diversity, and distribution.

The long-term goal is to develop a comprehensive hydrodynamic, sediment transport, and water quality modeling capability for the Upper Newport Bay. This modeling capability will be utilized by the U.S. Army Corps of Engineers, California Regional Water Quality Control Board, County of Orange, City of Newport, and possibly other groups as a management decision-making tool and as an educational tool. The U.S. Army Corps of Engineers Los Angeles District (RMA, October 1997) funded the first phase of model development. During the first phase the RMA2 hydrodynamic model and RMA11 sediment transport model were configured for the Upper Newport Bay. The hydrodynamic model was calibrated to available observed stage and velocity data from the 1992-93 Reconnaissance Study (Coastal Frontiers Corporation, February 1993). The sediment transport model was calibrated to observed deposition patterns during the period of 1985-1997. And an initial simulation of the 50-year future without project condition was performed.

This report describes the baseline conditions analysis for the second phase of development and calibration of the hydrodynamic and sediment transport models for the Upper Newport Bay.

1.2 Objectives

The specific objectives of baseline conditions analysis for Phase 2 of the Upper Newport Bay Numerical Model Development are as follows.

- Revise the finite element network that represents the Upper and Lower Newport Bay to include additional marsh areas in the Upper Bay.
- Tighten the coupling between the 2-D depth-averaged hydrodynamic and sediment transport models so that changes in bathymetry due to sediment deposition and scour are immediately reflected in the hydrodynamics.
- Reconfigure the 2-D depth-averaged sediment transport model to eliminate the maximum limit on sediment deposition.
- Re-run the 2-D depth-averaged hydrodynamic and sediment transport model calibration using the newly configured model and modified finite element network.
- Perform high flow simulations using the 2-D depth-averaged hydrodynamic and sediment transport models and the data collected during the large winter storm event of December 1997.
- Perform a new simulation of 50-year future without project condition using the newly calibrated model.

1.3 Organization

The development and application of the hydrodynamic and sediment transport models for the Upper Newport Bay has been carried out by Resource Management Associates, Inc. acting as a sub-contractor to Coastal Frontiers Corporation. Dr. Gib Bogle participated in the configuration and calibration of the hydrodynamic model. Dr. Ray Krone of Ray B. Krone and Associates was retained as a consultant for application of the sediment model including development of the modeling strategy, estimation of model parameters, and evaluation of results.

2. MODEL CONFIGURATION

2.1 Geographic Extents

The model of the Upper Newport Bay extends from the ocean boundary at the entrance to the Lower Bay to San Diego Creek approximately 750 feet upstream of Jamboree Road (see Figure 1 and 2). The basic computational mesh includes all areas of the estuary that were at or below mean higher high water in October 1985, the beginning of the calibration period. The area of marsh between the Unit I/III basin and the salt dike that was not incorporated in the Phase 1 computational mesh is included in the meshes for the Phase 2 modeling. For the December 1997 flood simulation, additional marsh area around Middle and Shellmaker Islands were included to accommodate the high water surface elevations resulting from the extreme flow event.

2.2 Bathymetric Data

The County of Orange provided bathymetric data sets for the system. Bathymetry at the beginning of the calibration period is defined by the Design and As-Built hard copy bathymetric maps from the Unit I and Unit II basin construction. Bathymetry at the end of the calibration period is defined by the 1997 survey performed for the Upper Newport Bay Feasibility Study. This data set was provided in digital form as contours for areas above lower low water and as spot elevations in the channels. The 1989 and 1995 Lower Newport Bay Condition Survey by the Corps of Engineers provided additional data for the Lower Bay and the region near the Pacific Coast Highway Bridge. Bathymetric data for the starting condition of the 50-year without project simulation is based on the post Unit III construction as defined by the design drawings (County of Orange Public Facilities and Resources Department, July 1997).

The most complete data set was the 1997 survey. This data set was used to develop the base finite element mesh. The mesh used for sediment transport calibration simulation was derived from the base finite element mesh by adjusting bed elevations and by adding additional mesh detail to match the as-built drawings from the Unit I and Unit II basins and access channel. The mesh used for the 50-year without project simulation was derived from the base finite element mesh by adjusting bed elevations and adding detail to represent the post Unit III dredging condition.

The majority of bathymetric data was provided in the CCS NAD27 zone 6 coordinate system with units of U.S. feet. Because the finite element sediment model uses metric units exclusively, the data was converted to metric for construction of the finite element mesh. The hydrodynamic and sediment transport models were run using metric units. For this report, spatial plots and computed bed elevation have been converted back to English units to facilitate comparison with other GIS coverages of the Upper Newport Bay.

During and after the flood event of December 1997, additional data were collected including spot bathymetric survey data, dive observations of scour and deposition, sediment discharge and flow data from San Diego Creek, and post-storm aerial photographs.

2.3 Finite Element Mesh Generation

The starting point for the finite element mesh in Phase 1 was the mesh created by WEM (Numerical Modeling of Hydrodynamics and Transport, Upper Newport Bay, part of the Upper Newport Bay Reconnaissance Report, Coastal Frontiers Corporation, 1993) for the reconnaissance study conducted by CFC in 1992. Because of changes in the bathymetry of the bay over the intervening period, significant changes in the mesh were required in the Upper Bay. Since the focus of the current study is on sedimentation, greater attention was given to the mudflat areas, which were treated rather approximately in the previous study. The number of elements in the Unit I and Unit II basins was increased significantly, and the mesh now extends to an elevation of 3.0 ft (0.915 m) above MSL (mean sea level) in most of the Upper Bay. This is roughly the mean higher high tide level at the ocean boundary, and is also the maximum elevation created by sedimentation. In order to ensure correct simulation of flows across the mudflats, elements in these areas were defined with sides that follow, to the maximum feasible extent, the bathymetric contour lines, with a maximum depth change across an element of 1 ft (0.3 m). The main channels that intersect and drain the mudflats have been represented faithfully in the mesh. Mesh resolution was increased in the mid-bay and Lower Bay as well. The new mesh has at least four elements across the main channel everywhere, and most channels are at least three elements wide. Most recently, additional elements have been included to represent the extensive marsh areas in the Upper Bay.

The resulting mesh has 3451 elements and 9791 nodes, compared with the 872 elements and 2752 nodes in the 1992 mesh. Improvements in the RMA2 solver and in computer technology have combined to make this higher level of detail computationally feasible. The RMASIM mesh generation and visualization tool developed by RMA greatly facilitated the mesh generation, and ensured a higher quality result. The complete view of the finite element network is shown in Figure 1, while Figure 2 presents a more detailed view of the Unit I and II basins.

The finite element mesh developed in Phase 1 was extended for Phase 2 to include the areas of marsh between the Unit I/III basin and the salt dike. This is an area of the Upper Bay marsh region that will be inundated at higher high water during high flow events and affected by sedimentation in the 50-year future, no project simulation. For the other marsh regions (Upper Island, Middle Island and Shellmaker Island), the deposition rate on the marsh is very small, and of relative magnitude to the consolidation of the underlying marsh sediments. This process maintains an elevation approximate to higher high water for the marsh islands.

As noted above, the finite element mesh based on the 1997 bathymetric survey was modified to represent the condition of the bay following dredging of the Unit I and Unit II basins to serve as the initial condition for the calibration simulation. Construction of Unit I was completed in 1985. The main Unit II basin was dredged in 1987 and surveyed in November and December of that year. The initial bathymetry for the calibration simulation reflected the completed dredging for both Unit I and Unit II. To compensate for the fact that Unit II was not completed until the 1988 water year, sediment was not permitted to deposit in the model in or below Unit II until 1988. Thus the initial condition bathymetry is referred to as the 1985/87 condition. Bathymetric contours of the initial condition are shown in Figure 4. A comparison of the Unit I and II area in 1985/87 and 1997 is shown in Figure 5.

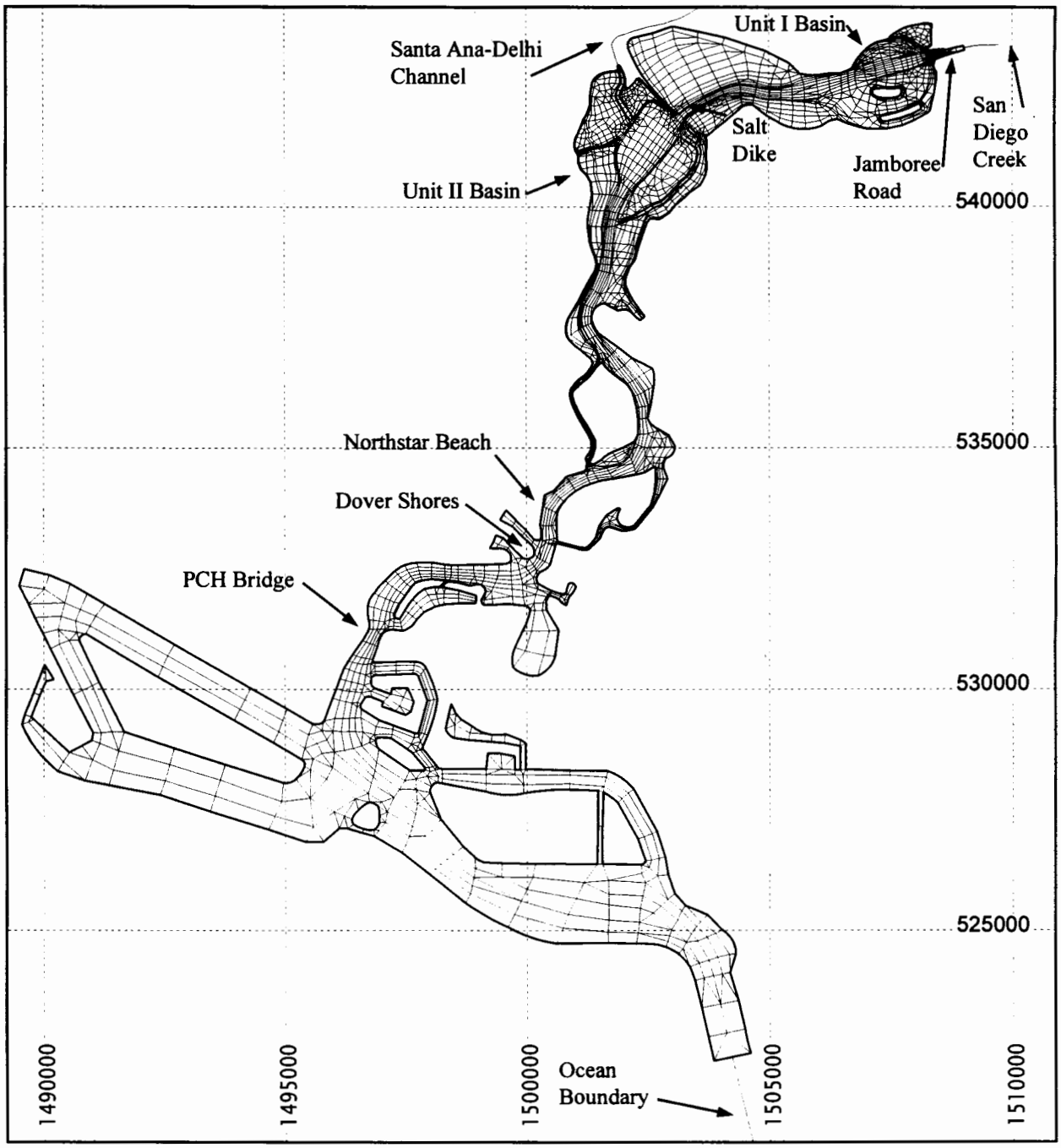

Figure 1. Finite element configuration for Newport Bay, CCS NAD27 zone 6 coordinate grid in feet.

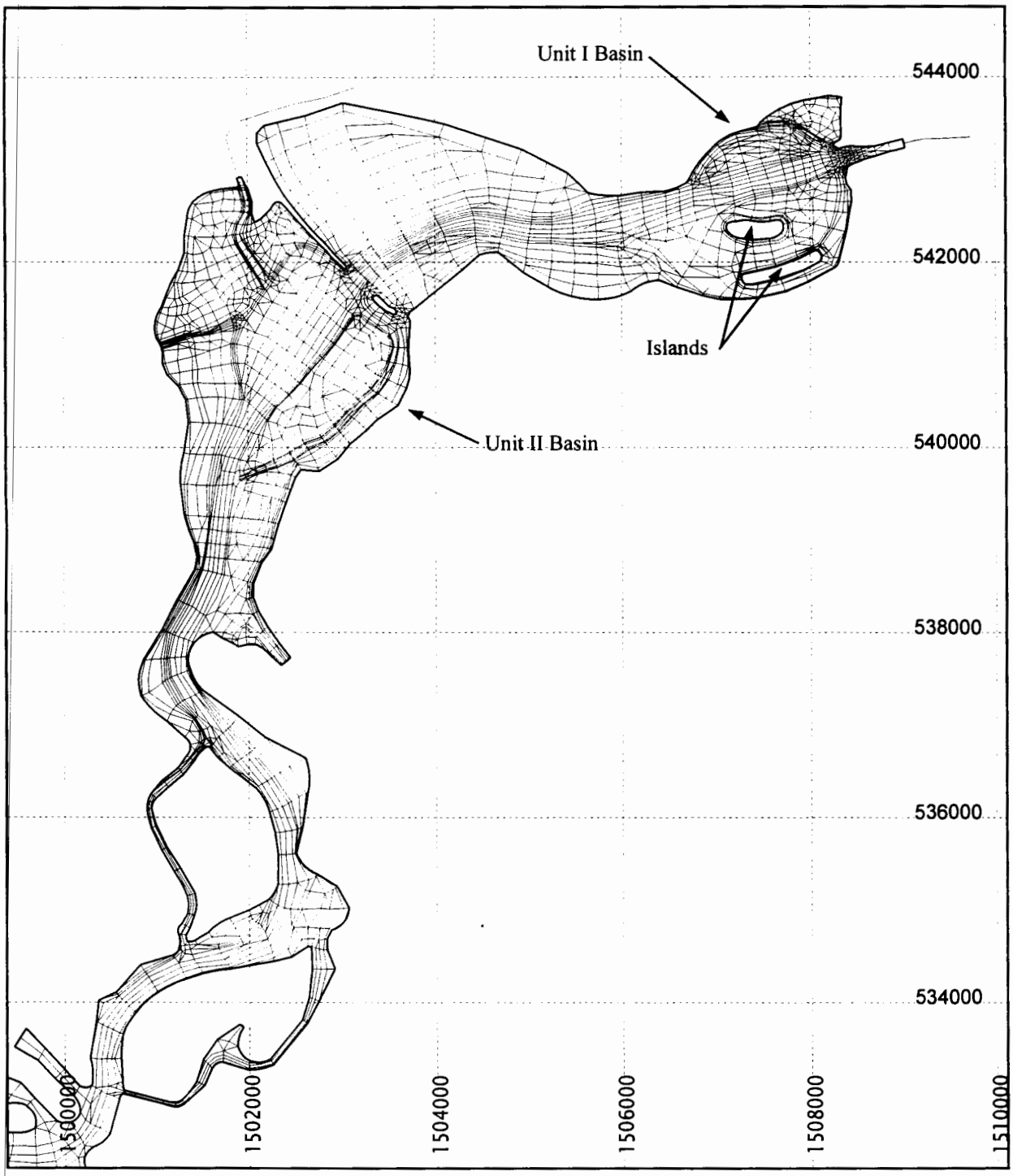

Figure 2. Finite element configuration for Unit I and Unit II Basins, CCS NAD27 zone 6 coordinate grid in feet.

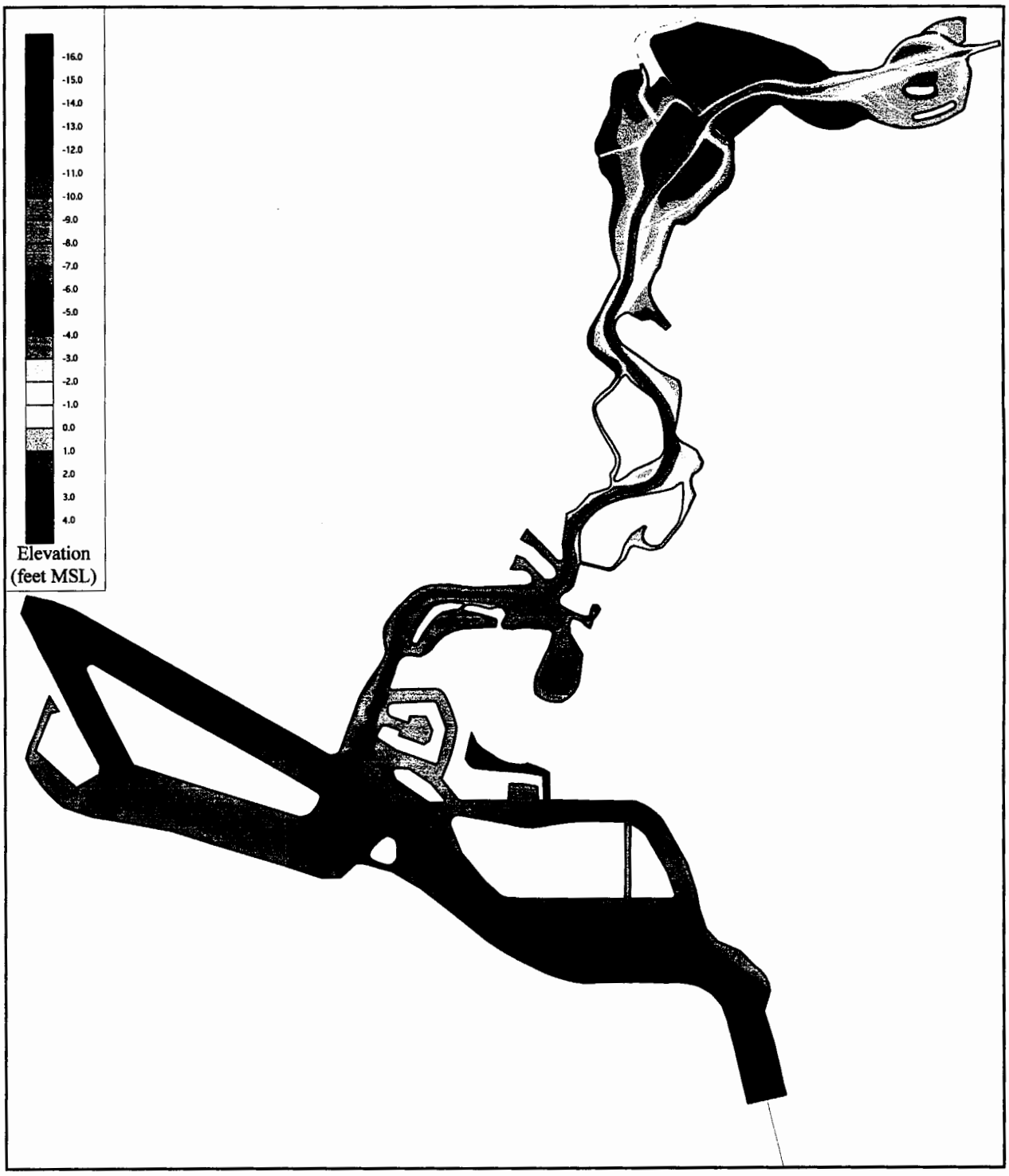

Figure 3. Newport Bay finite element mesh bathymetry, 1997 condition.

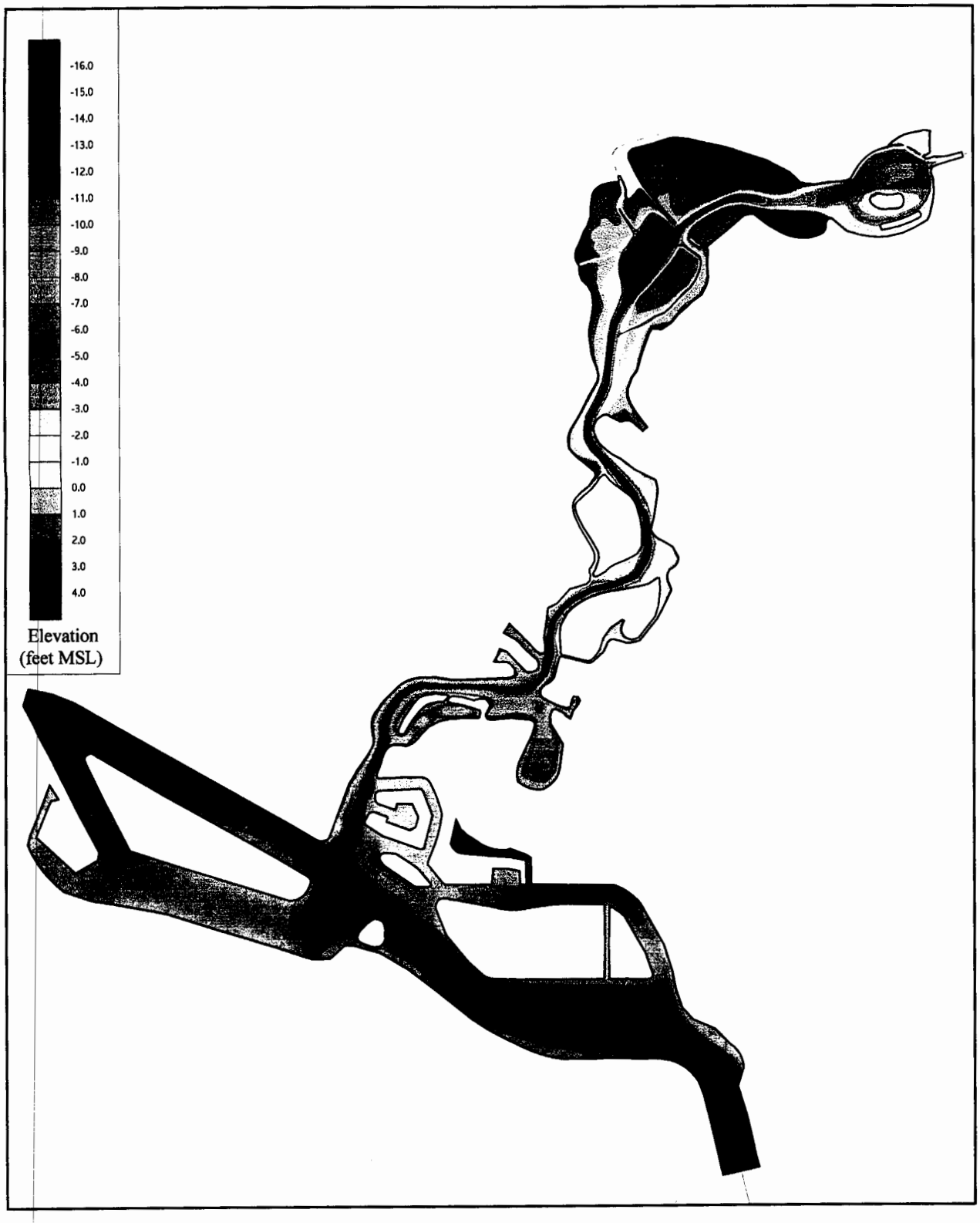

Figure 4. Newport Bay finite element mesh bathymetry, 1985/87 condition.

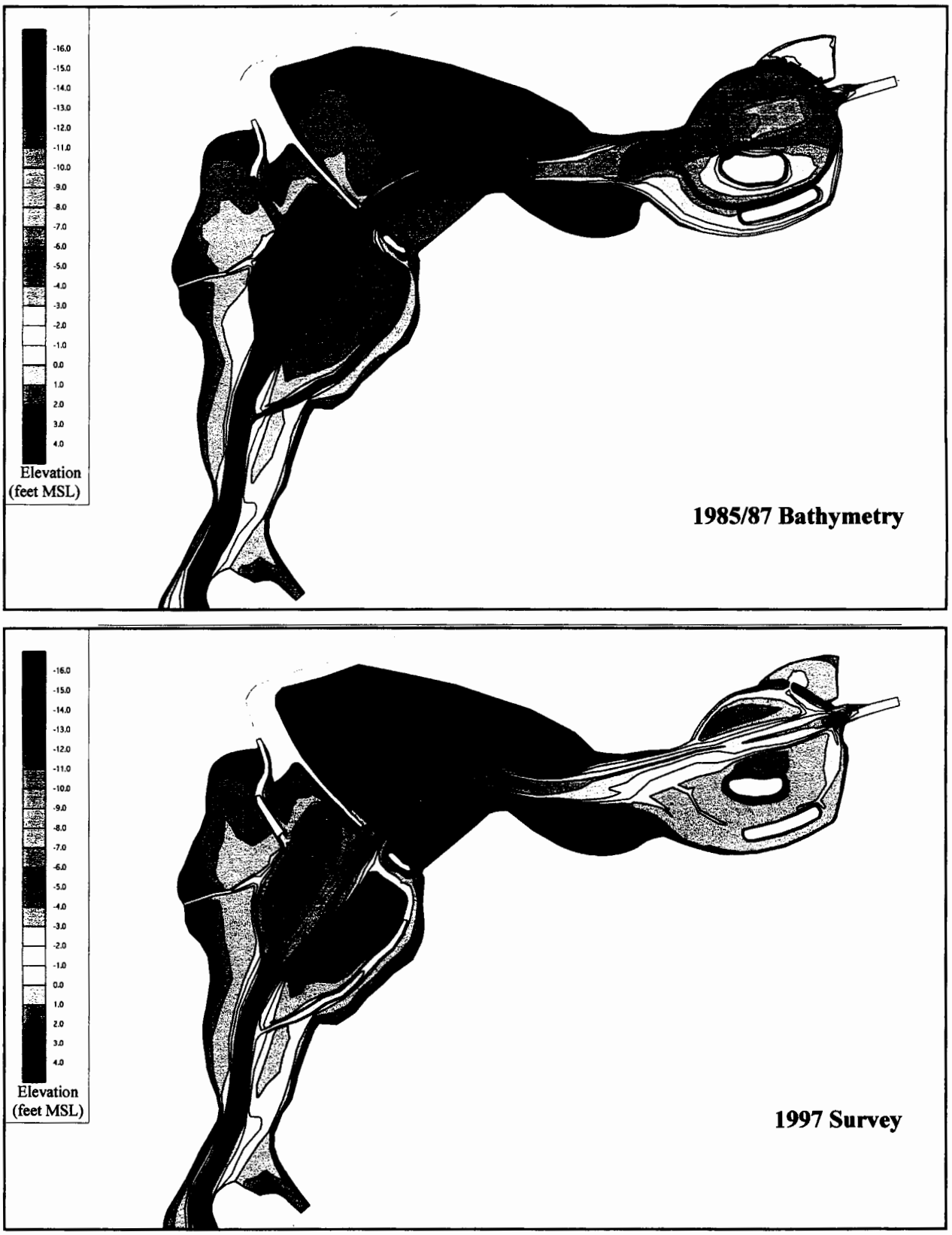

Figure 5. Comparison of 1985/87 and 1997 finite element mesh bathymetric contours.

3. HYDRODYNAMIC CALIBRATION

In Phase 1 of this project the hydrodynamic model was calibrated to observed stage and spot velocity measurements from the 1992-93 Reconnaissance Study (RMA, October 1997). For Phase 2, additional detail in the marsh areas between the Unit I and Unit II basins was added to the finite element network. Water surface elevations at the harbor entrance, Dover Shores, and the salt dike were checked with the new network, and are still in good agreement with the observed data. Plots of computed and observed water surface elevations are shown for the above locations on June 11-12, 1992 and June 23-24, 1992 in Figures 6 through 11 (observed data were not available for the entire June 11-12 period at the salt dike).

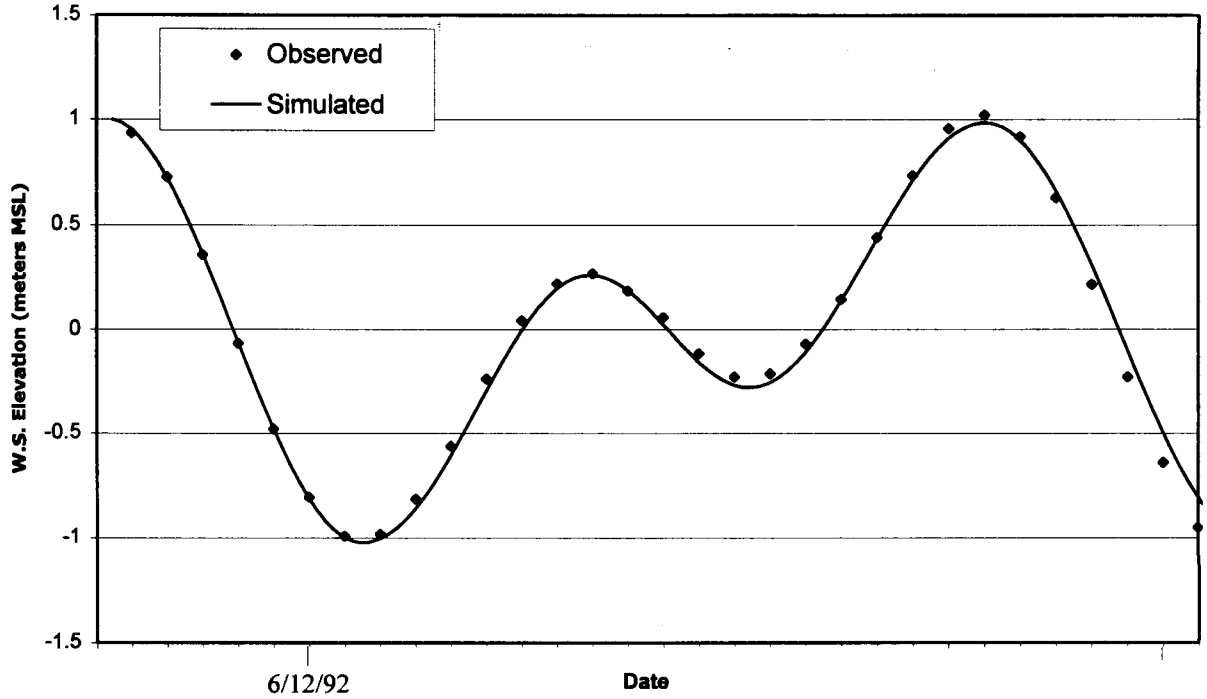

Figure 6. Simulated and observed water surface elevations at the harbor entrance for June 11-12, 1992.

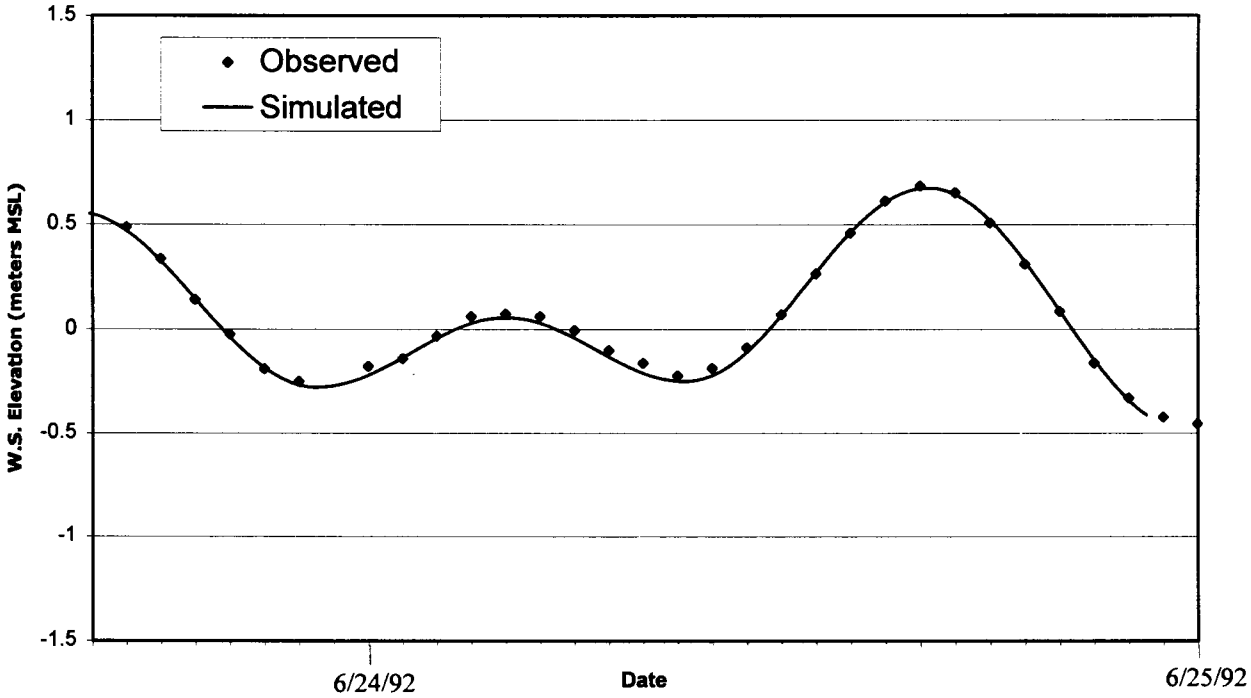

Figure 7. Simulated and observed water surface elevations at the harbor entrance for June 23-24, 1992.

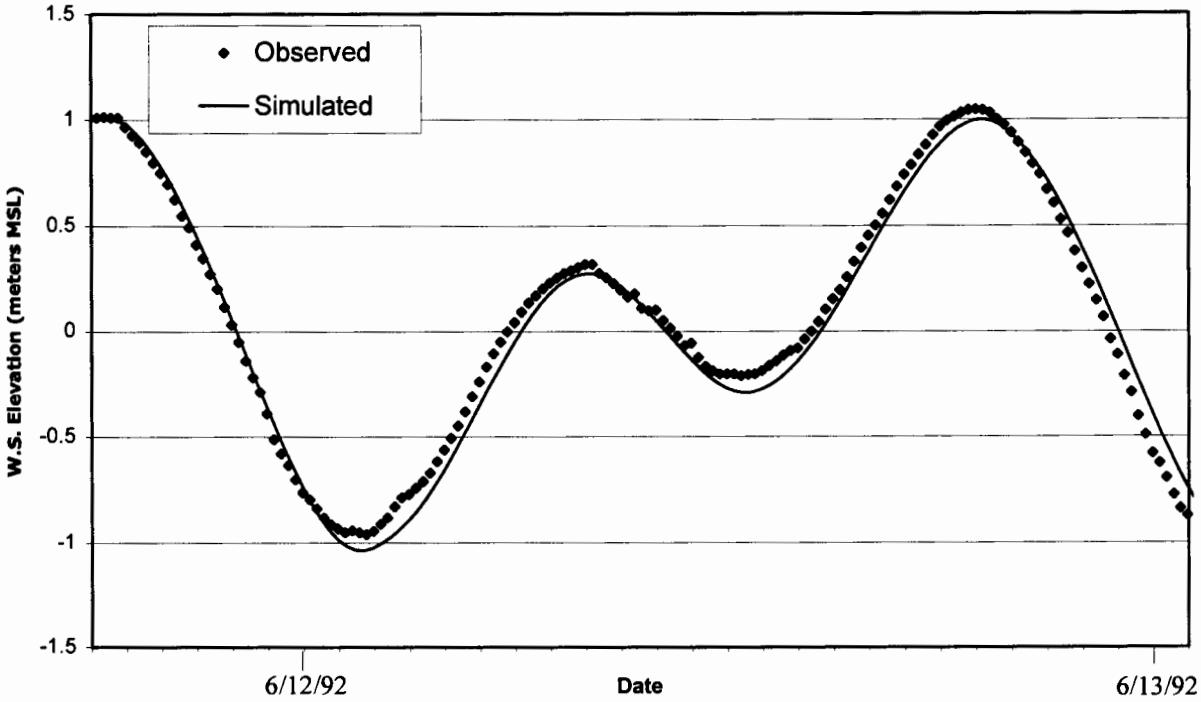

Figure 8. Simulated and observed water surface elevations at Dover Shores for June 11-12, 1992.

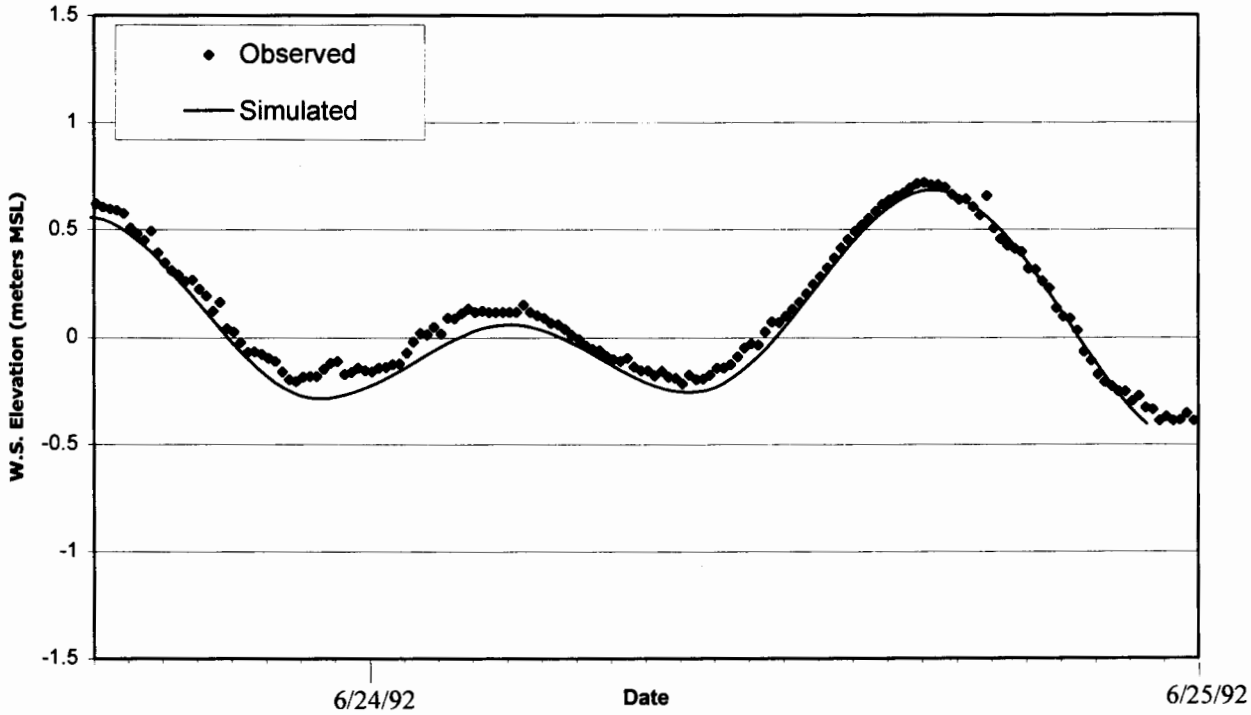

Figure 9. Simulated and observed water surface elevations at Dover Shores for June 23-24, 1992.

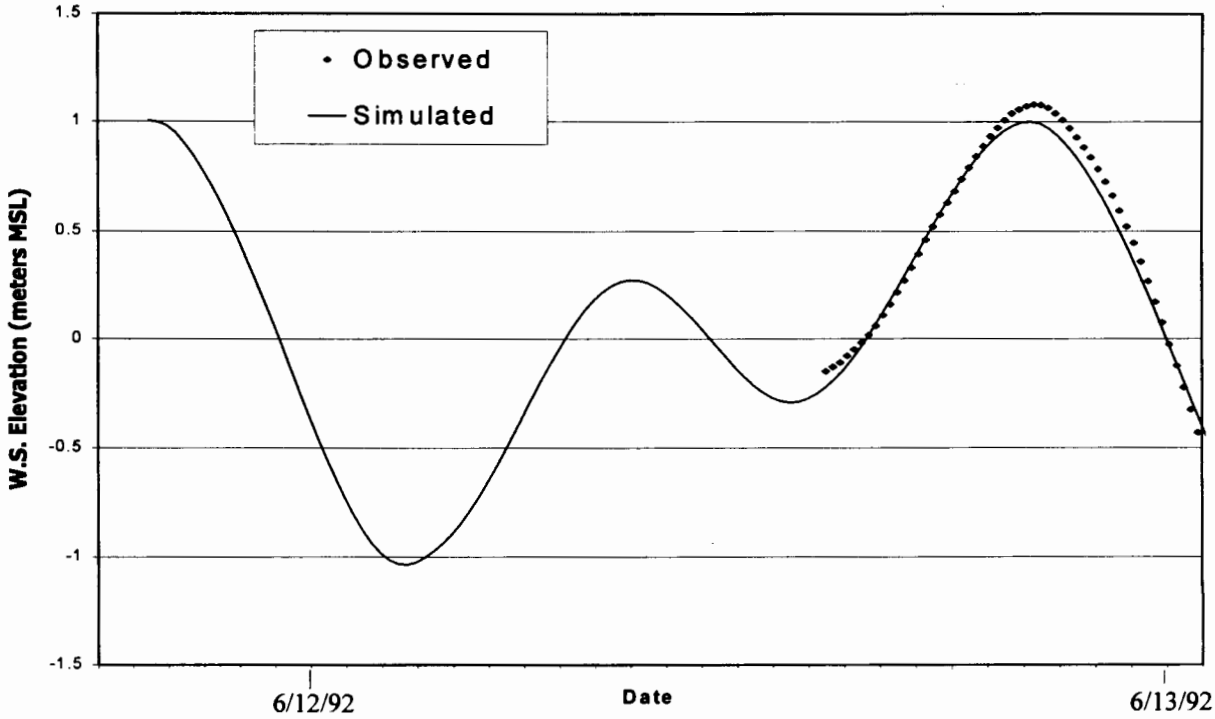

Figure 10. Simulated and observed water surface elevations at the salt dike for June 11-12, 1992.

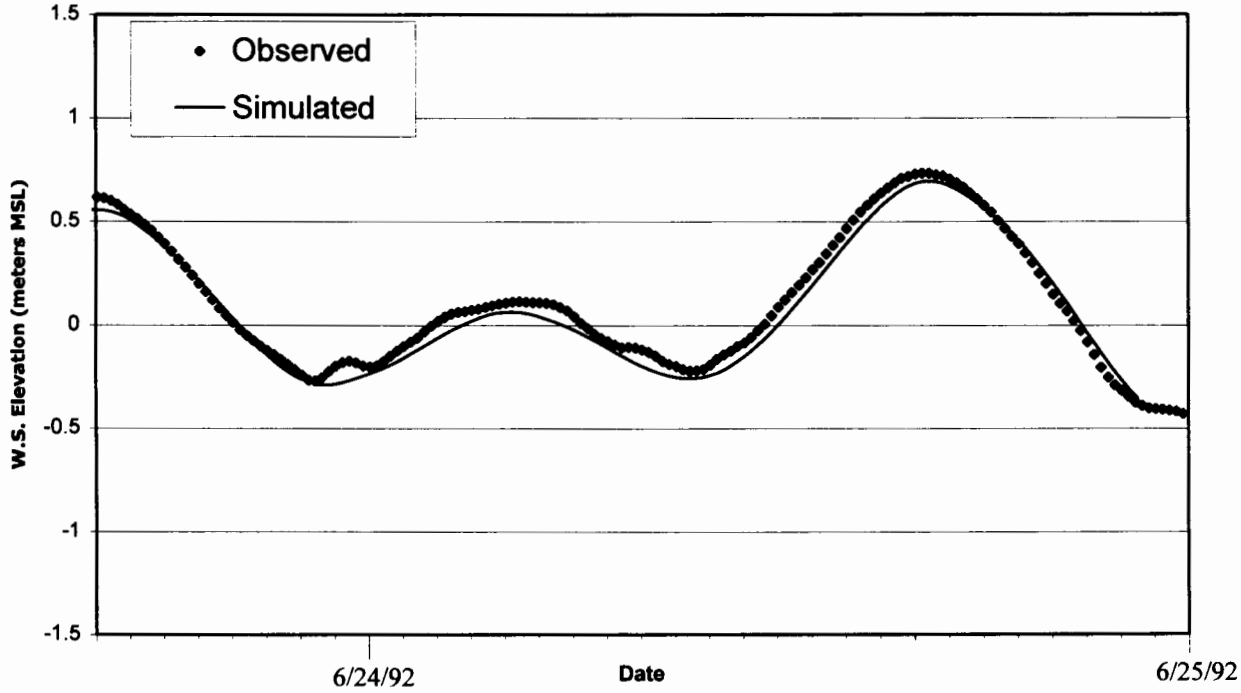

Figure 11. Simulated and observed water surface elevations at the salt dike for June 23-24, 1992.

4. SEDIMENT TRANSPORT CALIBRATION

The objective of the sediment transport model calibration is to reproduce historical deposition patterns observed in the Upper Newport Bay. Calibration of the sediment model requires adjustment of model parameters to best represent the processes of transport, settling, deposition, and scour occurring in the Bay. The calibration process also involves developing an appropriate method of approximating the sediment loading and forcing functions affecting sediment transport.

The methodology for simulating long-term sediment deposition in Upper Newport Bay was established during Phase 1 of the model development. A representative wet weather deposition (storm) event is simulated for each year. The resulting deposition is extrapolated to represent the total sediment loading for the year. A longer dry weather simulation in which sediments may be resuspended and redistributed due to tidal currents and wind-induced waves follows the deposition event. The sediment loading used in the model simulation is approximated to provide the total yearly load based on the historic inflow at San Diego Creek and the flow-suspended sediment relation.

In addition to adjusting model parameters, several improvements in the modeling strategy were implemented for the Phase 2 calibration. First, during wet weather simulation the coupling between the hydrodynamic and sediment transport modeling was tightened so that each hydrodynamic simulation step was followed by a sediment transport simulation step and updating of the bed elevations. This tight coupling resulted in better representation of scour in channels during storm flows. Secondly, the artificial restriction on the maximum elevation at which deposition occurs was removed from the model. The maximum bed elevation is now limited only by erosive forces of flow and wind-induced scour. And finally, the strategy for incorporating the effects of resuspension and redistribution of sediments during low flow months was improved to reduce computation time.

4.1 Calibration Period

The period for the sediment transport model calibration begins in October 1985, after completion of the Unit I basin, and ends in February 1997, the date of the most recent comprehensive bathymetric survey. The main Unit II basin was completed in 1987 and surveyed in November and December of that year. After that time, sedimentation in the model becomes active in the Unit II basin and in the access channel dredged during the Unit II construction.

As discussed in Section 2, the model bathymetry was developed primarily from the 1997 survey data set (Figure 3). Model bathymetry for the beginning of the calibration period was constructed by modifying the 1997 bathymetry to reflect the Design and As-Built hardcopy drawing from the Unit I and Unit II construction (Figure 4). As shown in the comparison between the 1985/87 and 1997 bathymetric contours

(Figure 5), over the calibration period approximately 3 ft of sediment deposited in the main channel of Unit I, and up to 6 ft deposited to the north of the channel. Approximately 3 ft of sediment deposited in the central channel of the Unit II basin, and up to 10 ft deposited near the edges of the basin.

4.2 Sediment Properties

The parameters required by the sediment transport model include the number and thickness of sediment bed layers, critical shear stress for erosion for each layer, sediment density for each layer, critical shear stress for deposition, and sediment particle settling rate.

Sediment properties are a function of depth. Newly deposited sediment is generally less dense and more easily scoured than sediments which have been covered and have begun to consolidate. The variation in sediment properties is often significant over the first few centimeters of the bed. RMA11 represents the variation in bed properties as series of thin fixed layers over a variable thickness layer. Sediment is always deposited into the top layer. As the top layer fills, sediment is shifted down to the lower layers. The bottom layer can grow indefinitely. When scour occurs, the upper layers are removed first. A six-layer model was used for the Newport Bay. The set of sediment properties for each layer is shown in Table 1.

Table 1 presents two sets of bed properties. The existing or "Old" bed properties represent sediments deposited before the current simulation period and are the bed sediments available for scour if sufficient bed shear stress develops from flood flow during a wet season simulation, or from tidal currents and wind driven wave action during a dry season simulation. The sediments deposited in the immediately previous simulation period fill the first five layers of the "existing" bed listed in Table 1 to the extent possible. Sediments accumulated in previous years are allocated the bottom most layer (layer 6), and can be resuspended in years with large storm events. The thickness of the individual old bed layers in the Phase 2 simulations are greater than those used in Phase 1, and allow for more scour in channels during wet season simulations and resuspension of sediments deposited on mudflats for dry season simulations.

The critical shear stresses for erosion of the old bed layers were partly determined by calibrating layer properties with a numerical simulation of the December 6, 1997 flood. However, in both the 1986-1997 calibration simulation and the 50-year future, without project simulation, only mean daily flow data were available. Peak storm flows are typically 4 times or more the mean daily flows for the same date of occurrence. The calibrated value for critical shear stress for erosion is less than would be expected if hourly storm flow hydrographs were used that incorporated peak flow data.

The concept of the sediment bed growing from the bottom most layer is important when performing the update of the bottom bathymetry from one simulation period to the

Table 1. Sediment model parameter values at current level of calibration.

Previously Existing (Old) Bed						
Layer	1	2	3	4	5	6
Layer Thickness (m)	0.005	0.015	0.020	0050	0.200	---
Critical Shear Stress for Erosion (N/m^2)	0.18	0.38	0.68	0.82	1.00	2.00
Bulk Density (kg/m^3)	1126	1155	1224	1269	1310	1350

Newly Deposited Bed						
Layer	1	2	3	4	5	6
Layer Thickness (m)	0.010	0.010	0.020	0.043	0.127	---
Critical Shear Stress for Erosion (N/m^2)	0.16	0.35	0.55	0.68	0.82	1.5
Bulk Density (kg/m^3)	1105	1126	1143	1164	1269	1310

Critical Shear Stress for Deposition (N/m^2)	0.11
Bulk Density (kg/m^3) bottom consolidated layer	1430
Settling Velocity, $v_s = KC^{\alpha}$	
Wet weather simulation:	
v_s at C < 300 mg/l (m/s)	4.44x10-5
α	1.0
v_s at C > 3000 mg/l (m/s)	4.44x10-4
Dry weather simulation:	
v_s at C < 300 mg/l (m/s)	2.22x10-5
α	1.33

next. The density used to convert the mass of sediment deposited to a thickness value should be representative of the many feet of sediment deposited over the time of simulation.

An estimate of sediment density was available from previous studies in the estuary. Bed layer densities for the sediment model were initially selected to correspond with soft clay sediments. Through the calibration process, the density for the bottom most consolidated layer was increased to 660 kg/m^3 (1430 kg/m^3 bulk density). This was done to reduce the volume of the deposited sediments. It is recommended that new sediment density data be collected at several locations in the Upper Bay to guide future refinements of the calibration.

Deposition can only occur when the shear stress on the bed is less than the critical shear stress for deposition. The critical shear stress for deposition is only a function of the uppermost bed layer so only one value is required.

Sediment particle settling velocities are calculated in the model as a function of suspended sediment concentration. The settling rate parameters are the base settling velocity when suspended sediment concentrations are less than or equal to 300 mg/l, and the exponent controlling concentration dependence.

4.3 Boundary Conditions

The principal boundary conditions for the sediment model are the suspended sediment loads at all inflow boundaries and the time varying wind field.

Daily average flows in San Diego Creek from 1972 through 1996 provided by the County of Orange were used in conjunction with a functional relation between flow and suspended sediment concentration to develop a time series of yearly sediment loads to the Upper Newport Bay to be used in the 1985/87 simulation. The inflow from San Diego Creek was assumed to be 95% of the total inflow to the Upper Bay, with the additional 5% coming from the Santa Ana-Delhi Channel. The Sediment Transport Curve for San Diego Creek at Campus Drive (Figure 12) was used to derive a smooth functional relationship between suspended sediment concentration and flow (Figure 13).

For each year in the 25-year historic record, the total sediment load was calculated based on the mean daily flow and the suspended sediment – flow relation. The calculated sediment loading to the Upper Newport Bay for each year of the calibration period is shown in Figure 14. The total sediment load applied over the calibration period was 1,205,000 tons.

To produce realistic deposition patterns, it was necessary to simulate deposition during a storm flow. Figure 12 shows that for a given year, the bulk of sediment entering the Upper Bay occurs from one, two, or three similarly sized large storm events. The current modeling strategy is to simulate the largest storm event for each particular year, and then scale the deposition resulting from that storm event by the ratio of the total sediment load estimated for that year to the sediment load introduced by the simulated storm. For very wet years (e.g. water years 1993 and 1995) two peak storm events were simulated.

For the wet season, mean daily stream discharge records for San Diego Creek were used to develop a 3 to 4 day hydrograph (Figure 15) for the peak storm event for each simulated year. Six to 7 day hydrographs encompassing two peak storm events were developed for simulating very wet years. The peak flows and the associated scaling factors for deposition for each of the calibration years are shown in Table 2. Suspended sediment concentrations for San Diego Creek and the Santa Ana-Delhi Channel were dynamically adjusted in the model according to the suspended sediment – flow relation shown in Figure 13. Since the flood flows represent the primary factor for sediment transport in the wet season, a mean tide was used at the ocean boundary for these simulations with the higher-high, lower-high, higher-low, and lower-low elevations equal to +2.62, +1.15, -0.89, -2.76 ft (+0.80, +0.35, -0.27, -0.84 m) MSL respectively.

For dry season simulations the inflow at San Diego Creek and Santa Ana-Delhi Channel were taken as 15 cfs (0.42 cu.m/sec) and 1.5 cfs (0.042 cu.m/sec). Inflow sediment concentrations for both streams were set to zero. For this phase of the modeling study, a spring tide was used to drive the hydrodynamic model. A constant wind 18 mph (29.0 kph) field was applied in the dry weather simulation. Sediment resuspension was greatly reduced for the marsh areas within the computational model to reproduce the shielding effects of marsh plants.

The spring tide and the constant wind were used to accelerate the sediment redistribution process in the current modeling effort so the dry season simulation could be accomplish by a one month run. In Phase 1, the dry season simulation was performed using a two-month simulation period, with the second month sediment deposition/erosion rate projected for an additional eight-month period. A time dependent wind field was used in Phase 1 to simulate the typical daily cycle of the April to September period where peak winds develop in the afternoon. However, little sediment redistribution would actually occur in the model outside the few hours of the peak wind.

Table 2. Peak storm flows and associated deposition scaling factors for the calibration period.

Water Year	Mean Daily Flow (cfs)								Additional Deposition Factor
	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
1985-1986	18	270	547	1589	106	---	---	---	0.65
1986-1987	24	659	177	69	---	---	---	---	1.23
1987-1988	13	649	201	17	---	---	---	---	2.26
1988-1989	10	512	828	15	---	---	---	---	1.33
1989-1990	13	1772	175	38	---	---	---	---	0.12
1990-1991	10	1030	2370	1700	47	---	---	---	0.58
1991-1992	175	2020	2350	712	60	---	---	---	0.95
1992-1993	410	1950	2980	625	129	3240	395	64	1.00
1993-1994	12	835	200	15	---	---	---	---	3.76
1994-1995	97	3950	394	4510	437	3997	70	---	0.83
1995-1996	24	1600	978	89	---	---	---	---	0.64
1996-1997	24	1600	978	89	---	---	---	---	0.64

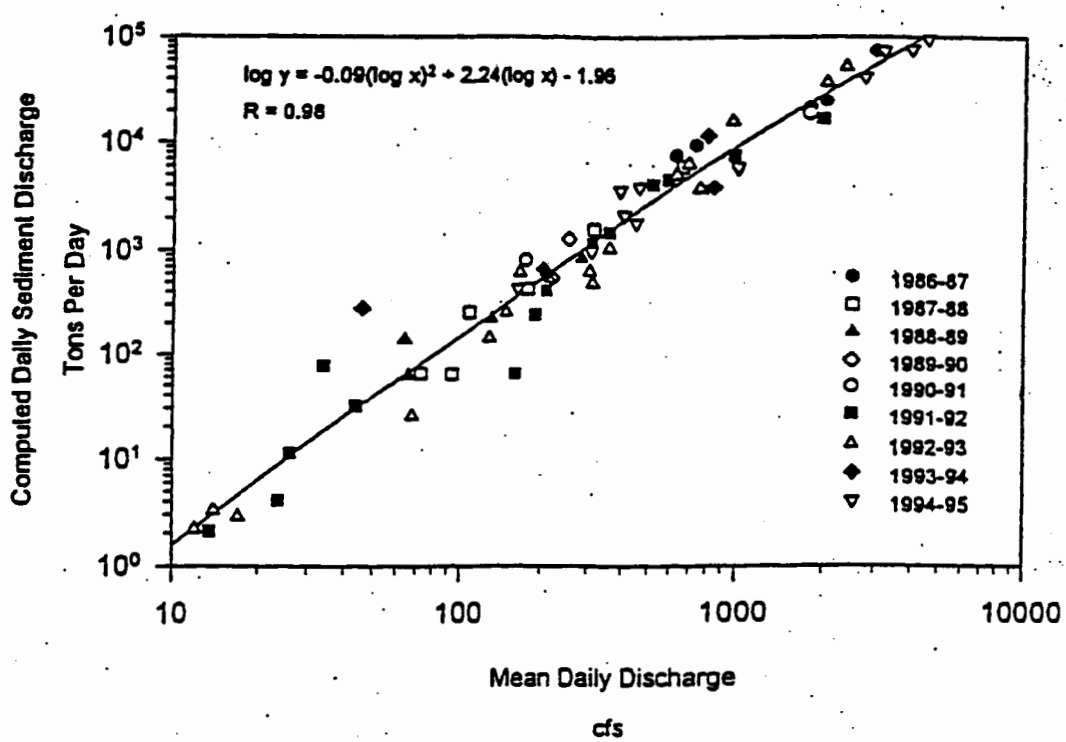

Figure 12. Sediment transport curve, San Diego Creek at Campus Drive, 1986-1995.

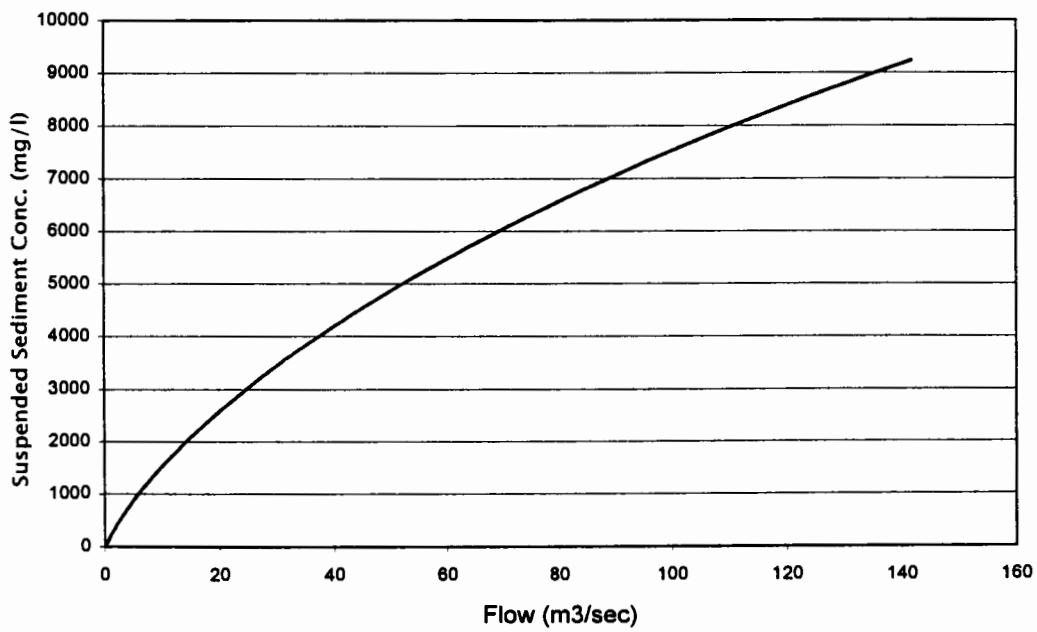

Figure 13. Suspended sediment concentration vs. flow for San Diego Creek inflow.

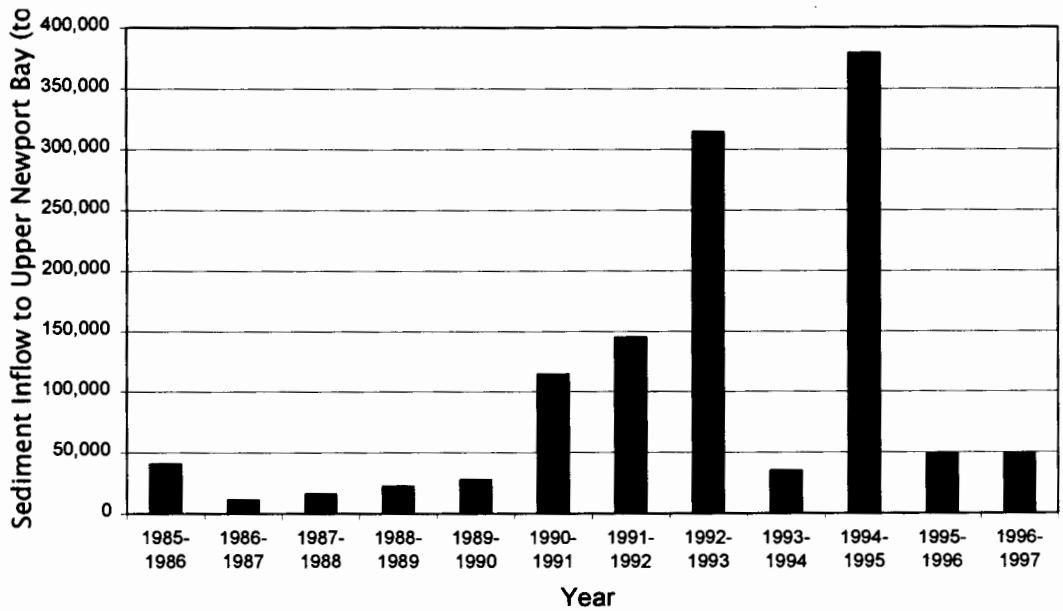

Figure 14. Yearly sediment load into Upper Newport Bay, calibration simulation.

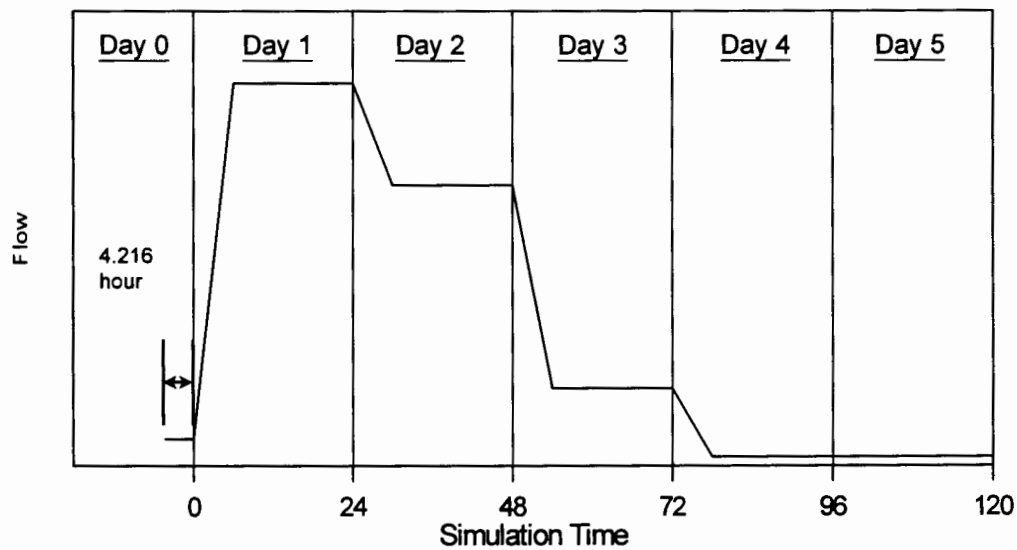

Figure 15. Application of daily storm flow values to San Diego Creek boundary condition for the wet weather simulations. The RMA-11 sediment transport simulation is run for hours 0 to 120. The Day 0 flow is used in the RMA-2 flow modeling as a steady-state starting condition with an additional 4.216 hour of dynamic simulation to "spin-up" the model.

4.4 Typical Wet and Dry Weather Simulation

Each model year includes a wet and dry weather simulation. Sediment is supplied to the system during the wet weather simulation. During the dry weather simulation, tidal currents and wind-induced waves resuspend and redistribute sediments. The simulation includes the following steps.

1. Perform 3 to 7-day wet weather combined hydrodynamic and sediment transport simulation with RMA2-RMA11 using mean tide conditions, updating bed elevations for each time step of the deposition event (3 to 4-day simulations were performed for low to moderate flow years, and 6 to 7-day simulations were performed for wet years).
2. Scale the change in bed elevation to represent the total yearly sediment load.
3. Update model bathymetry.
4. Perform 1-day dry weather hydrodynamic simulations with a spring tide using RMA2.
5. Perform 1-month dry weather sediment transport simulation with RMA11 (repeating the hydrodynamic result each day).
6. Calculate the net change in bed elevation over the dry weather simulation.
7. Update the model bathymetry.

The simulation procedure is performed automatically by an executive program that coordinates the data flow between RMA2 and RMA11 and performs the updates on the model bathymetry.

The state of the new sediment bed from the wet weather simulation is carried over to the dry weather simulation. The net change in the sediment bed is used to compute a change in model bed elevation assuming a bulk density of the sediment of 1430 kg/m^3.

4.5 Calibration Results

The hydrodynamic and sediment transport models for the Upper Newport Bay have been used to simulate the 12-year period beginning in the fall 1985 and continuing through spring 1997. The parameter values and modeling approach described above are the result of an iterative process of running the models for the calibration period and adjusting the parameters and methodology to improve the comparison of the simulated 1997 bathymetry and the 1997 bathymetric survey.

For the purpose of comparing the computed and observed bathymetry, the finite element mesh based on the 1997 bathymetric survey is used to represent the observed bathymetry. This is done because the finite element mesh provides a continuous surface that facilitates the comparison.

The starting bathymetry for the simulation is shown in Figure 4. The bathymetric contours of the Newport Bay resulting from the Phase 2 calibration simulation are shown in Figure 16. These may be compared with the 1997 bathymetric contours shown in Figure 3. The comparison is generally very favorable. The sediment distribution in the Upper Bay is virtually the same in both plots. There are still some discrepancies between the simulated and observed bathymetry in the Unit I area, however it is an improvement over the Phase 1 results. A more detailed comparison of the computed bathymetry and the finite element bathymetry based directly on the 1997 survey in the Unit I and Unit II area is shown in Figure 17. In Figure 18, bathymetry is shown for Phases 1 and 2 to illustrate the changes in the results brought about by the improvements made to the model in Phase 2. In Phase 1, the sediment model over predicted deposition in shallow regions surrounding Unit I, particularly to either side of the mouth of San Diego Creek. The bathymetry near the mouth of San Diego Creek is predicted with much greater accuracy in Phase 2. The most important improvement in Phase 2 is that the channels through the Unit I and Unit II basins are maintained. Although the Unit I channel is not as deep as the observed data indicate, it is better defined than in Phase 1. The channel through Unit II is a very good match with the surveyed channel and a great improvement over the Phase 1 calibration results. In Figure 18, it can be seen that in Phase 1 there is excess deposition within the Unit II channel, but in Phase 2 there is less deposition within the channel and it is instead concentrated in the shallower areas beside the channel. The model does a good job of predicting the bed elevation in the dredged basins. The overall sediment distribution in the Unit II region is well represented.

The net deposition based on the Phase 2 calibration result and the 1997 survey bathymetry has been computed relative to 1985/87 initial condition bathymetry. Deposition was computed for each of the regions shown Figure 19. The deposition volumes are shown in Figure 20 and Table 3. The total computed deposition volume for these regions was within 2% of the 1997 survey. The deposition volume in the Unit I and II areas and in the channel south of Unit II was over predicted in the calibration simulations by approximately 8% in Phase 1, and under predicted by approximately 6% in the current phase of the study. The deposition in the channel between Unit I and II was slightly under predicted in Phase 1, and to a lesser extent under predicted in Phase 2 as well. In Phase 1, the model over predicted the deposition in the mudflats adjacent to Unit II by approximately 67%. For Phase 2, this was greatly improved with under prediction of deposition in this area of approximately 12%. From the upstream boundary to Middle Island, the model over predicted the sediment deposition volume by 14% for Phase 1. For phase two, this was improved to a 10% under prediction. The greatest error in both phases was in the deposition from Middle Island to the PCH Bridge. Only a slight improvement was made in this area in Phase 2. Further review of the historical bathymetric data and dredging activity (if any) between Middle Island and the PCH Bridge is required to determine whether the estimate of the historical deposition in that region is inaccurate or whether the model needs significant adjustment.

Table 3. 1985-1997 net deposition volume by region, calibration simulation.

	Net Deposition (cubic yards)	
	Observed	Computed
Unit I	414,000	354,000
Unit II	358,000	371,000
Channel between Unit I & II	66,000	53,800
Mudflats adjacent to Unit II	53,000	46,700
Channel South of Unit II	170,000	129,000
Middle Island to PCH	18,000	103,000
Total	1,079,000	1,057,500

In examining Figure 17, simulated deposition in the marsh areas added in Phase 2 appears to be underpredicted. The starting 1985/87 and ending 1997 elevations for the marsh areas (Figure 5) are based upon 1986 and 1997 aerial surveys. However, the aerial surveys produced elevations for marsh areas mainly representative of the tops of plants. Bed elevations were estimated from the aerial survey data to the extent possible. The differences in marsh elevations between the 1997 survey and 1997 calibration result (0.2 to 0.3 feet) may largely be due to error in extrapolating ground elevations from the elevations of plant tops.

The time series of cumulative sediment deposition by region is shown in Figure 21. The impact of wet versus dry years is readily apparent. Water years 1986 through 1990 were relatively dry and little sediment was deposited in the system. 1991 through 1993 were wet years as evidenced by the rapid increase in deposition. 1995 was another wet year, and again there is a rapid increase in deposition. Over the course of the simulation, deposition in the Unit I region nears an equilibrium and more sediment moves farther downstream in the system.

The model shows significant deposition downstream of the PCH Bridge toward the end of the calibration period. At this point no attempt has been made to check the validity of the model results below the PCH Bridge. It is likely that the model would over estimate deposition in the Lower Bay. Stratification in the Lower Bay could greatly reduce the residence time of the fresh water storm flows, allowing sediments to be carried out of the ocean boundary. Because the model is currently being run in the two-dimensional depth averaged mode, the model will not capture the effects of stratification. Stratification may be part of the explanation for the models apparent overestimate of deposition below Middle Island. At this time, the models estimate of deposition below the PCH Bridge should be viewed as sediment that is *potentially* available for deposition.

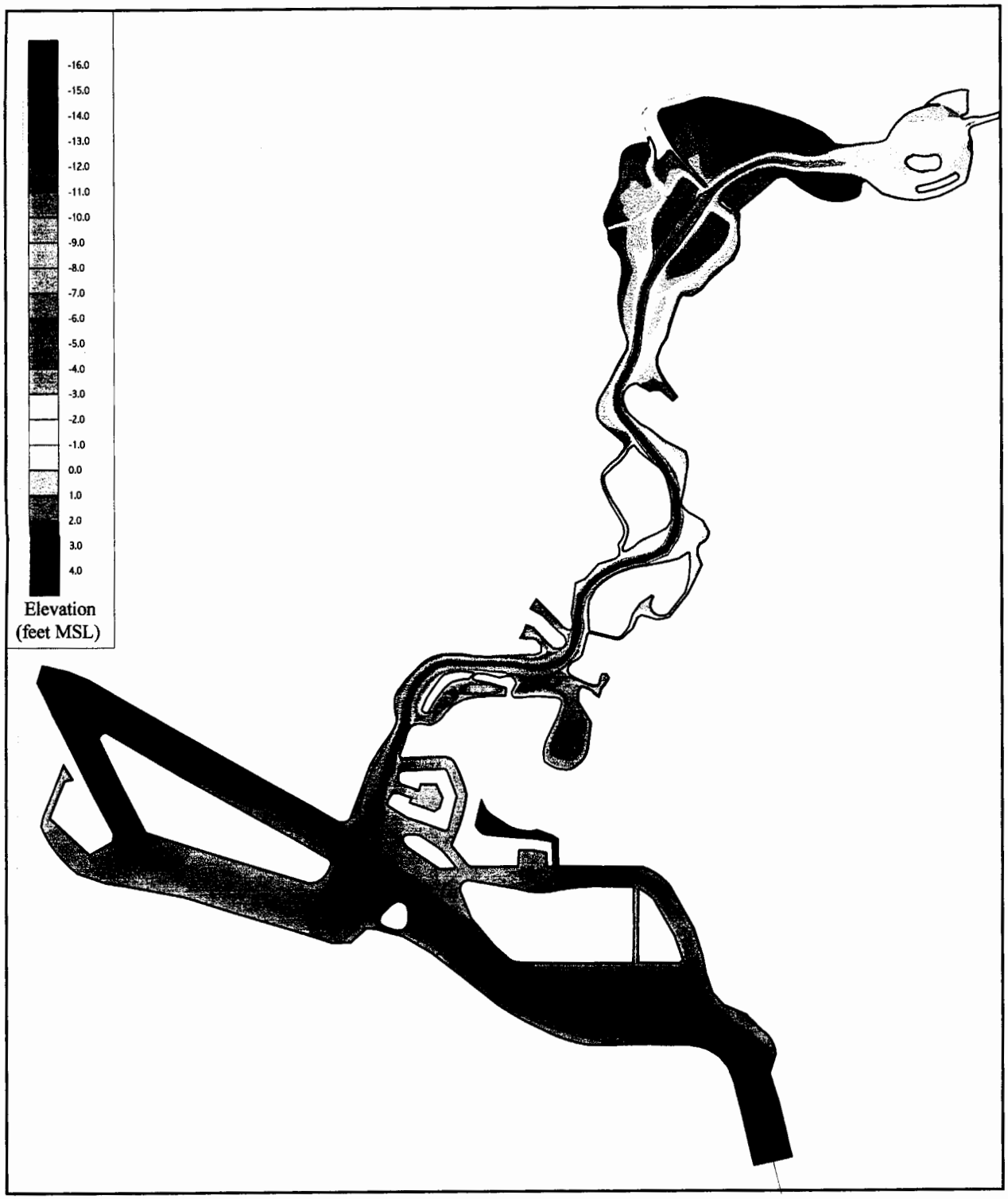

Figure 16. Newport Bay finite element mesh bathymetry, 1997 calibration result.

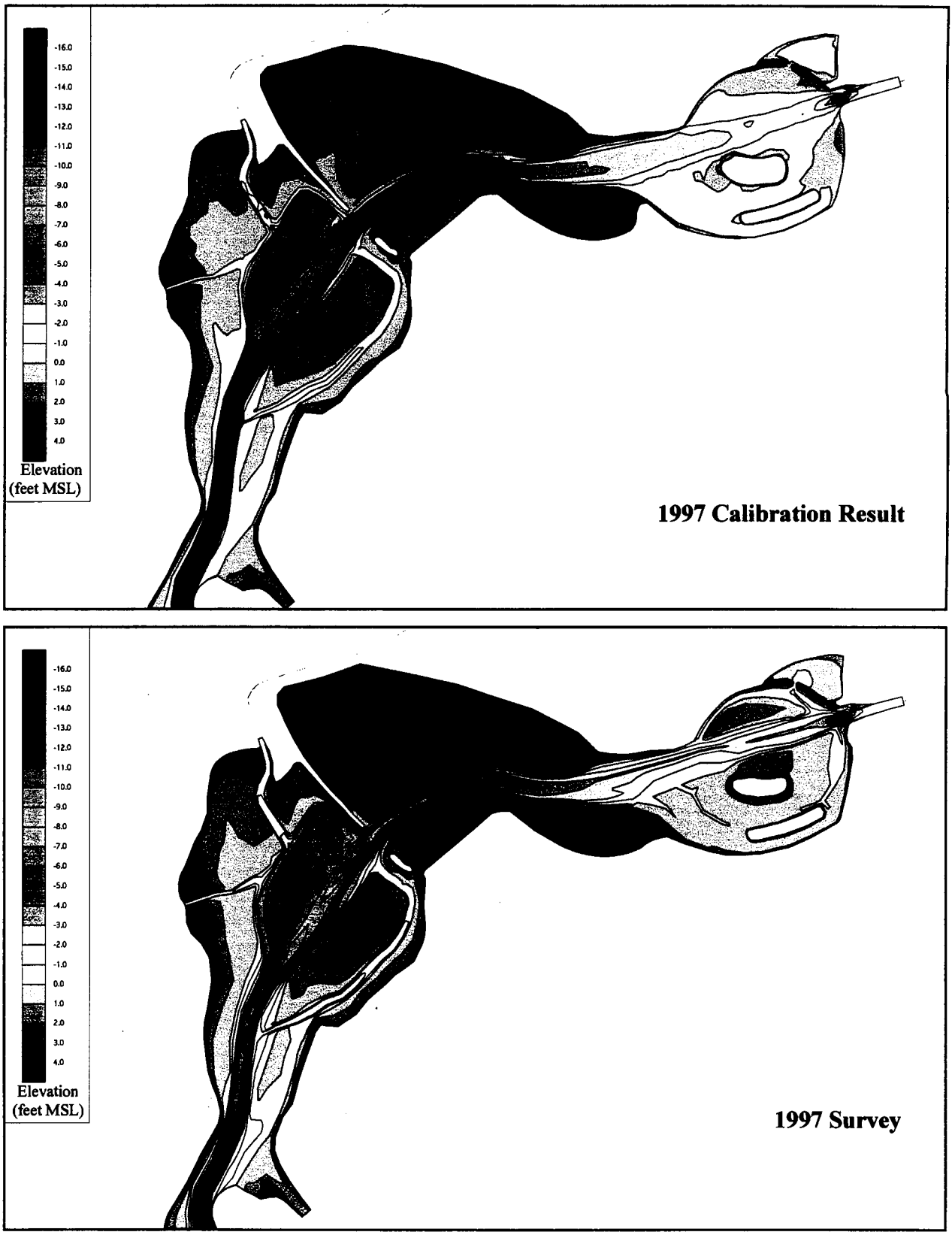

Figure 17. Comparison of bathymetric contours between the 1997 calibration run result and the finite element mesh based on the 1997 survey.

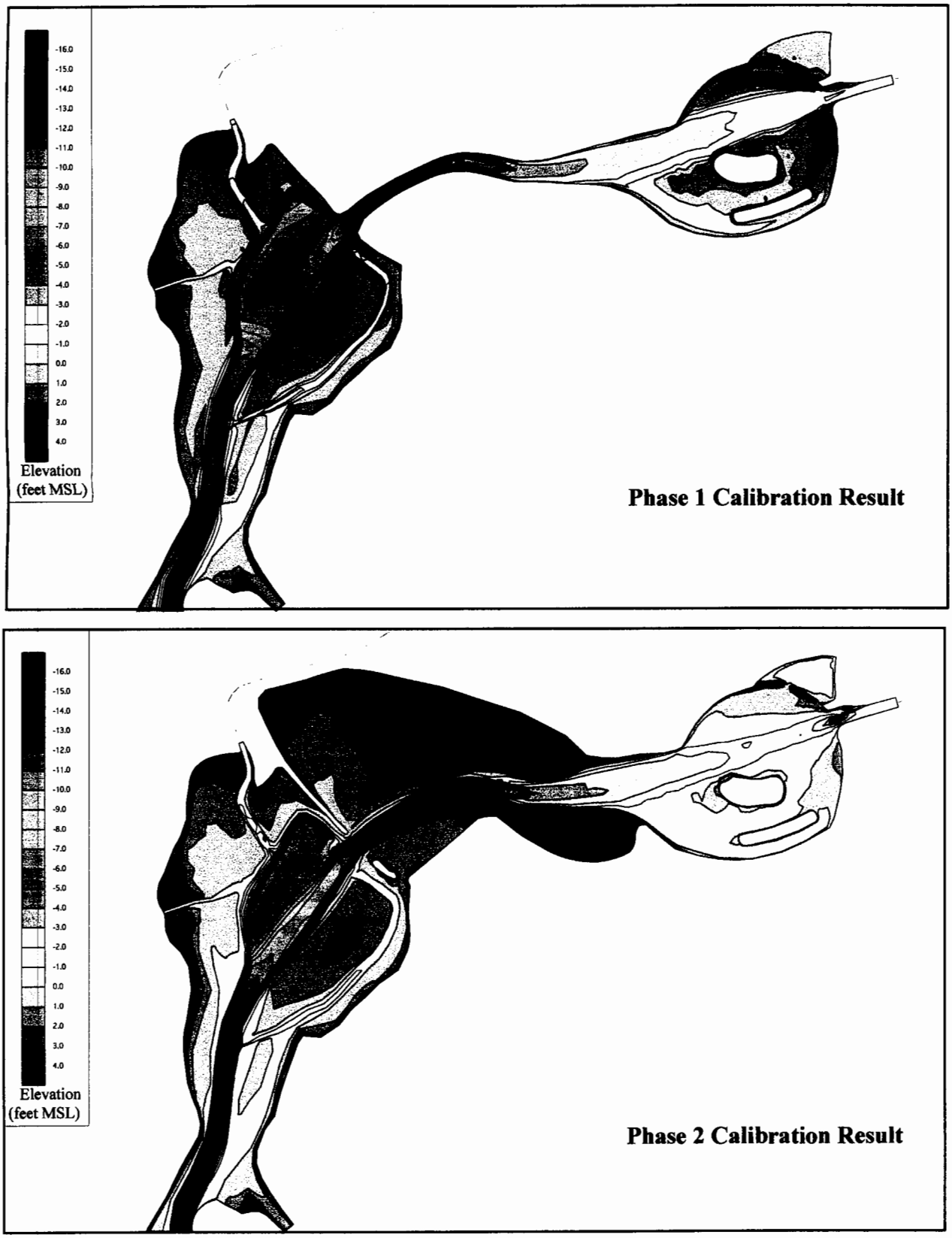

Figure 18. Comparison of bathymetric contours between the Phase 1 and Phase 2 1997 calibration run results.

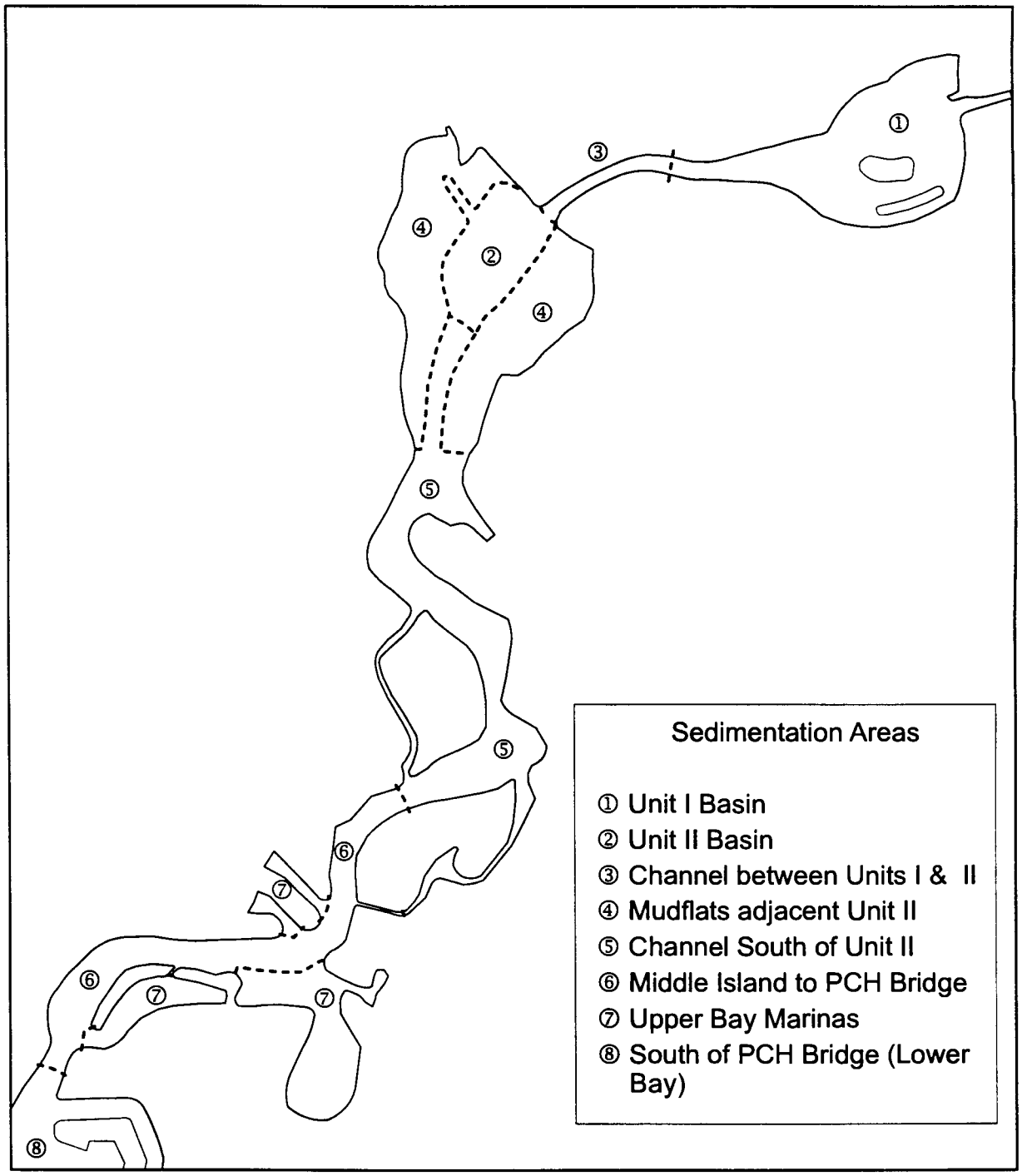

Figure 19. Boundaries of the sedimentation areas used in evaluations of the calibration and 50-year future simulations.

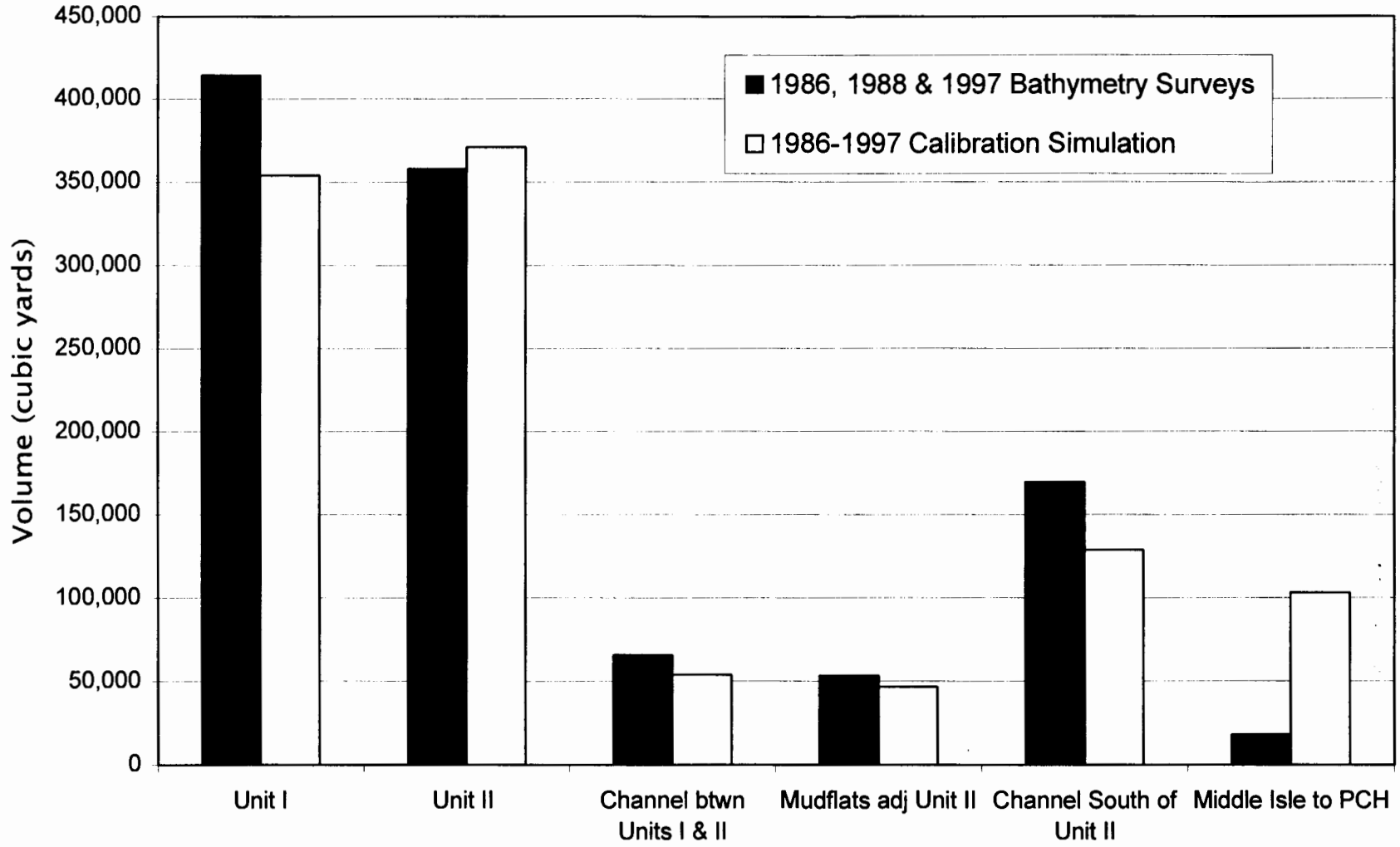

Figure 20. Comparative deposition by region for the calibration result with the deposition estimated from the relative changes in the 1997 survey bathymetry vs. the 1985/87 initial condition bathymetry.

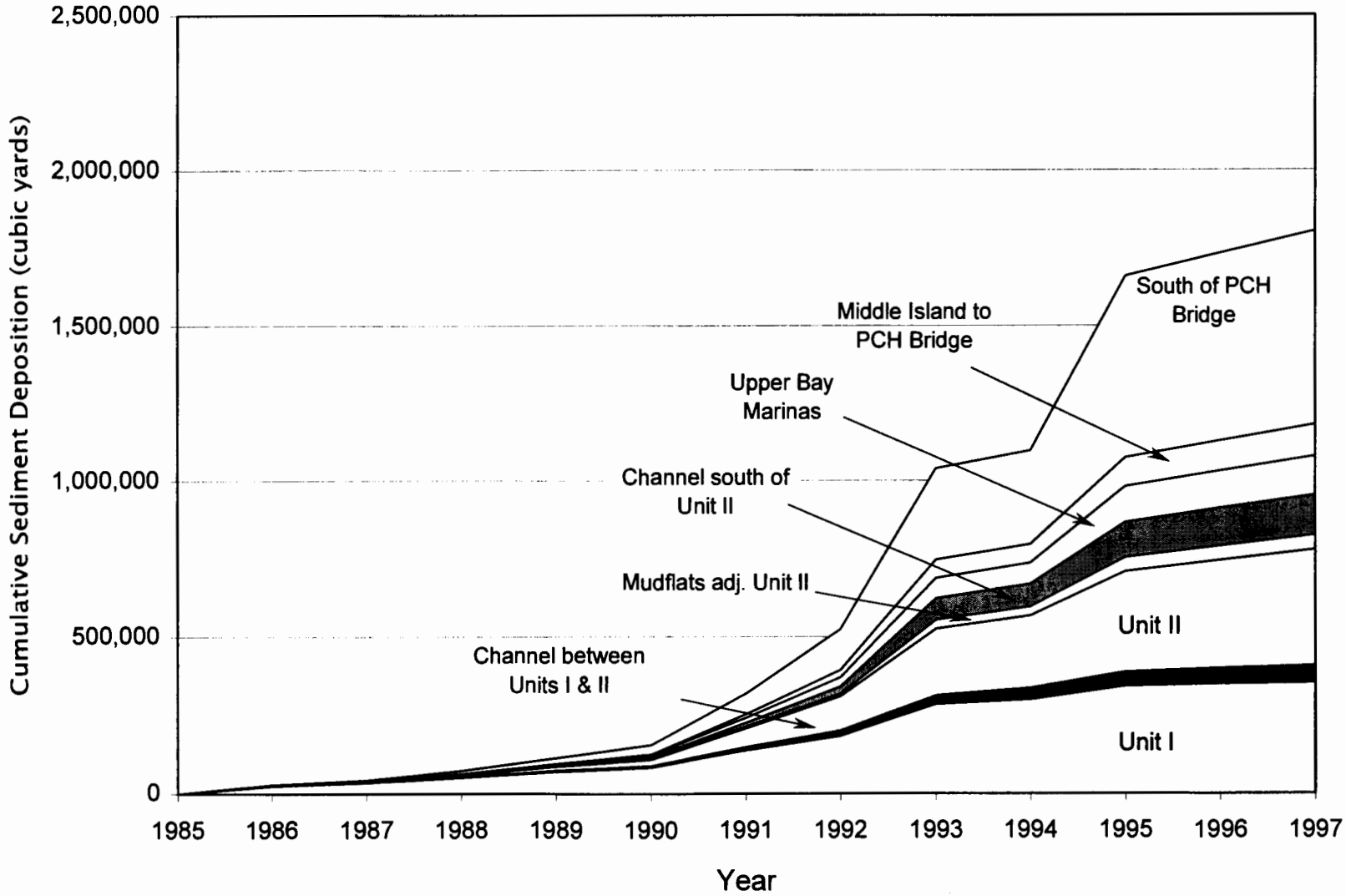

Figure 21. Cumulative volume of sediment deposition by region for the calibration simulation.

5. DECEMBER 1997 FLOOD SIMULATION

The December 1997 flood event was simulated using the re-calibrated model. This simulation was performed to test the model under extreme high flow conditions.

5.1 Changes to the model

As discussed in section 4, the hydrodynamic and sediment transport models were modified to run tightly coupled with updating of bed elevations at each time step, and the restriction on maximum bed elevation was removed.

To accommodate the extreme high flows from the December 1997 flood event, the finite element mesh was expanded to include marsh areas in the mid-bay, principally Upper Island, Middle Island and Shellmaker Island. This is in addition to the marsh areas between the Unit I and Unit II Basins included in the Phase 2 calibration and 50-year future without project meshes. These mid-bay marsh areas were inundated during the December 1997 flood, conveying significant flow at peak flood. Not including these areas in the mesh restricts the flood flow and raises the simulated water surface in the Upper Bay to excessively high levels. The finite element mesh for the flood simulation is shown in Figure 22.

5.2 Input Data and Boundary Conditions

For the 1997 flood simulation, sediment discharge and flow measurements for San Diego Creek taken during the December 6, 1997 flood were used to develop flow and sediment load time series boundary conditions at San Diego Creek. The San Diego Creek inflow hydrograph and inflow sediment concentrations for the first 36 hours of the flood simulation are shown in Figures 23 and 24 respectively. Flow data was available for the first 11 hours of the simulation only. Flows for the remainder of the simulation period were estimated and are represented by a dashed line in Figure 23.

5.3 Results

Modeled water surface elevation time series for the flood simulation are shown in Figure 25. A map of the time series locations is shown in Figure 26. There may be a discrepancy between simulated and observed water surface elevations as a result of the effect of El Nino on tides within the Bay. Observed tides have been about 0.6 ft to 1.4 ft higher than NOAA tide charts this year. The simulated water surface elevations in Unit I and Unit II exceeded +9 ft MSL during peak flood. The top of the salt dike is at approximately +7 ft MSL and should have been overtopped during the simulation. However, the current configuration of the model does not permit overtopping of the salt dike. Representing the salt dike as a weir would be a better approach for modeling extreme high flows. The RMA2 hydrodynamic model can include weir structures in a 2-D mesh, however, the RMA11 sediment transport model does not yet support weir

structures. In the current model, no flow is permitted over the salt dike. As a result, water surface elevations are probably over estimated in the Upper Bay and under estimated near the PCH bridge for three to four hours near the peak flood. However, the difference in the simulated water surface just upstream and downstream of the salt dike is less than 1 foot at the peak flood. Any overestimation of the Upper Bay water surface elevation by not permitting flow over the salt dike should be limited to this amount.

Simulated net deposition (positive) and scour (negative) for the flood simulation are shown as color contours with spot values of observed deposition and scour in Figure 27 for the Upper Bay, Figure 28 for the mid-bay, and Figure 29 for the Lower Bay. In general, the model predicted scour in the main channel throughout the Bay, and deposition in the higher areas. As much as 1.5 ft of deposition was predicted around the mouth of San Diego Creek and in some of the shallower portions of Unit I basin. Up to 2 ft of scour was predicted in the main channel at the mouth of San Diego Creek. Throughout the remainder of the Bay, the maximum scour predicted in the main channel was approximately 1 ft.

The 1997 flood data include post-flood bathymetry data. The net deposition and scour that occurred during the December 1997 flood event is estimated by taking the difference between the surveyed 1997 pre-flood bathymetry and the post-flood bathymetry. The general areas of scour and deposition were accurately predicted. Computed deposition in the shallower areas was a good match with observed data, however scour in the main channel was slightly under predicted.

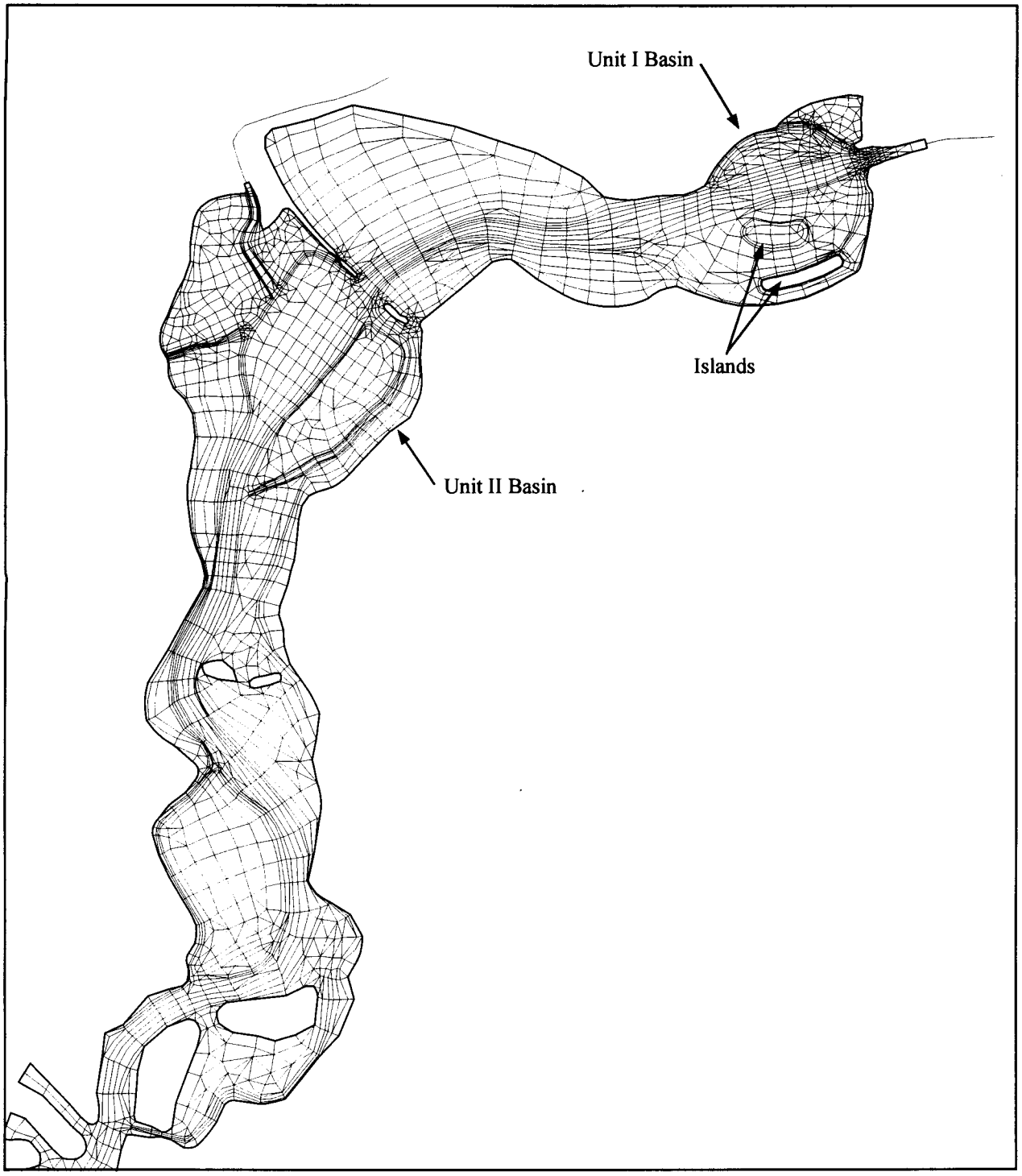

Figure 22. Finite element configuration for December 1997 flood simulation, Unit I and Unit II Basins.

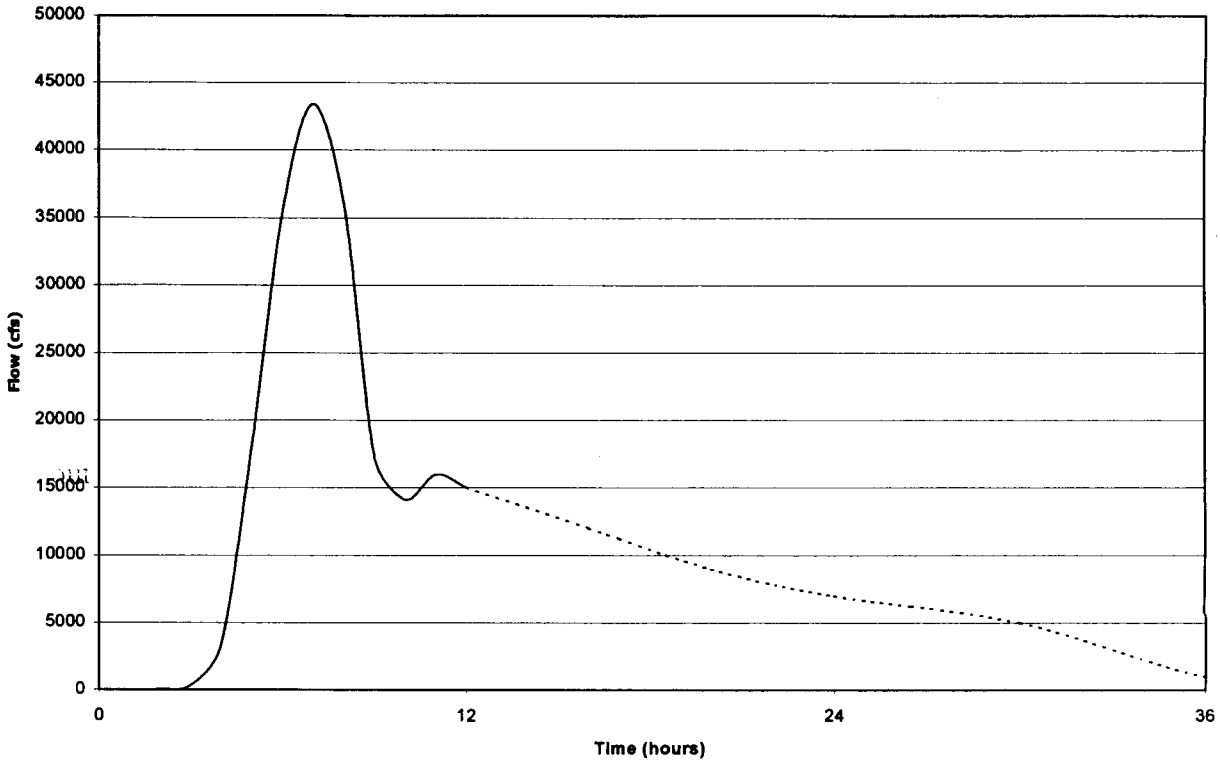

Figure 23. San Diego Creek inflow hydrograph for December 6, 1997 flood simulation (estimated data shown as dashed line).

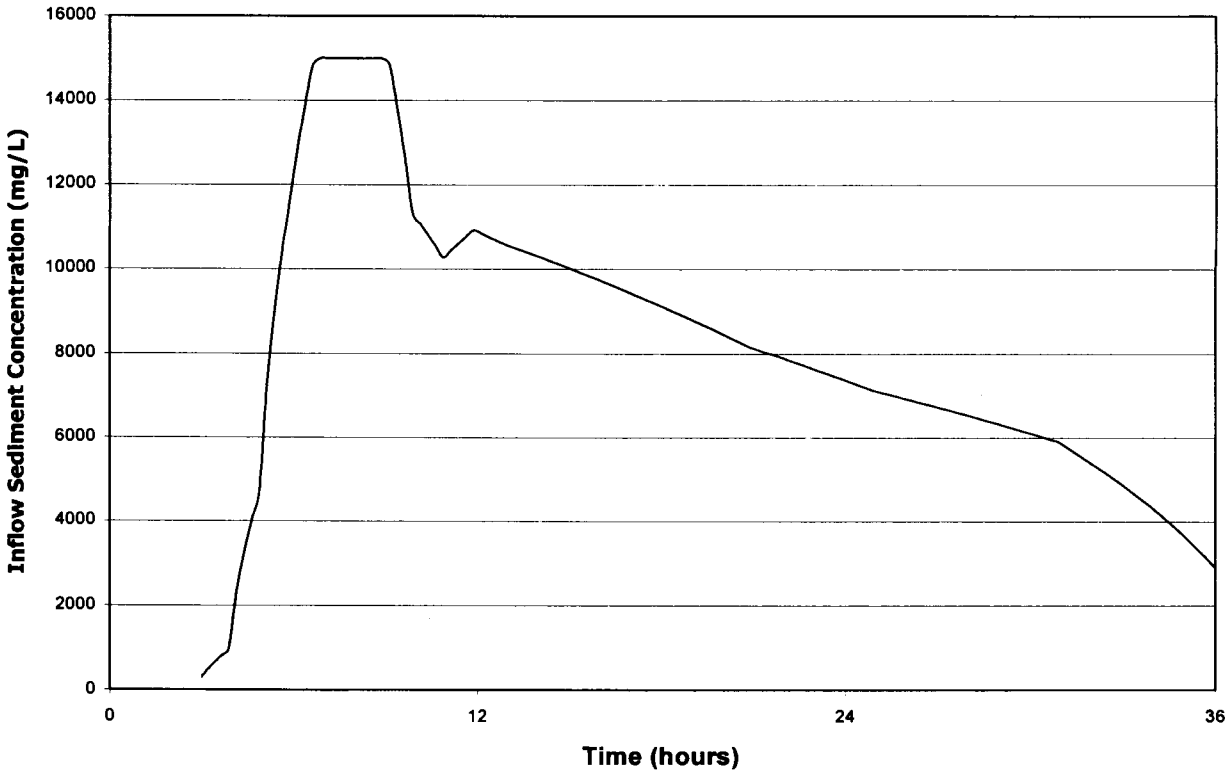

Figure 24. San Diego Creek inflow sediment concentration for December 6, 1997 flood simulation.

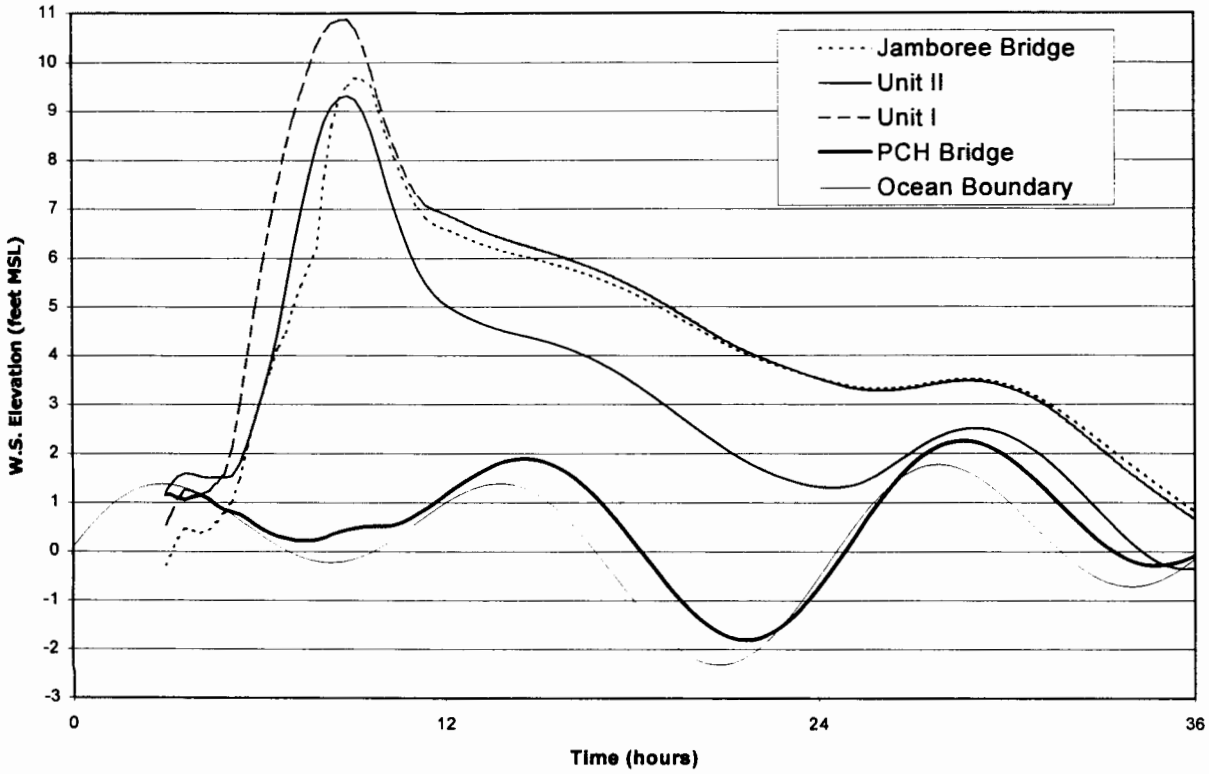

Figure 25. Computed water surface elevation time series for December 6, 1997 flood simulation.

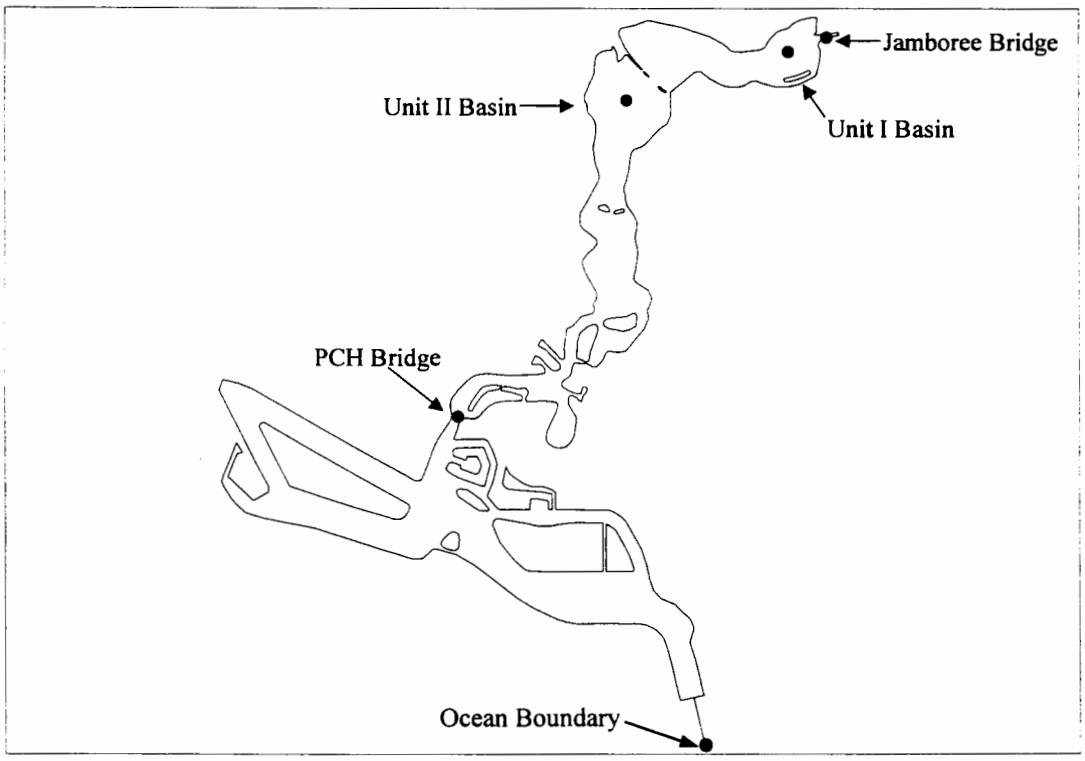

Figure 26. Water surface elevation time series locations shown for December 6, 1997 flood simulation.

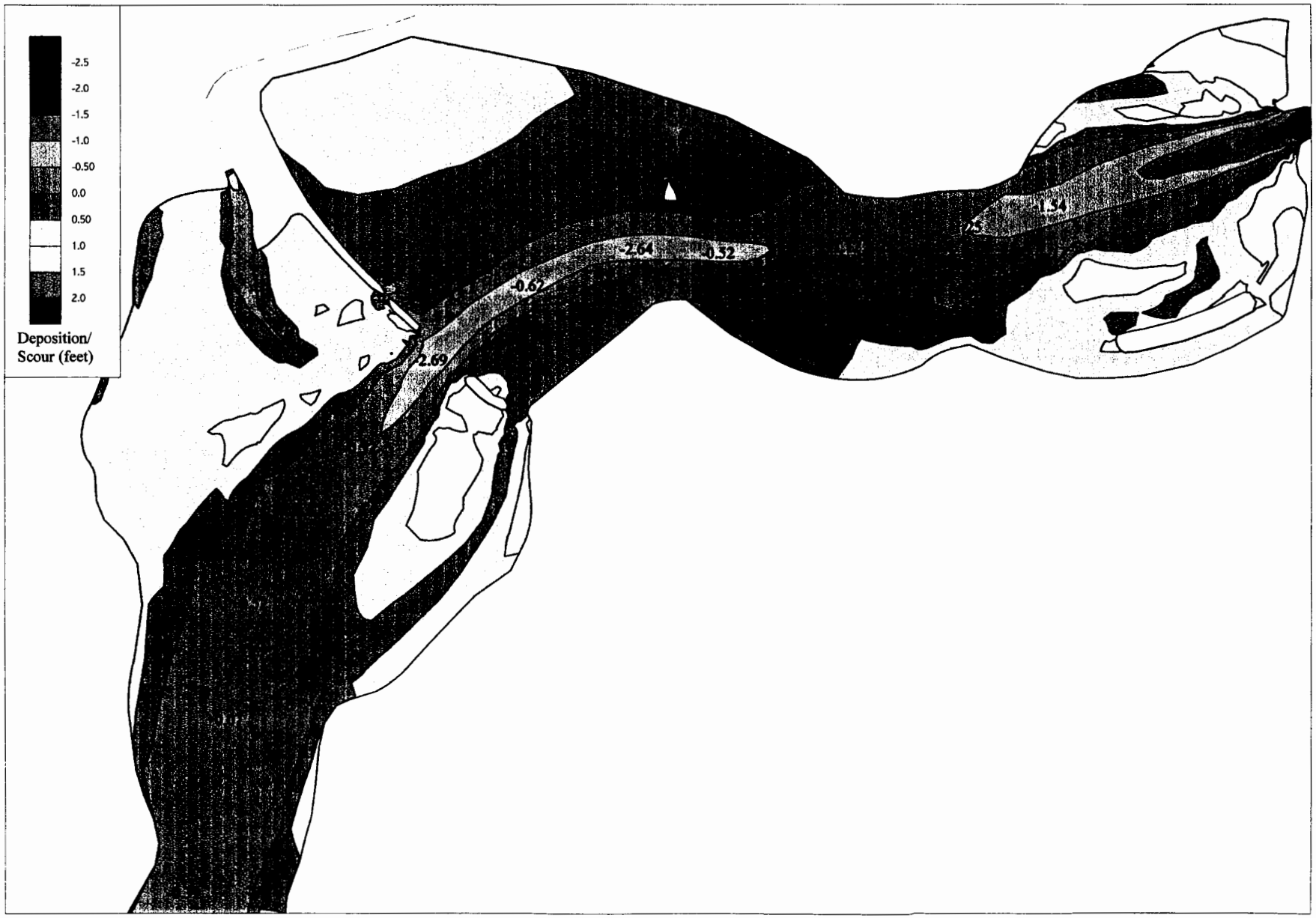

Figure 27. Upper Bay net deposition/scour for the December 6, hour 18:00 of the 1997 flood simulation with spot values of observed deposition/scour taken as the difference between May 1997 and December 1997/March 1998 survey elevations.

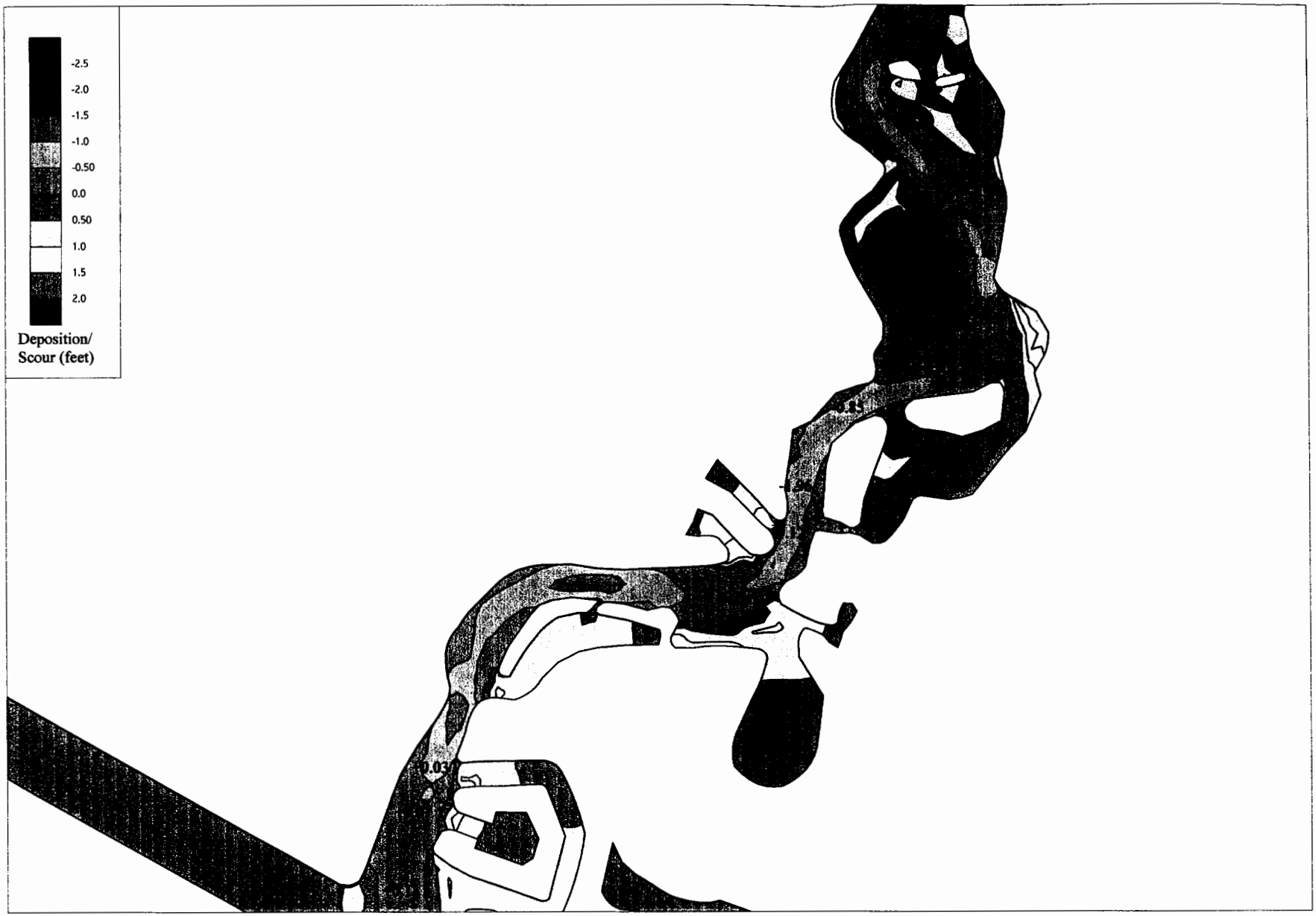

Figure 28. Mid Bay net deposition/scour for the December 6, hour 18:00 of the 1997 flood simulation with spot values of observed deposition/scour taken as the difference between May 1997 and December 1997/March 1998 survey elevations.

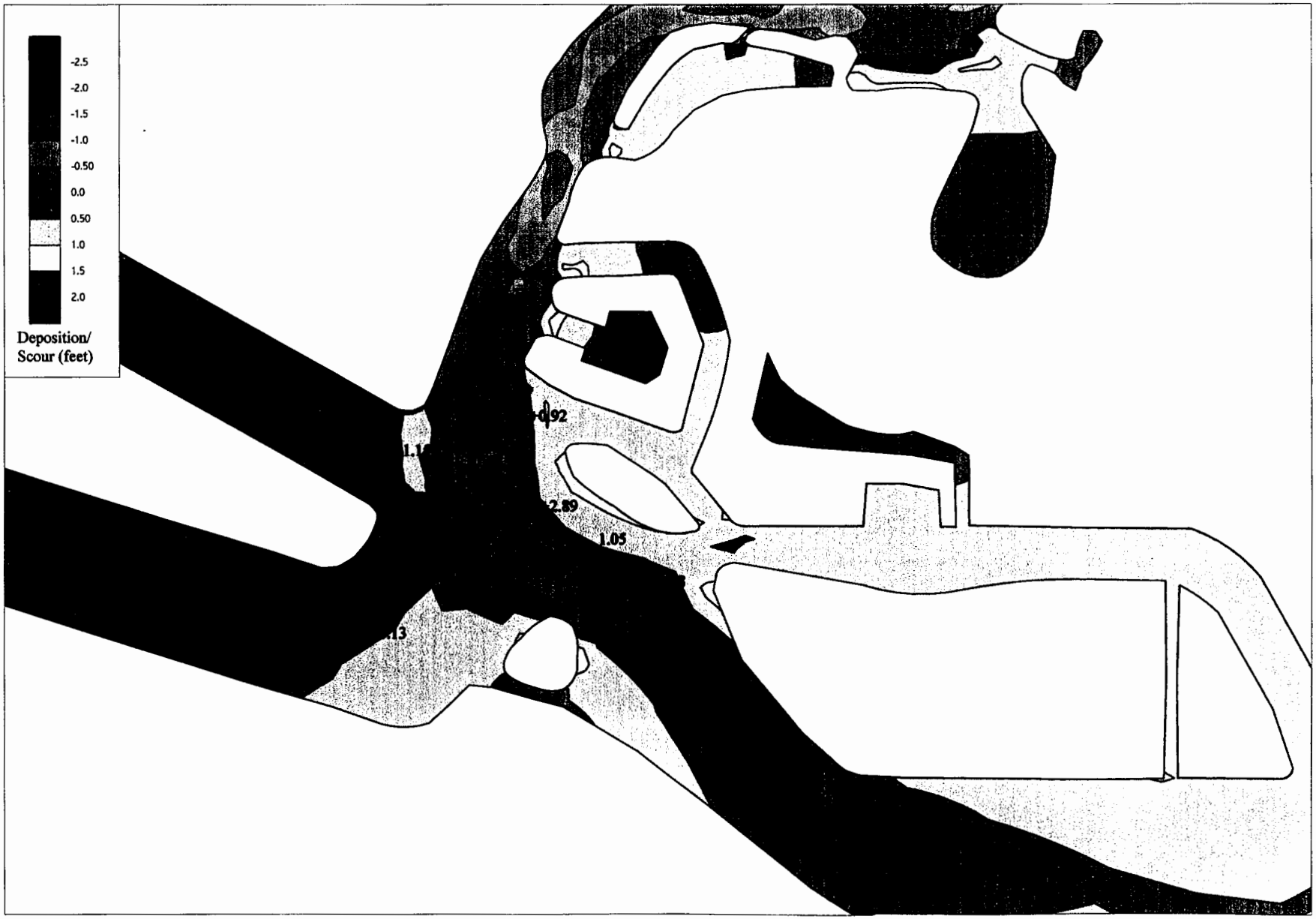

Figure 29. Lower Bay net deposition/scour for the December 6, hour 18:00 of the 1997 flood simulation with spot values of observed deposition/scour taken as the difference between May 1995 and March 1998 survey elevations.

6. 50-YEAR FUTURE WITHOUT PROJECT CONDITION

The simulation of the 50-year future without project condition has been completed using the reconfigured and newly calibrated hydrodynamic and sediment models for the Upper Newport Bay. The computational mesh for the 50-year future without project condition includes the completed components of the Unit III Upper Newport Bay Sediment Control and Enhancement Project under construction at the time of this report. The project includes dredging of the Unit III basin to –14 ft. MSL, dredging of an access channel between PCH bridge and the Unit III basin to –14 ft. MSL, and dredging of the area in and around Dover Shores to –10 ft. MSL. Computational mesh for the simulation is shown in Figure 30. The starting bathymetry for the 50-year future without project condition is presented in Figure 31.

6.1 Boundary Conditions

The flow and sediment boundary conditions for this simulation have been based on 25 years of historic record for San Diego Creek. The flow record was used to create representative storm flow hydrographs for the wet weather deposition period as described in Section 4. The 25-year record was repeated to form a 50-year record for the simulation. The mean daily storm flows and associated deposition scaling factors are shown in Table 4. Sediment loading by mass is shown in Figure 32.

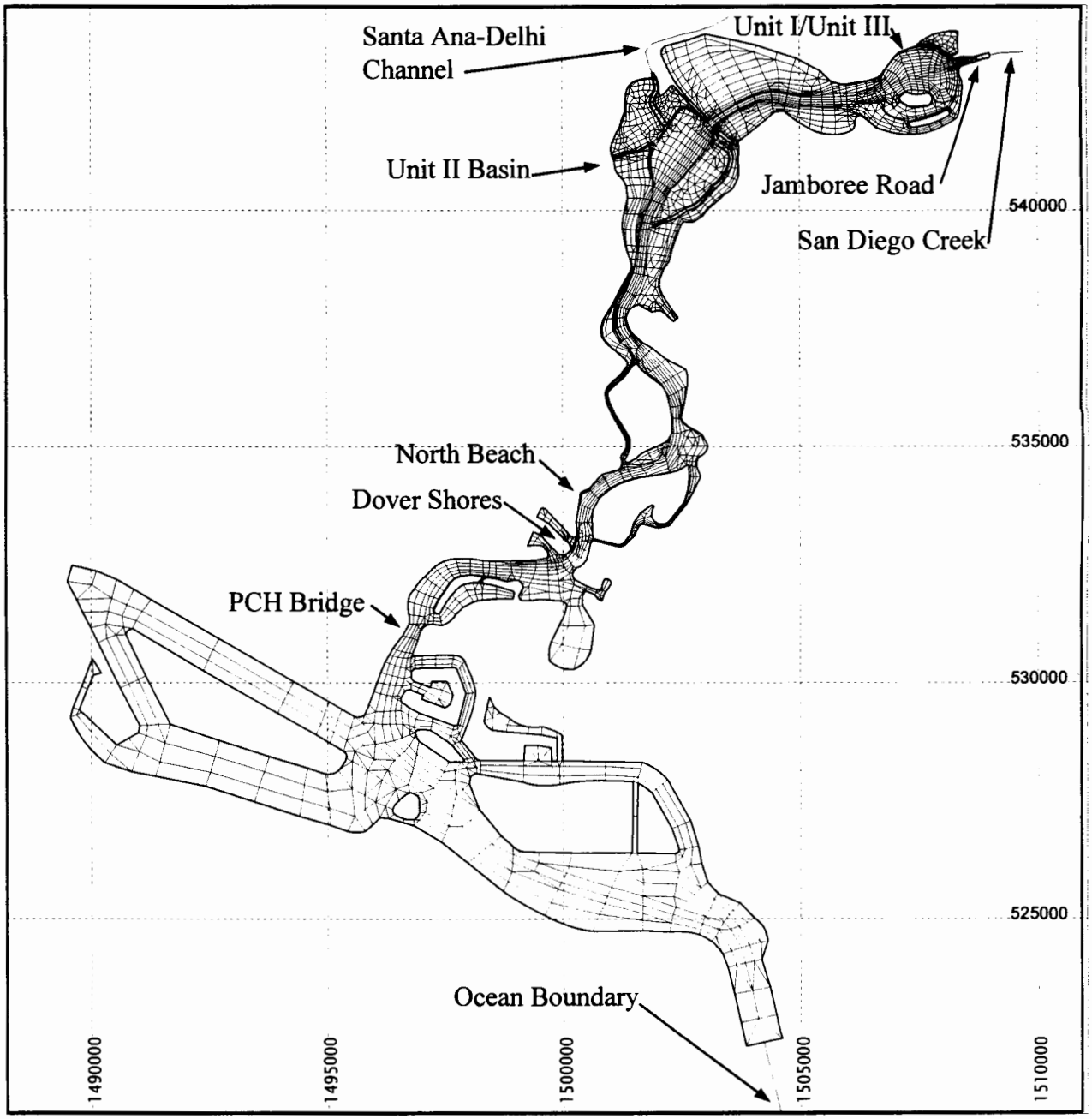

Figure 30. Finite element configuration for 50-year future without project simulation, CCS NAD27 zone 6 coordinate grid in feet.

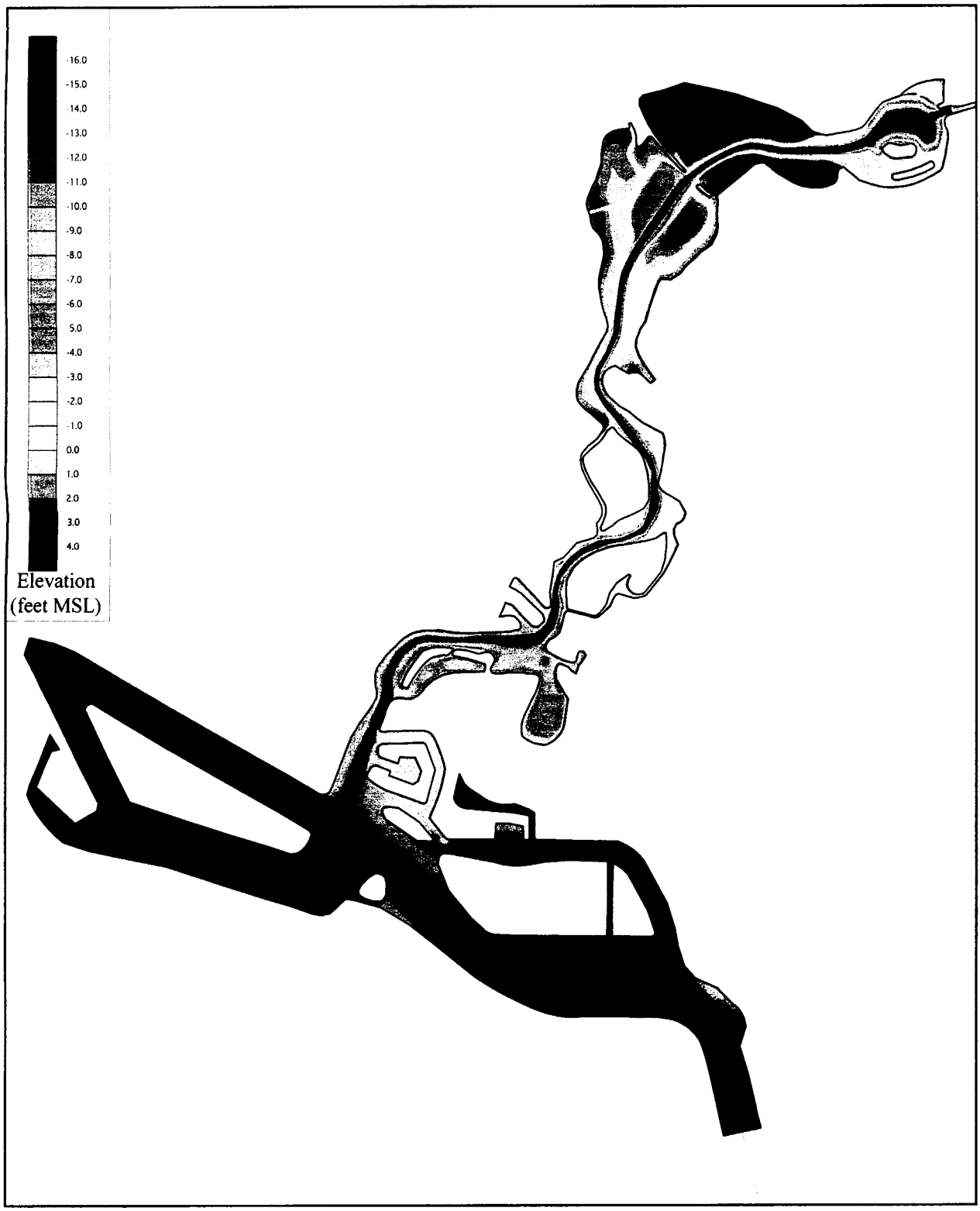

Figure 31. Newport Bay finite element mesh bathymetry, initial condition for the 50-year future without project simulation.

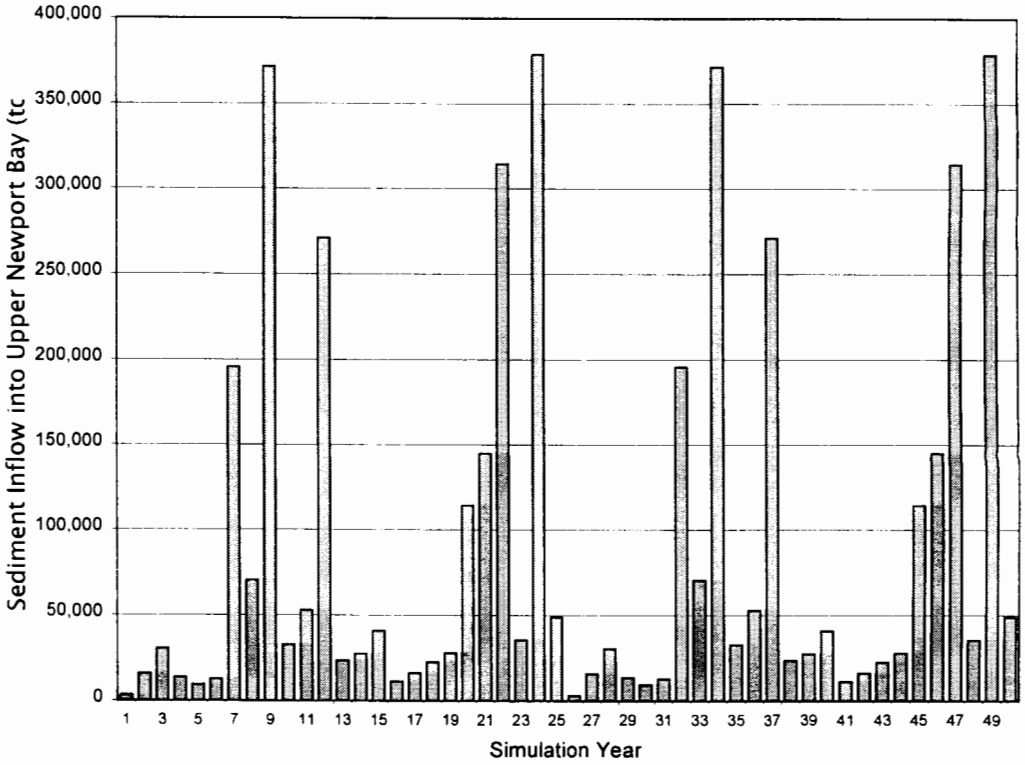

Figure 32. Yearly sediment loading for 50-year future without project simulation.

Table 4. Daily Flows for Wet Weather Simulation.

Simulation Year	Water Year	Mean Daily Flow (cfs) Day 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Additional Deposition Factor
1, 26	1972	90	233	339	55	---	---	---	---	0.52
2, 27	1973	38	631	164	240	---	---	---	---	1.94
3, 28	1974	290	296	1015	379	30	---	---	---	1.37
4, 29	1975	29	851	31	---	---	---	---	---	0.90
5, 30	1976	157	185	553	43	---	---	---	---	1.36
6, 31	1977	60	775	109	22	---	---	---	---	1.06
7, 32	1978	319	940	1870	127	2340	1130	226	---	1.27
8, 33	1979	26	1490	780	169	---	---	---	---	1.84
9, 34	1980	37	2630	1432	920	3523	2332	2158	567	0.67
10, 35	1981	24	852	656	76	---	---	---	---	0.79
11, 36	1982	19	1642	822	57	---	---	---	---	0.86
12, 37	1983	588	1150	470	4140	3100	2070	100	---	0.33
13, 38	1984	25	349	1170	51	---	---	---	---	0.73
14, 39	1985	26	371	781	131	---	---	---	---	2.42
15, 40	1986	18	270	547	1589	106	---	---	---	0.65
16, 41	1987	24	659	177	69	---	---	---	---	1.23
17, 42	1988	13	649	201	17	---	---	---	---	2.26
18, 43	1989	10	512	828	15	---	---	---	---	1.33
19, 44	1990	13	1772	175	38	---	---	---	---	0.12
20, 45	1991	10	1030	2370	1700	47	---	---	---	0.58
21, 46	1992	175	2020	2350	712	60	---	---	---	0.95
22, 47	1993	410	1950	2980	625	129	3240	395	64	1.00
23, 48	1994	12	835	200	15	---	---	---	---	3.76
24, 49	1995	97	3950	394	4510	437	397	70	---	0.83
25, 50	1996	24	1600	978	89	---	---	---	---	0.64

6.2 Simulation Results

Bathymetric contours for year 25 and year 50 of the 50-year simulation are shown in Figures 33 and 34. A comparison of bathymetric contours for the Upper Newport Bay at year 0 (1997 survey condition with Unit III dredging), and at 5-year intervals through year 50 are shown in Figures 35 and 36. Net deposition is shown at 5-year intervals through year 50 in Figures 37 and 38.

Over the 50-year simulation the Upper Bay above Middle Island fills with sediment until only the main channel remains lower than 0.0 ft MSL.

In the Phase 1 calibration simulation, the model did not maintain the main channels through the Unit I and Unit II basins. For Phase 2, the model has been adjusted to allow scour of sediments deposited in previous years if a sufficiently large storm flow occurs. This remedied the situation in the Phase 1 modeling in which storm flow velocities in a dry year would not be sufficient to clear the channels of sediments deposited during the previous summer.

As the system fills, more sediment reaches the Lower Bay. At year 50, over 12 feet of sediment deposited near the entrance to the Upper Bay. The time series of deposition by region is shown in Figure 39. Over the first 11 years approximately one million cubic yards of sediment deposit in the Upper Bay and ¼ of a million cubic yards deposit in the Lower Bay. Over the next 25 years another 1 ½ million cubic yards deposit in the Upper Bay while nearly 3 ¾ million yards deposit in the Lower Bay. As noted in Section 4, the model has not been calibrated for deposition in the Lower Bay so these values must be considered as representative of the potential for deposition.

Model results have been post-processed to compute areas between bathymetric contours in the Upper Bay. These values are presented in Table 5.

Table 5. Areas between bathymetric contours for the 50-year future without project simulation initial condition (1997 survey), year 25, and year 50.

Elevation	Area (ac)		
(feet)	Initial Condition	Year 25	Year 50
3 to 4	81	92	86
2 to 3	58	49	52
1 to 2	41	53	71
0 to 1	73	109	92
-1 to 0	34	107	148
-2 to -1	29	25	44
-3 to -2	22	24	33
-4 to -3	23	25	23
-5 to -4	21	25	22
-6 to -5	22	27	28
-7 to -6	26	29	24
-8 to -7	21	27	35
-9 to -8	49	20	43
-10 to -9	32	29	63
-11 to -10	30	52	78
-12 to -11	38	110	78
-13 to -12	141	128	103
-14 to -13	196	133	72
-15 to -14	126	61	29
-16 to -15	45	26	19

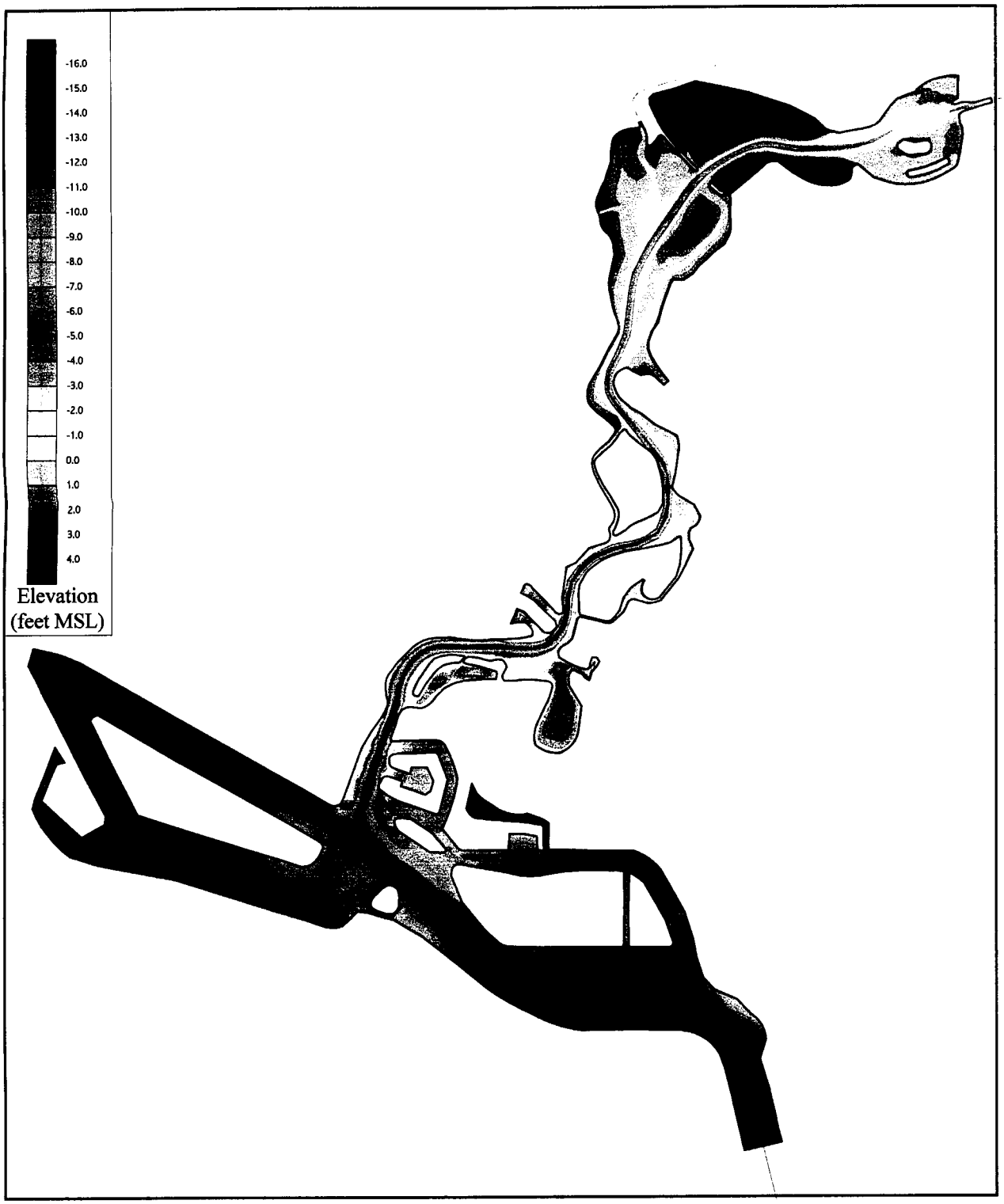

Figure 33. Newport Bay finite element mesh bathymetry, year 25 result from the 50-year future without project simulation.

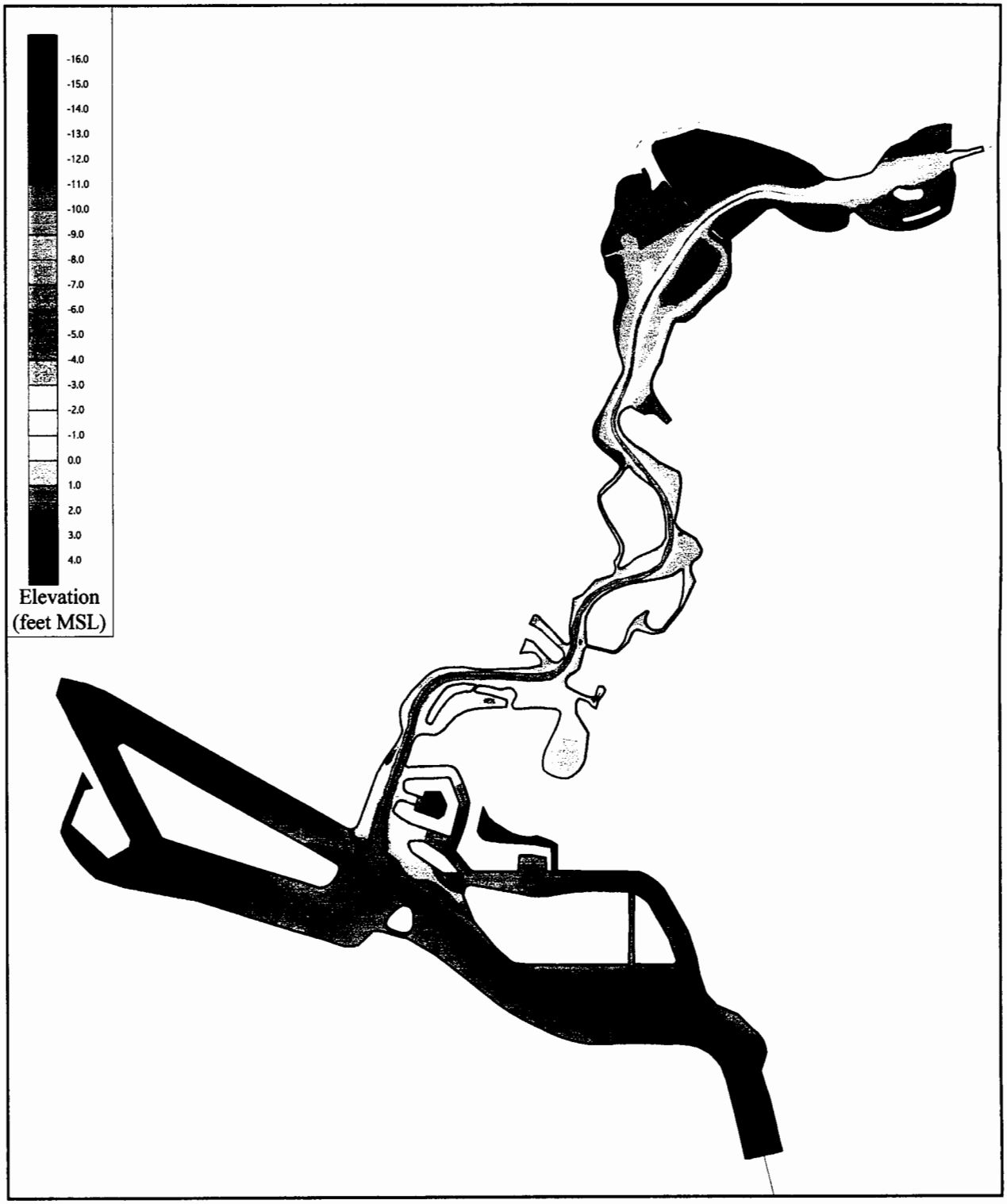

Figure 34. Newport Bay finite element mesh bathymetry, year 50 result from the 50-year future without project simulation.

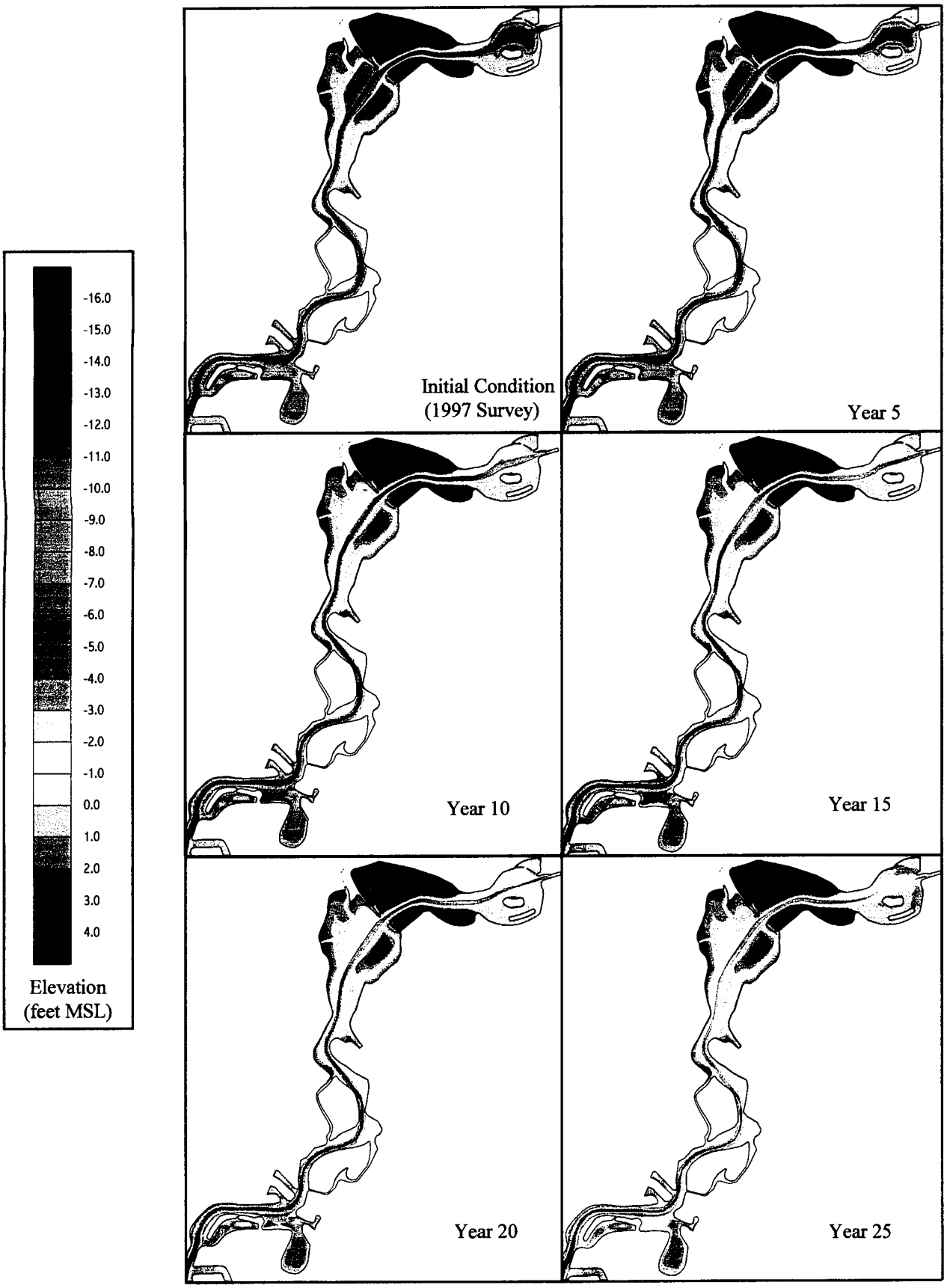

Figure 35. Comparison of Upper Bay bathymetric contours for the initial condition (1997 survey), years 5, 10, 15, 20, and 25 of the 50-year future without project simulation.

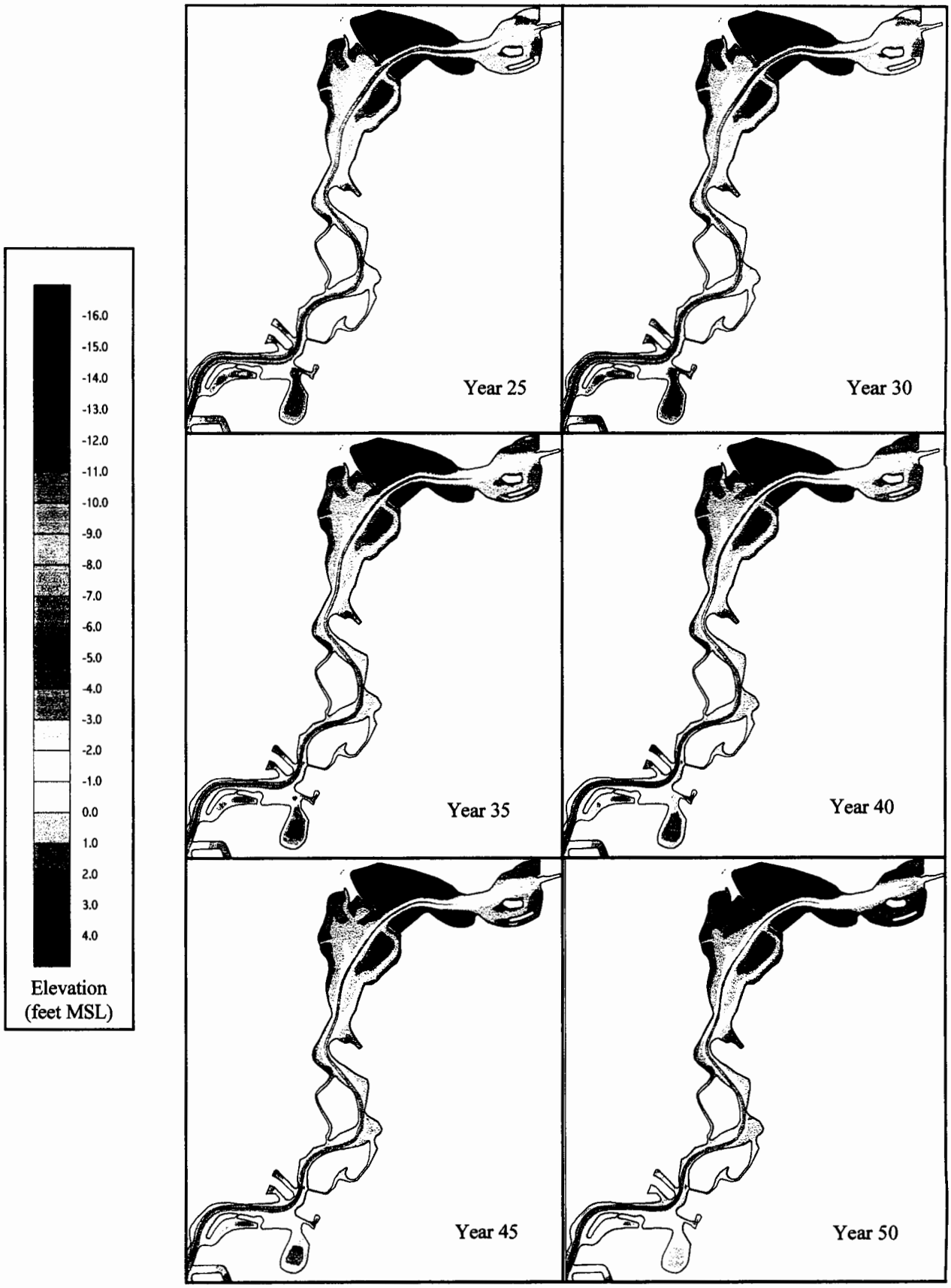

Figure 36. Comparison of Upper Bay bathymetric contours for years 25, 30, 35, 40, 45 and 50 of the 50-year future without project simulation.

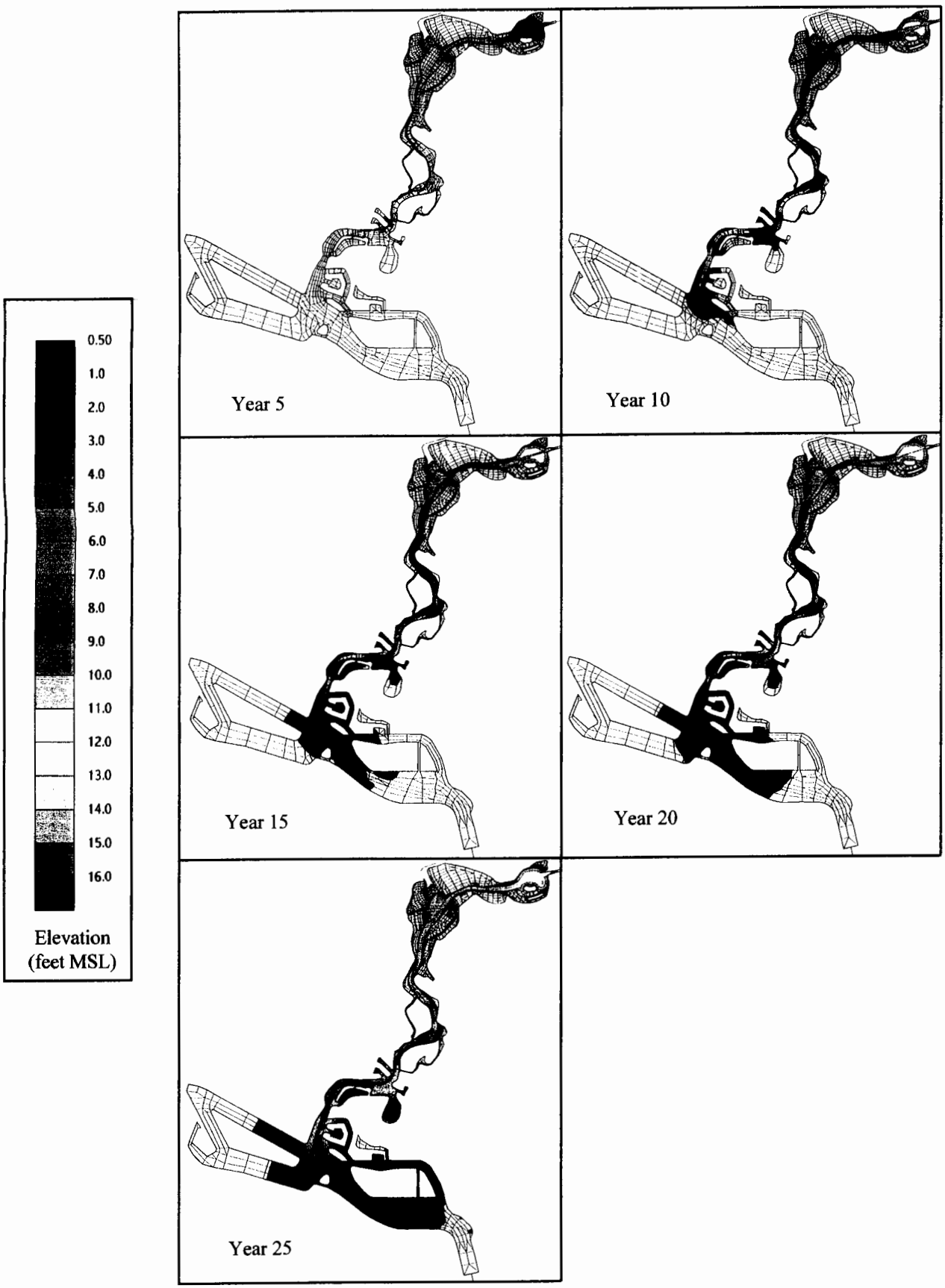

Figure 37. Comparison of Upper Bay net deposition for years 5, 10, 15, 20, and 25 of the 50-year future without project simulation.

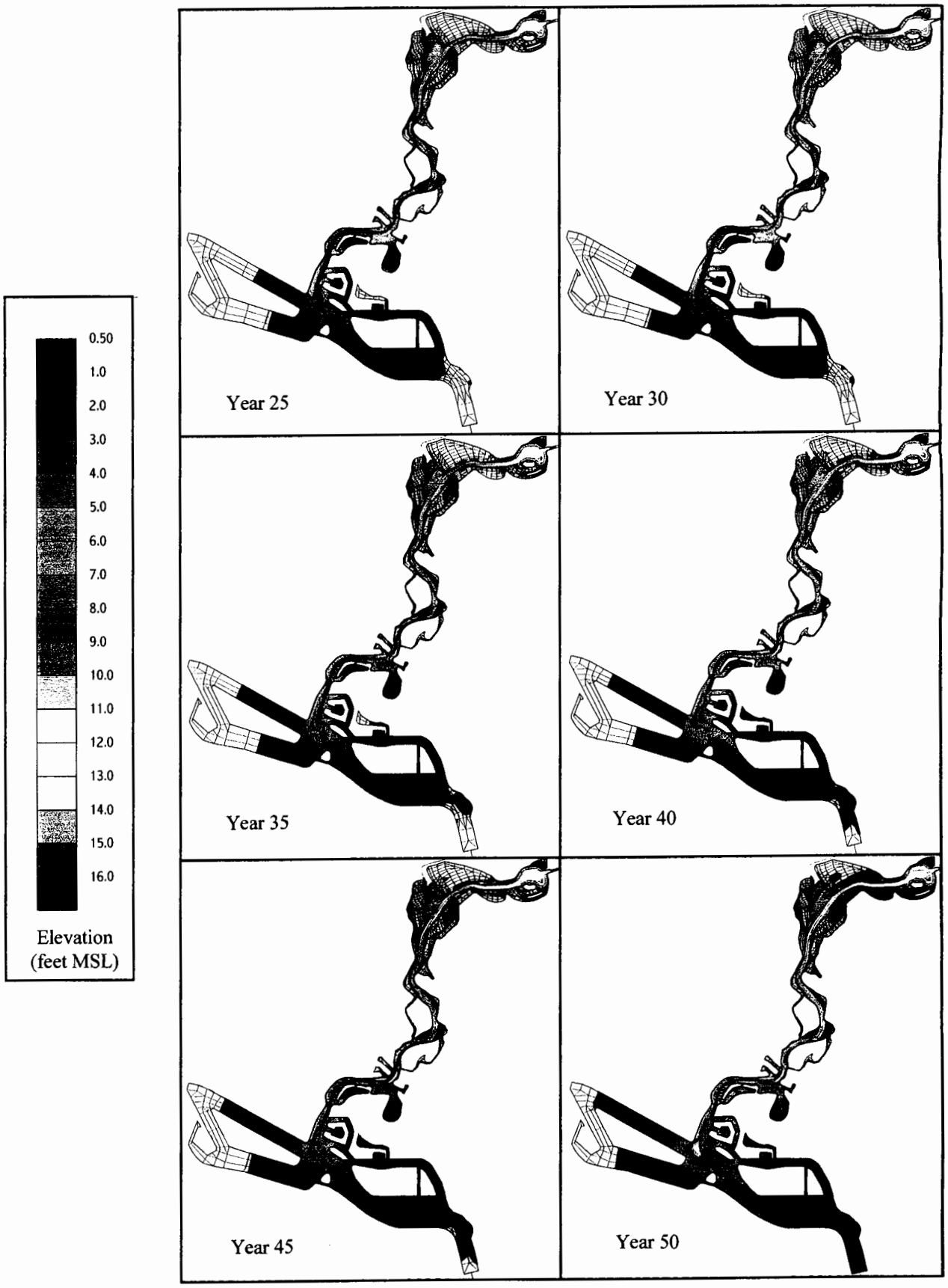

Figure 38. Comparison of Upper Bay net deposition for years 25, 30, 35, 40, 45 and 50 of the 50-year future without project simulation.

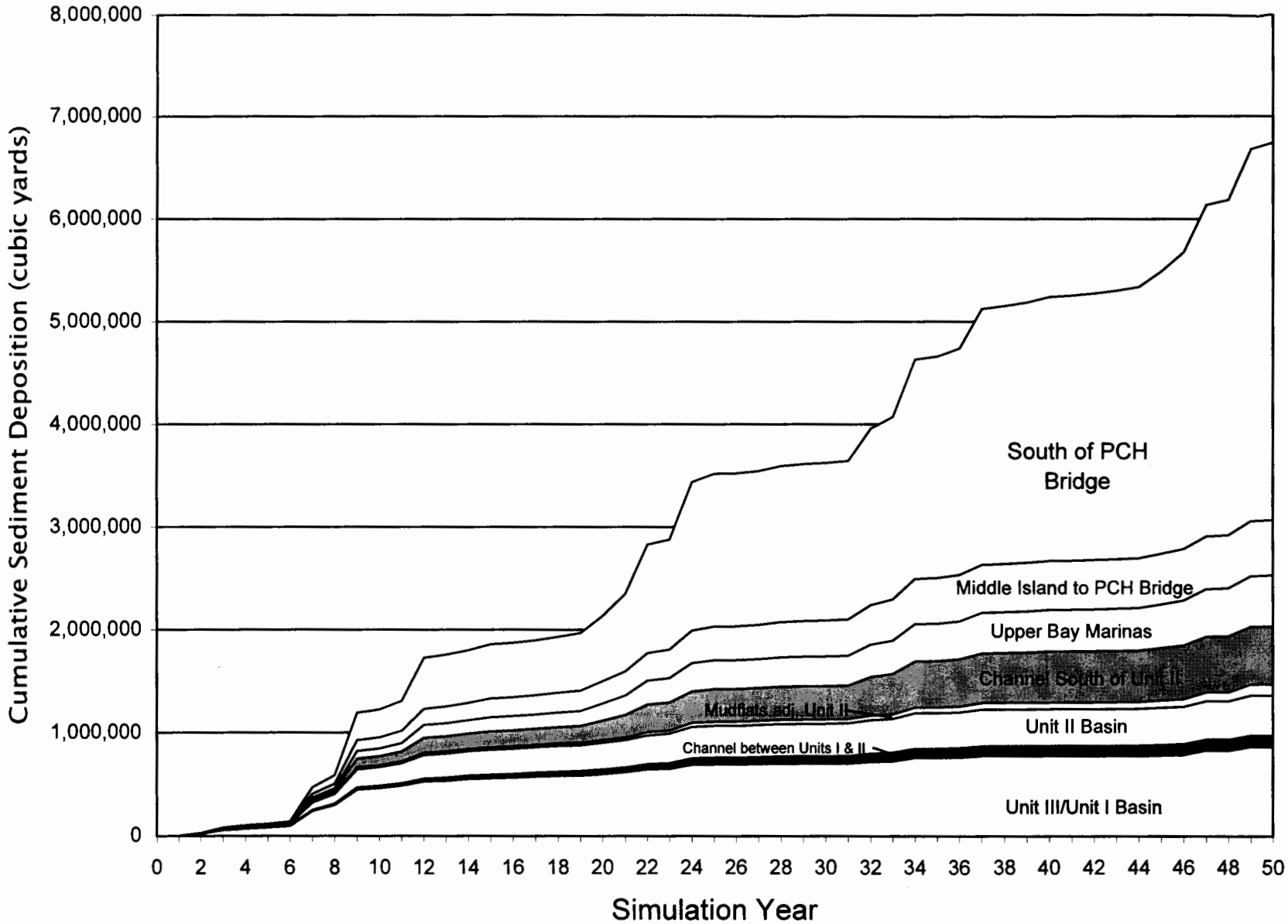

Figure 39. Cumulative sediment deposition by area for 50-year future without project simulation.

7. SUMMARY

The RMA2 and RMA11 finite element models for two-dimensional depth averaged flow and sediment transport have been configured for the Upper Newport Bay. The hydrodynamic model has been calibrated to the extent possible given existing data. Reconfiguration and recalibration of the sediment transport model and a new simulation for the 50-year future without project condition are complete.

7.1 Hydrodynamic Model Calibration:

The RMA2 finite element hydrodynamic model originally developed during the Upper Newport Bay Reconnaissance Study has been refined and extended to more accurately represent the entire estuary up to mean higher high water. Additional detail in the marsh areas between the Unit I and Unit II basins has been included in Phase 2. The new model has sufficient spatial resolution to accurately represent the tidal mudflats.

The hydrodynamic model was previously calibrated in Phase 1 of this study. With the updated finite element mesh, simulated water surface elevations were checked against the limited observed data and found to be in good agreement.

The hydrodynamic simulations completed through this phase of the modeling study lead to the following conclusions.

- The hydrodynamic model has been calibrated to the extent possible with the available data.
- Inter-tidal hydrodynamic simulation provides a good representation of the wetting and drying in shallow regions of the Upper Newport Bay.

7.2 Sediment Model Calibration

The sediment transport model has been reconfigured for the system in Phase 2 of this project, and a new calibration is complete. The calibration period begins in the end of 1985 following completion of the Unit I basin and continues to 1997. Sedimentation in the Unit II basin area and the access channel leading to the Lower Bay begins during 1988. Through the calibration process, a modeling strategy has evolved that produces reasonable sediment distributions. Each year a 3 to 7 day representative peak storm event is simulated to introduce sediment into the system. The hydrodynamic and sediment transport models are combined and bed elevations are updated every time step. The net deposition from that simulation is scaled to represent the total sediment load for the year. A one-month dry weather simulation is performed to allow resuspension and redistribution of sediments. The net deposition from this period is scaled to represent

eight months of dry weather. The deposition predicted by the model for the calibration period was compared to the observed deposition and shown to provide reasonable distribution of sediments.

The methodology described above requires approximately 5 hours of computer time per year of simulation on a 500 MHz Alpha-based PC running MS Windows NT. The computer time required to run the simulation is strongly dependent on the spatial resolution of the finite element network developed for the system.

The sediment transport calibration simulations completed through this phase of the modeling study lead to the following conclusions.

- The sediment model reasonably reproduced the observed sediment deposition patterns in most of the Upper Bay over the 1985-1997 calibration period.
- The total computed volume of sediments deposited in the Upper Bay during the calibration period was within 2% of the deposition volume based on the observed changes in bathymetry.
- The depth of sediment deposits in the Unit I and Unit II basins were correctly predicted.
- In the current phase of the study, the main channels through the Unit I and Unit II basins were maintained in the model result. The channels were slightly shallower than indicated by the observed data, however the results are much improved over Phase 1.
- The problem of excess deposition seen in Phase 1 in the shallow areas near Unit I and Unit II has been corrected in Phase 2.
- In Phase 1, and to a lesser extent in the current phase, the predicted deposition between Middle Island and the PCH Bridge was significantly higher than the observed change in bathymetry suggests. More information is required to determine whether the estimate of the observed deposition is accurate or whether the model parameters or simulation methodology should be adjusted.

7.3 1997 Flood

A simulation of the December 1997 flood event was performed using the reconfigured and recalibrated model with sediment discharge and flow data collected during that event.

- The model successfully predicted the areas of scour and deposition, however the model underestimated scour in the main channel in some areas.

- Computed water surface elevations upstream of the salt dike indicate that the Dike would have been overtopped, however, the current model configuration does not permit flow over the salt dike. This results in an overestimation of the water surface elevation above the salt dike for several hours near the peak flood. To improve the model representation the salt dike should be configured as weir. This is currently supported by the hydrodynamic model, but formulation of the sediment model would have to be updated to accommodate a weir in a 2-D flow region.

- The results of this simulation indicate that in the current state, the model is capable of representing high flow events and reasonably predicting sediment distributions. Better simulation of extreme high flows can be achieved if the sediment model is updated to support weir structures.

7.4 50-Year Future Without Project Simulation

A new 50-year future without project simulation was performed using the reconfigured and recalibrated sediment model. Sediment loadings were constructed from 25 years of flow record and an empirical relation between flow and suspended sediment loads for San Diego Creek. The model results provide a time series of predicted bed elevations at the end of each wet and dry weather simulation. Bed elevation and net deposition have been presented in this report at 5-year intervals. The initial condition and the results at 5-year intervals were post-processed to report areas associated with bathymetric contour intervals.

The following conclusions may be drawn from the initial 50-year future without project simulation result.

- After 50 years the predicted deposition volume in the Upper Bay was approximately 3 million cubic yards. The Unit I and Unit II regions reached near equilibrium condition.

- After 50 years the predicted deposition volume in the Lower Bay was approximately 3 ¾ million cubic yards. The model was not calibrated for deposition in the Lower Bay so this value should only be considered as an indication of potential for deposition.

7.5 Recommendations

The hydrodynamic and sediment transport models for the Upper Newport Bay are now configured and calibrated to a level that provides a reasonable prediction of long-term sediment deposition in the system. Recommendations for the future improvements of the models are as follows.

The sediment transport model results are strongly dependent on the sediment density estimate for each bed layer. The sediment density values used in the model are best estimates based in limited historic data from Newport Bay and experience with sediment modeling in other estuaries. Any new data on sediment density profiles in the Upper Bay will be useful in future modeling exercises.

If additional modeling is required for extreme high flow events, the formulation of the sediment transport model should be updated to permit the use of 2-D weir structures. This will permit the correct representation of overtopping the salt dike. There is no problem simulating wet weather events for long-term simulation because the maximum mean daily flows are not high enough to overtop the salt dike.

The current long-term sediment transport simulation does not represent evolution of marsh plants in the estuary. As marsh plants develop bed friction increases, sediment deposition rates increase, and wind resuspension is inhibited. This results in relatively rapid increase in bed elevation toward the mean high water elevation. It also resists redistribution of sediments deposited after storm events. Because the current sediment model formulation does not consider marsh evolution, the model may underestimate bed elevations in some areas. A reasonable assumption is that once the bed elevation reaches +1 to +1.5 ft MSL marsh vegetation may begin to grow and will become well established over the next 10 to 15 years. This approximation could be incorporated into the long-term sediment model to estimate the evolution of marsh plants and their effect on bed elevations.

8. REFERENCES

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