Appendix G

BATHYMETRIC AND HYDRODYNAMIC STUDY

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SAND MINING RESOURCE EVALUATION AND IMPACT ANALYSIS

COAST & HARBOR
ENGINEERING

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SAND MINING RESOURCE EVALUATION AND IMPACT ANALYSIS

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COAST & HARBOR ENGINEERING

Sand Mining Resource Evaluation and Impact Analysis

Executive Summary

Coastal engineering analysis was performed by Coast & Harbor Engineering, Inc. (CHE) as a subconsultant to Environmental Science Associates (ESA) under contract with California State Lands Commission (CSLC) to evaluate potential future sand resources within certain Central Bay and Suisan Bay sand mining lease areas, as well as the potential impacts of the proposed mining lease renewal for the next 10 years. The study consisted of morphological analysis and hydrodynamic modeling, and covered a wide spectrum of physical processes including tidal and river circulation, salinity, sediment transport, and morphology.

Morphological analysis indicates a measurable depletion of sand resources in the Central Bay lease areas. The vast majority of sediment mined from these areas during the past decade is still missing from the lease and immediately adjacent areas. It appears that recovery of the Central Bay sand mining leases in Central Bay is a long-term process. The study indicates that for the purposes of the proposed 10-year mining lease renewal, sand mining resources in Central Bay are largely limited to material already in place.

In addition, analysis indicates that the proposed additional 10 years of sand mining in the Central Bay lease areas is not likely to cause a significant impact on sediment transport and budgets in areas outside the immediate vicinity of the lease areas, such as the San Francisco Bar, Ocean Beach, etc. It appears that only small amounts of sediment have been impounded in the mining holes. Numerical modeling results indicate that changes in hydrodynamics, salinity and sediment transport/morphology are likely to be confined to the immediate vicinity of the mining areas.

In Suisun Bay, for the majority of lease areas sand mining resources are relatively stable and were not noticeably depleted in the period 2004 to 2008. However, in the deeper areas of the Middle Ground (TLS39) lease area, sand resources appear to have been measurably depleted and for the short-term, sand for mining is likely to be limited to material that is already in place. It appears that the proposed 10 years of further sand mining in the Suisun Bay lease areas and control sites is not likely to cause measurable impacts (in terms of sediment loss) to the surrounding areas. Numerical modeling results for Suisun Bay indicate that changes in hydrodynamics, salinity and sediment transport/morphology are likely to be confined to the vicinity of the mining areas.

Although analysis indicates that significant impacts are not likely to exist outside the immediate vicinity of the lease areas, analysis for both Central Bay and Suisun Bay sites should be repeated prior to subsequent renewal of the sand mining lease.

Sand Mining Resource Evaluation and Impact Analysis

1. Introduction

The following coastal engineering analysis was performed by Coast & Harbor Engineering, Inc. (CHE) as a subconsultant to Environmental Science Associates (ESA) under contract with California State Lands Commission (CSLC) to evaluate potential future sand resources within certain specified CSLC lease areas and the potential impacts of the proposed mining lease renewal for the next 10 years. The study consisted of analysis of bathymetry changes for the purpose of evaluating future sand resources availability and potential impacts of mining, as well as numerical modeling to determine potential impacts of mining on San Francisco Bay circulation, water quality, and sediment transport/morphology.

2. Description of Proposed Sand Mining

Sand mining is proposed to occur within designated CSLC lease areas using a variety of dredging methods over the next 10-year period to maximum depths of 90 feet (MLLW, Hanson Environmental 2004). The lease areas in Central Bay and Suisun Bay are shown in Figures 2-1 and 2-2, respectively. Table 2-1 shows the proposed annual mining volumes for the next 10 years provided to CHE by ESA.

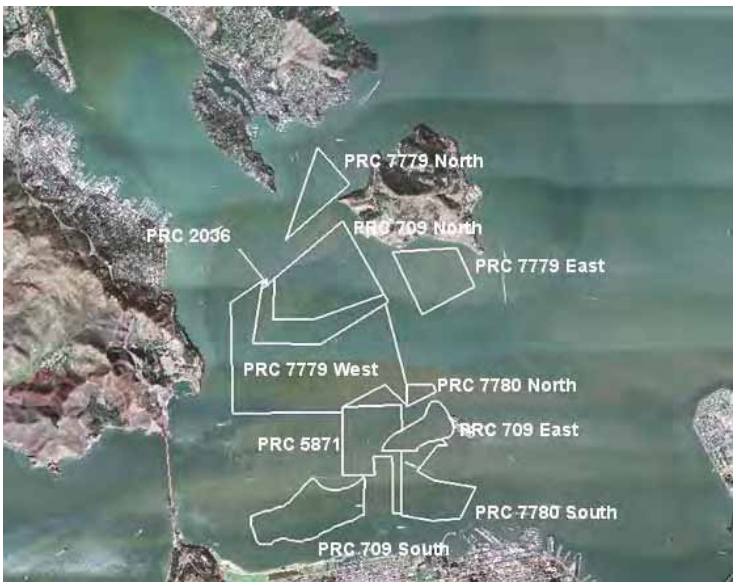

Figure 2-1. Central Bay lease areas (Note: no mining is proposed in lease area PRC 5871 during the next 10 years)

Figure 2-2. Suisun Bay lease areas

Table 2-1. Proposed Annual Mining Volumes by Lease Area

Lease Area	Requested Amended Volume (cy)
PRC 709.1	340,000
PRC 2036.1	450,000
PRC 7779.1	550,000
PRC 7780.1	200,000
Suisun Associates (East and West)	300,000
Middle Ground (TLS 39)	200,000

In addition to the lease areas, a series of control sites were surveyed (PLS surveys, see Section 3.1) to be used as a control site for sand resource availability and morphology analysis (see Figures 2-3 and 2-4).

3. Analysis of Sand (Sediment) Resource Availability and Bottom Morphology

3.1. Project Bathymetry Data

Many different bathymetry data sets exist in San Francisco Bay. However many of these data sets have insufficient spatial coverage and do not cover the period of interest when sand mining occurred and was documented. Evaluation of *sand* resource availability is not feasible without field data collection (borings), which are beyond the scope of this analysis. Instead, the analysis that was conducted evaluated the *sediment* availability in the lease areas purely in terms of material volumes. For analysis of sediment availability, bathymetry data sets covering the specific lease

areas of interest were provided by CSLC. The bathymetry data sets used for analysis are shown in Table 3-1.

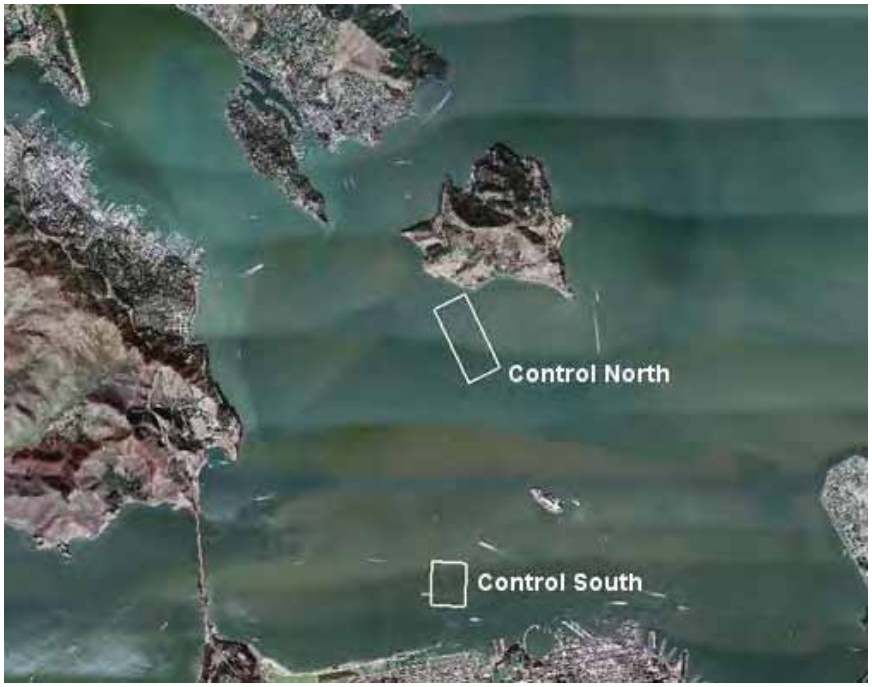

Figure 2-3. Control sites in Central Bay

Figure 2-4. Control sites in Suisun Bay

Table 3-1. Bathymetry Data Sets used for Analysis

Source	Type	Period	Coverage
USGS	Multi-beam	2008	Central Bay / Suisun Bay
E-Trac	Single-beam	2007	Central Bay / Suisun Bay
USGS	Multi-beam	1997	Central Bay
PLS	Single-beam	1996 - 2007	Central Bay / Suisun Bay

Appendix A shows color-contour representations of all bathymetry data sets used for analysis in both Central Bay and Suisun Bay. The bathymetry data were quality-checked and processed in order to perform analysis of the past and present available sediment resources in Central San Francisco Bay and Suisun Bay lease areas.

PLS single-beam data were available at six-month intervals for the period 1996-2007 for the Central Bay and Suisun Bay lease areas. These survey data sets were used for the analysis of mining resources due to their high frequency and consistency to identify possible trends in reduced/increased availability of sediment in the lease areas. From the series of PLS bathymetry data, the volumes of sediment above bottom elevation -90 feet (MLLW) and below bottom -3 feet (MLLW) were calculated from each survey for each lease area and used to define the volume of sediment available for mining. These elevations were determined based on mining operational constraints (Hanson Environmental 2004).

3.2. Central Bay Sand Resource Availability

Figure 3-1 shows the evolving volume of available sediment in lease area PRC 2036 between December 2001 and June 2006 as an example. During this period, this lease area (which was heavily mined) lost on average approximately 2.3% of its total sediment on an annual basis. Appendix B provides plots with available sediment volumes from each of the available bathymetry surveys for all lease areas and control sites of Central Bay.

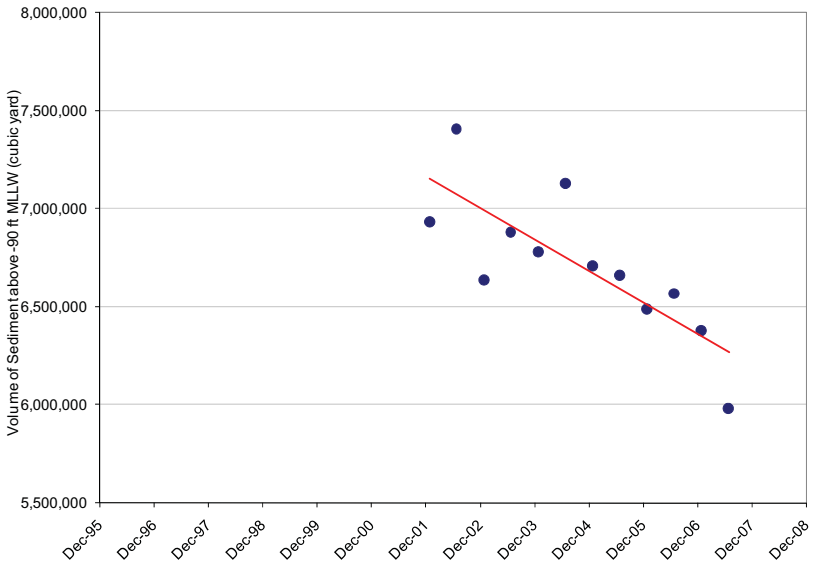

Figure 3-1. Volume of Available Sediment in Lease Area 2036

Bathymetry data analysis indicates recognizable trends of reduced sediment availability in most of the lease areas of Central Bay. Linear trend fits of the calculated sediment volumes shows that availability is reduced at rates between 0.6% and 2.5% per year (see Table 3-2). These relatively strong trends are clearly related to mining operations in the lease areas. Lease areas 7779 West and 7779 North do not seem to show clear trends of reduced sediment availability. This is because Lease area 7779 West is a very large area and mining occurred only in a limited portion of the area (Hanson Environmental 2004). Therefore the effects of mining are likely to have been hidden by natural sediment transport processes and survey/volume calculation uncertainties.

Lease area 7779 North shows no erosive trend because it was actually never mined (CSLC, personal communication 2008). The control site North shows a trend of reduced sediment availability (reduction equal to -1.4% per year), while control site South does not show any recognizable trend. Hanson Environmental (2004) shows that sand mining actually did occur within the control site North; therefore, the reduced sediment availability trend in this area is also likely related to sand mining operations in the control site and likely migration of mining holes from the two lease areas on either side (PRC 709 North and PRC 7779 East). Control site South was apparently never mined. In general, areas that were mined show clear erosion trends, and sites that were not mined do not show clear trends.

Table 3-2. Yearly Rate of Sediment Volume Change for Central Bay Lease Areas and Control Sites

Lease Area	Yearly Rate of Sediment Volume Change (%)
PRC 709 South	-0.6
PRC 5871	-1.0

Lease Area	Yearly Rate of Sediment Volume Change (%)
PRC 709 East	-1.3
PRC 7780 South	-0.9
PRC 7780 North	-2.5
PRC 7779 West	+0.3
PRC 2036	-2.3
PRC 709 North	-0.4
PRC 7779 East	-1.1
PRC 7779 North	+0.5
North Control	-1.4
South Control	+0.8

3.3. Suisun Bay Sand Resource Availability

Appendix C provides plots of the total available sediment volumes for all surveys for all lease areas and control sites of Suisun Bay. From the analysis of available sediment trends from PLS surveys, there is a recognizable trend of reduced sediment availability in the deeper parts of the Middle Ground (TLS39) lease area of approximately 1.0% per year. The Suisun Associates lease areas (West and East) do not show a clear trend in reduced sediment availability. Control Site 2, located upstream of the mining areas in the Sacramento River at the confluence with the San Joaquin River, shows a clear trend of ongoing erosion. There appears to be deepening occurring at this control site, however the calculated sediment volumes over time at the other control sites contain significant scatter and therefore trends are difficult to discern.

4. Analysis of Sand Mining Impacts

Sand mining impacts were evaluated in terms of changes in bay hydrodynamics, salinity, and sediment transport/morphology outside the lease areas. Two types of analysis were used to evaluate potential impacts outside the lease areas:

- Bottom morphology change analysis using hydrographic survey data. Potential impact analysis based on bathymetry change was conducted using the hydrographic survey data described in Section 3.
- Numerical modeling of currents, salinity and sediment transport/morphology. Impacts were evaluated by direct comparison of hydrodynamics, salinity and sediment transport/morphology for existing conditions and two after-mining scenarios.

4.1. Sand Mining Impact Evaluation from Measured Bathymetry Changes

Bathymetry/morphology changes in Central Bay and Suisun Bay were analyzed with the bathymetry data sets made available for the project to determine if sand mining is likely to cause potential impacts to Central and Suisun Bays. The morphology analysis was performed with the goal of determining if other areas away from the lease areas, such as the San Francisco Bar or Ocean Beach, could be deprived of natural sediment delivery due to mining operations. Bathymetry changes were calculated using the most consistent data sets with most complete coverage that spanned the longest time periods. As described in Section 3, hydrographic survey data from multiple sources were compiled, processed, filtered, and gridded to develop realistic bottom surfaces from which volume changes could be calculated.

4.1.1. Central Bay

Impact analysis from Central Bay bathymetry changes was most readily performed using the multi-beam data sets because they cover all the lease areas. USGS multi-beam data from 1997 and 2008 provided a highly detailed map of bottom elevation and map of bottom changes. Figure 4-1 shows the 1997 (top) and 2008 (bottom) multi-beam survey data sets.

Figure 4-2 shows the bottom changes since 1997, along with the lease areas and with sand mining "worm tracks," or GPS coordinates of actual mining event locations. Mining also occurred in other areas and the "worm tracks" are not a complete record. However, a clear correlation appears between measured erosion and locations of mining events. Hanson Environmental (2004) shows that in the period 1997-2004, mining operations were also conducted in areas slightly outside of the lease areas. After evaluating the volume bed changes in the lease areas on Central Bay and in these mined areas outside of the lease areas, a total bed erosion of approximately 11.6 million cubic yards (cu yd) was estimated during the period 1997-2008. Table 4-1 shows volumetric bed change results within each specific lease area.

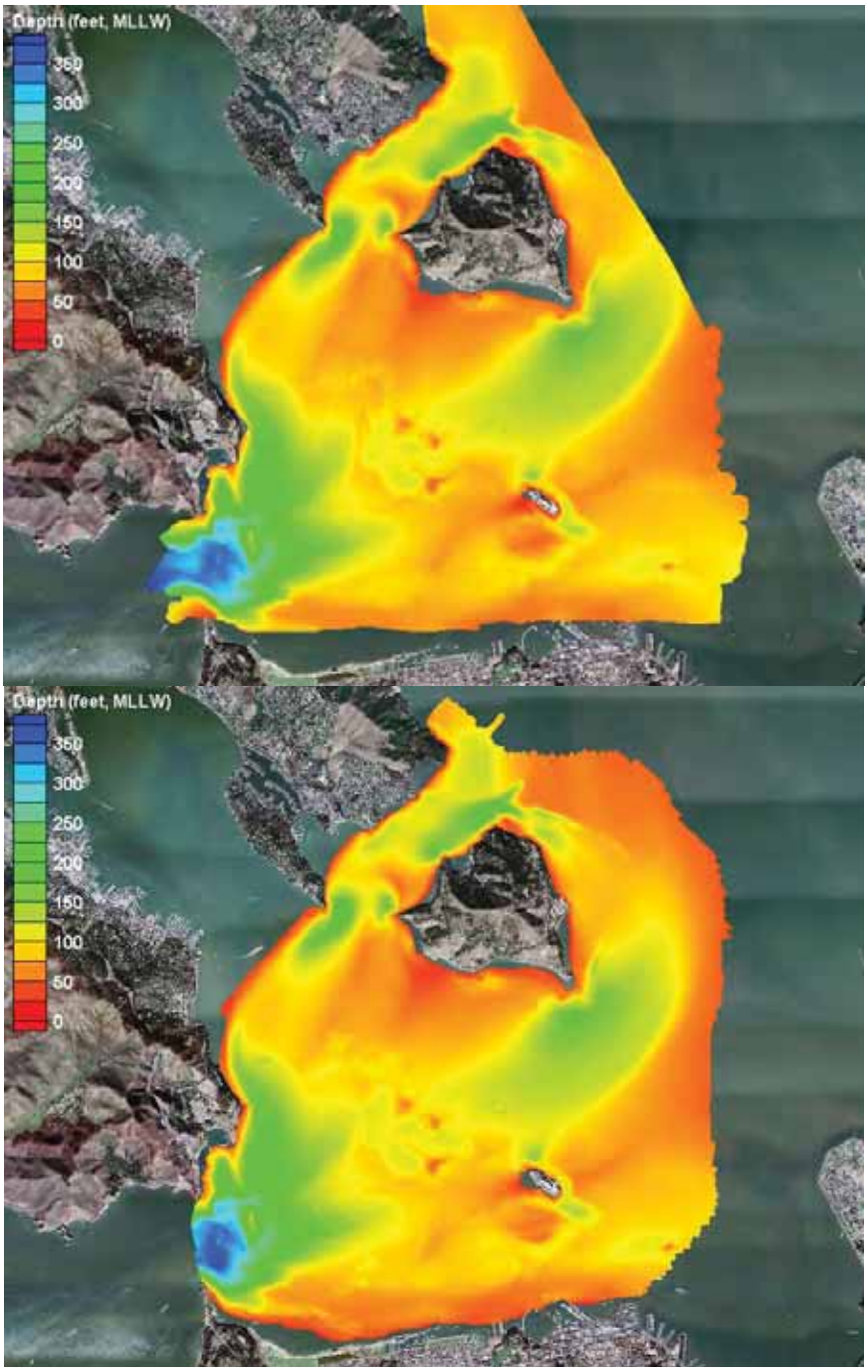

Figure 4-1. Central Bay depths from 1997 (various dates, top) and 2008 (various dates, bottom) USGS multi-beam bathymetry data sets (aerial photo USGS 2004)

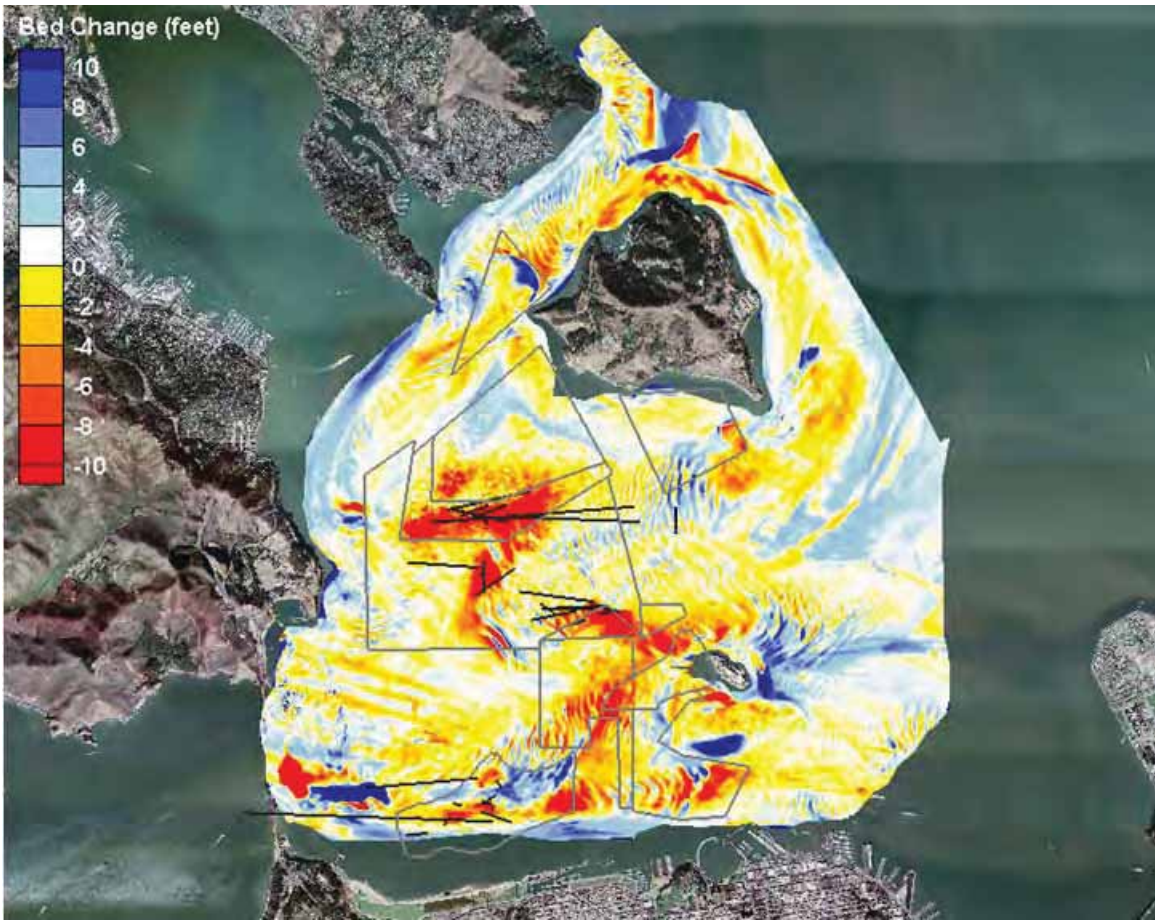

Figure 4-2. Central Bay depth changes between 1997 and 2008 calculated from USGS multi-beam bathymetry data sets (aerial photo USGS 2004) with sand mining location "worm tracks"

Table 4-1. Bed Volume Change for Lease Areas in Central Bay (1997 to 2008)

Lease Area	Bed Erosion (cubic yards)
PRC 709 SOUTH	-450,000
PRC 5871	-1,258,000
PRC 709 EAST	-670,000
PRC 7780 SOUTH	-834,000
PRC 7780 NORTH	-175,000
PRC 7779 WEST	-3,358,000
PRC 2036	-2,658,000
PRC 709 NORTH	-828,000
PRC 7779 EAST	-46,000
PRC 7779 NORTH	-88,000
Areas outside lease areas	-1,235,000
Total Central Bay	-11,600,000

Considering that the erosion volume within the lease and immediately adjacent areas was approximately 11.6 million cubic yards during this period, and that the sand miners reported a total Central Bay dredging volume of 13.5 million cubic yards (as reportedly measured in the barges after bulking), and considering a likely bulking factor on the order of 10%, the volume of material that was reported to have been mined during this period is nearly equivalent to the measured erosion inside and surrounding the lease areas. According to this calculation, only approximately 5% of the material in the lease areas that was mined has been replaced by natural processes. This indicates the following:

- Net bottom erosion due to sand mining has largely been contained within the lease and immediately adjacent areas. This indicates that the mining holes migrated/expanded only over short lateral distances, and erosion of adjacent areas did not spread outside the immediate vicinity of the lease areas.
- Since the vast majority of the mined material has been accounted for immediately adjacent to the lease areas, it appears that sand mining in Central Bay is not likely to cause measurable sediment depletion in areas outside the mining areas, such as the San Francisco Bar, Ocean Beach or other areas.
- Since mining in the lease areas beyond what was evaluate here could be expected to further deepen the holes and potentially attract more sediment in the future, analysis should be performed prior to subsequent lease renewal periods.

4.1.2. Suisun Bay

In Suisun Bay, only one USGS multi-beam data set was available (2008). Bottom changes were developed using a combination of the 2008 multi-beam data and the 2007 E-Trac single-beam data (2007). Figure 4-3 shows the 2008 multi-beam (left) and 2007 single-beam (right) survey data sets. Due to the consistency in the data sets and type of data and lack of earlier consistent data, only the PLS survey data sets between 2004 and 2007 were used for analysis of ongoing morphology in Suisun Bay.

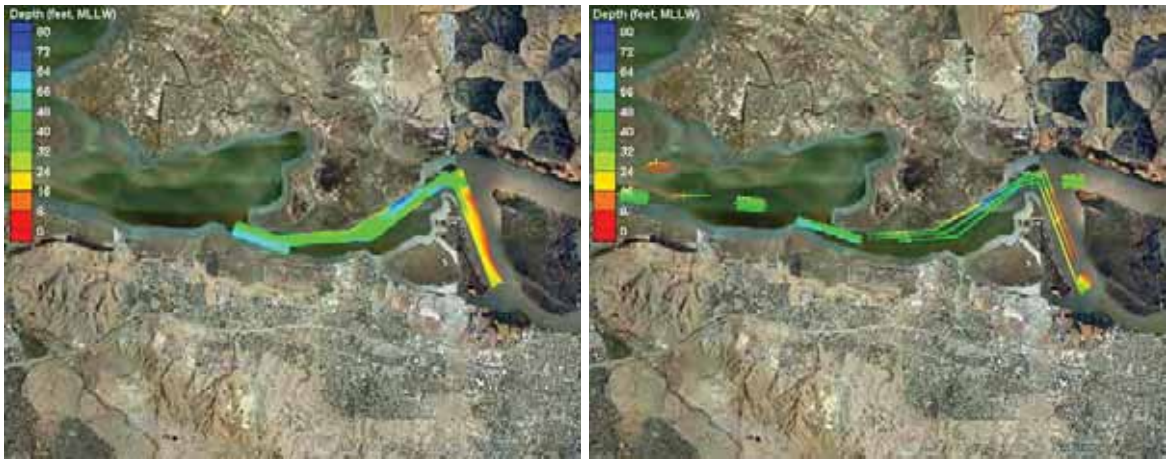

Figure 4-3. Suisun Bay depths from USGS multi-beam bathymetry data set, 2007 (various dates, left) and from E-Trac single-beam data set, 2008 (various dates, right)

With the exception of Middle Ground (TLS39), the volume changes over time in each lease area and most of the reference sites are without a clear pattern. The only other observed long-term trend was sediment depletion in control site 2, apparently due to general deepening occurring at this location (which is at the confluence of the Sacramento and San Joaquin Rivers).

The other control sites do not have a long-term depletion trend; however, all areas downstream of the Sacramento River, including East and West Suisun Associates, but excluding Middle Ground, showed noticeable depletion following the December 2005/January 2006 flood event (see Figure 4-4 for control site 2 as an example). The Middle Ground lease area did not experience erosion following this flood event likely because it contains relatively large depths that have been artificially deepened relative to the surrounding areas.

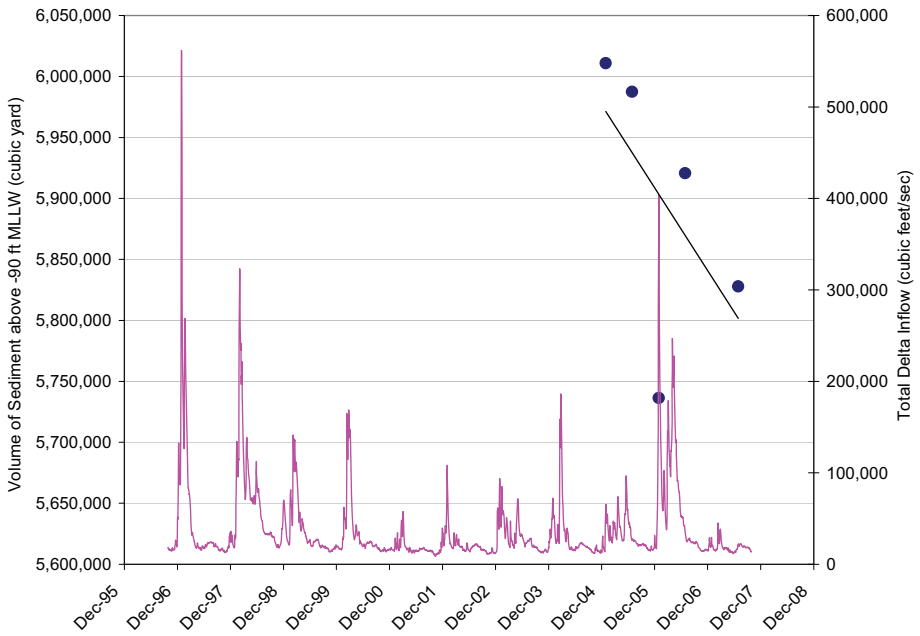

Figure 4-4. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 2 and total delta inflow (DAYFLOW model)

The observed net erosion in the control sites (which are in deeper areas near the channel centerline) immediately following the December 2005/January 2006 flood event appear to indicate that large river flows moving through the area tend to erode more sand/sediment from the main channel areas of Suisun Bay than they deliver. This finding is consistent with recent low maintenance dredging volumes reported by the U.S. Army Corps of Engineers (Bay Conservation and Development Commission, personal communication 2008). Given the apparent net erosion in the control sites following this flood event, it seems likely that sedimentation in the lease areas and navigation channels in recent years is mostly a result of local sediment transport, and that net transport through the area is small except during large flood events. Bathymetry change analysis in Suisun Bay indicates the following:

- Considering that a recent large flood event caused erosion rather than accretion in the reference sites, it appears that the material that was mined during this period had been mostly deposited from surrounding areas.
- Bottom changes in the reference sites and outside the lease areas were generally small from survey to survey (with the exception of control site 2), likely due to the large size of the surrounding areas that are contributing sediment to the deepened lease areas.
- Continuation of sand mining in Suisun Bay during the proposed 10-year period is not likely to cause measurable sediment depletion in areas outside the mining areas, such as the reference sites and areas in San Pablo/Central Bay.

- Since the material entering the lease areas appears to be finite and mostly from the surrounding areas, analysis should be performed prior to subsequent lease renewal periods.

4.2. Sand Mining Impact Evaluation from Numerical Modeling Tools

4.2.1. Modeling and Analysis Approach

The goal of the numerical modeling analysis was to provide an additional methodology for evaluation of potential impacts of sand mining on hydrodynamics, sediment transport, and salinity within San Francisco Bay on a short-term and longer-term basis. San Francisco Bay hydrodynamics are the primary driving force behind water quality and sediment transport/morphology. Therefore, the primary analysis effort and conclusions from the modeling results were made based on hydrodynamic modeling of tidal and river flows.

In order to develop more confidence in the hydrodynamic modeling results and choose the most appropriate tool for impact evaluation, four different well-respected numerical hydrodynamic modeling codes were applied to evaluate San Francisco Bay existing hydrodynamic conditions:

- SELFE (Zhang *et al.*, 2005). The model includes 3D simulation of flows, water levels, salinity and temperature.
- FVCOM (Chen *et al.*, 2006). The model includes 3D simulation of flows, water levels, salinity and temperature.
- ADCIRC2D (Luettich *et al.*, 1992). The model includes 2D simulation of flows and water levels.
- MORHPO-UNS (Kivva *et al.*, 2006). The model includes 2D simulation of flows and water levels.

The two main objectives of initially testing these four different hydrodynamic modeling tools were the following:

- Determine if differences existed between results from the modeling tools, and hence capture a more conservative, full range of potential impact results.
- Finalize which hydrodynamic tool to use for full-year hydrodynamic and sediment transport analysis.

Identical simulations were performed for all four model codes and the results of all codes are compared in Appendix D. The modeling tools were shown to generate similar results. The SELFE model was chosen for short-term and full-year impact analysis due to good validation results, efficient simulation of long time periods and inclusion of 3D flows with salinity. Appendix D describes the SELFE tidal hydrodynamic model development and validation. Figures 4-5 and 4-6 show color representations of the modeling domain.

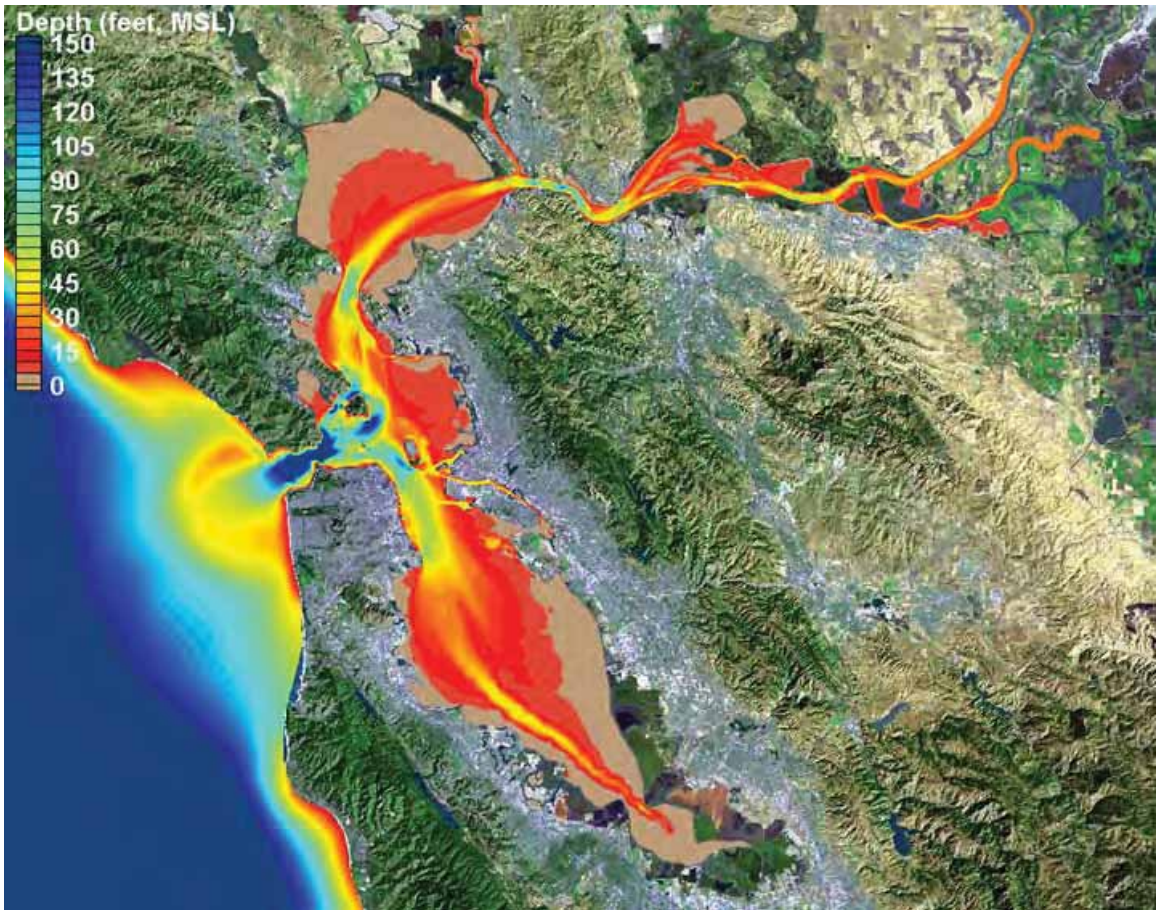

Figure 4-5. San Francisco Bay modeling domain coverage (areas inside the Bay shown) and water depths

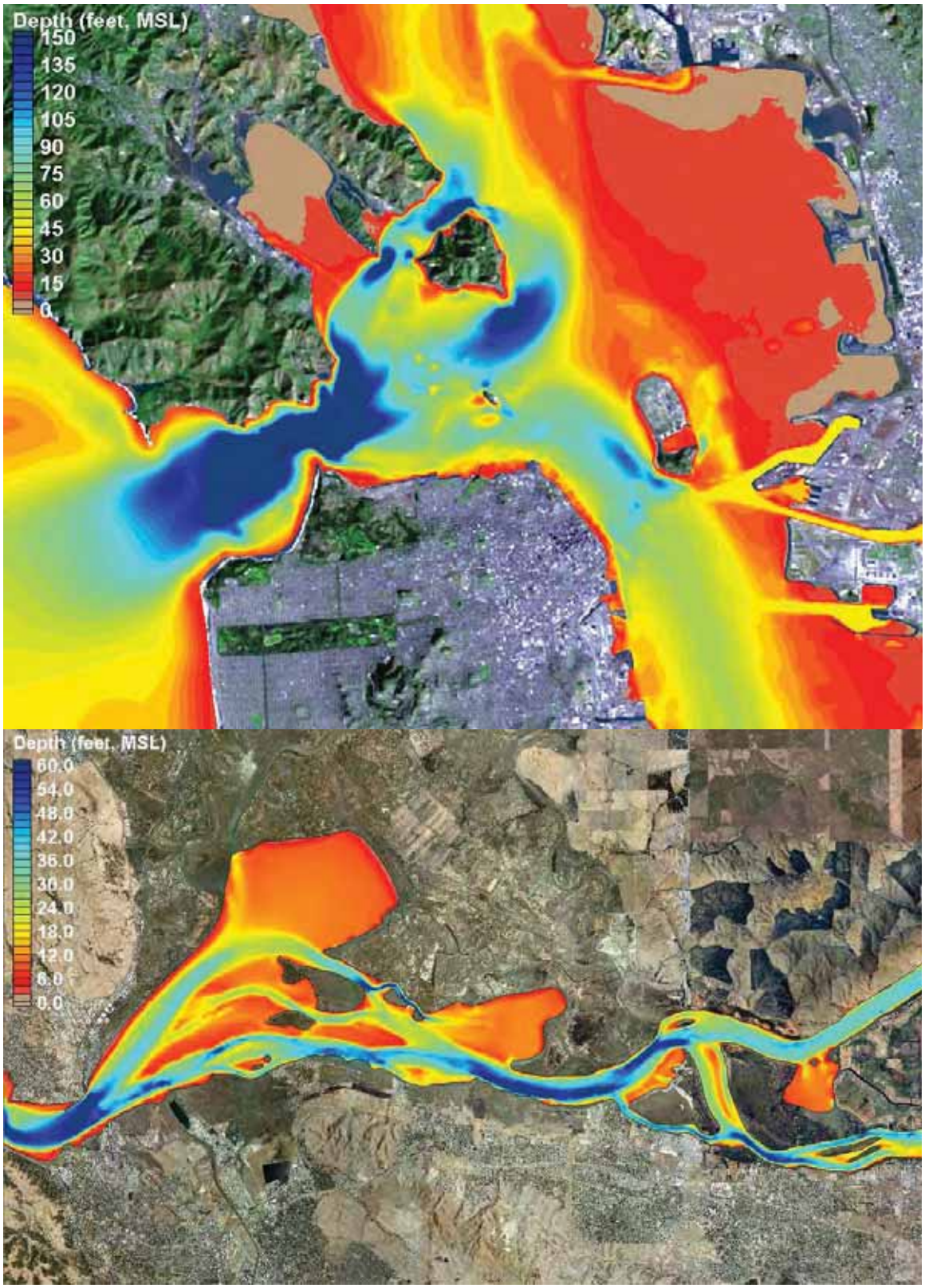

Figure 4-6. Modeling domain close-up in Central Bay (top) and Suisun Bay (bottom)

4.2.2. Modeling Scenarios

Circulation, sediment transport, and salinity were simulated for existing conditions and the following two mining scenarios developed in coordination with ESA and CSLC and approved by CSLC prior to analysis:

1. Scenario 1: 10 yrs of mining occurs all at once, covering the entire lease areas with a constant dredging thickness (Figure 4-7).
2. Scenario 2: 10 yrs of mining occurs all at once, with coverage determined from worm tracks from past mining events, using a constant dredging thickness. Dredging coverage was determined to be approximately 25% of the lease areas, on average (Figure 4-8). The lease areas were dredged only over areas consistent with the relevant sand mining regulatory permits.

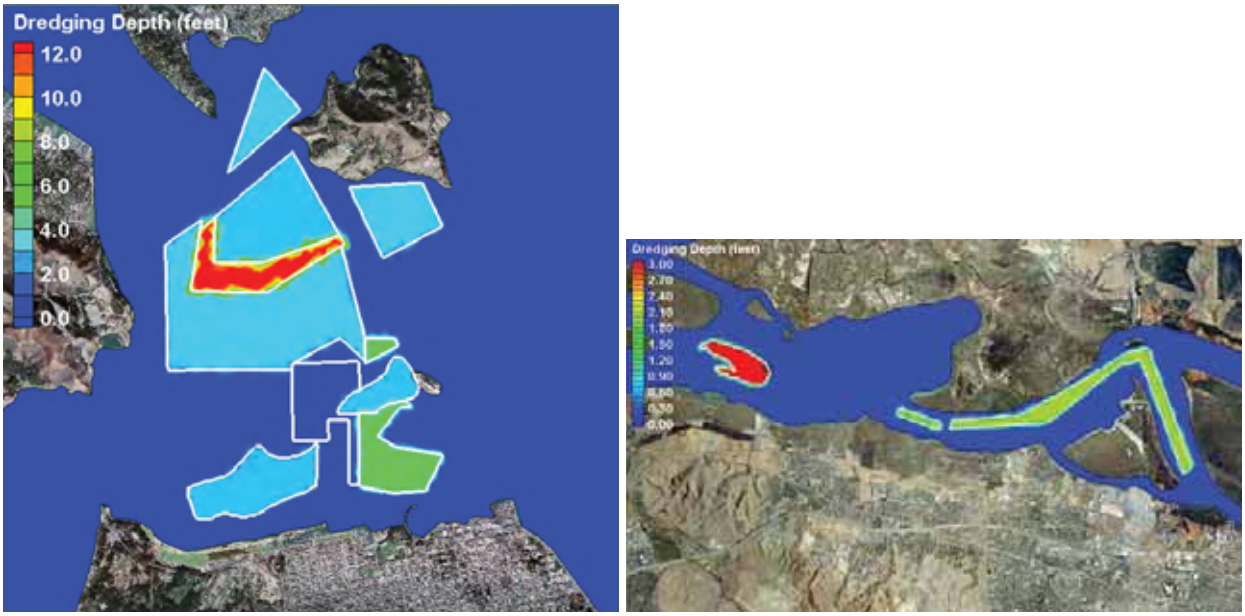

Figure 4-7. Sand mining depth changes for Scenario 1 for Central Bay (left) and Suisun Bay (right)

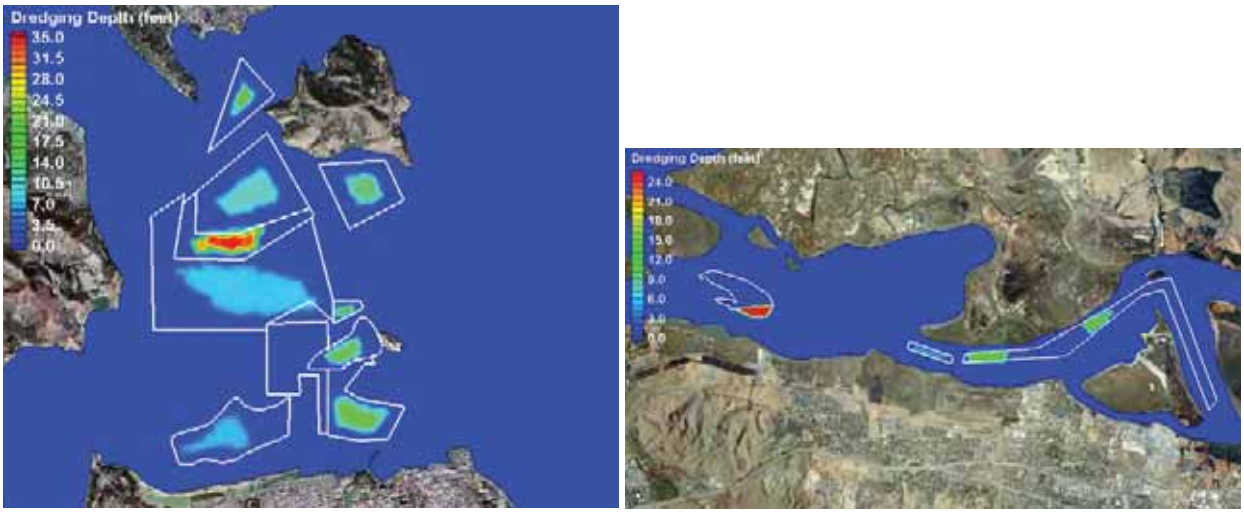

Figure 4-8. Sand mining depth changes for Scenario 2 for Central Bay (left) and Suisun Bay (right)

4.2.3. Simulation Conditions/Periods

Modeling simulations were conducted for 15-day periods (short-term runs), and full-year periods. The full-year modeling simulations were intended to span all types of potential hydrodynamic conditions, including both weak and strong river flows. The December 1, 1996 to December 1, 1997 period was used for modeling because analysis of historical records indicated that this time period contained physical processes with and without large river flow effects. Appendix D describes the river flow and initial salinity/temperature conditions used in the model.

Potential impact analysis was performed for two types of simulations: short-term (15 days) and full-year. The short-term simulations focused on details of strong tidal flows with low river flows (early December 1996). The full-year simulations focused on tidally averaged flows and longer-term analysis, including extreme flows that occurred in December 1996 and January 1997.

Two different analysis methods were used to determine short-term hydrodynamic changes from sand mining: 1) plan view differences in mid-depth velocities during typical peak ebb and flood currents; and 2) time series analysis of mid-depth velocities at selected points surrounding the lease areas (see Figures 4-9 and 4-10).

Figure 4-9. Locations of time history extraction points in Central Bay

Figure 4-10. Locations of time history extraction points in Suisun Bay

4.2.4. Changes in Circulation due to Sand Mining

Figure 4-11 shows typical peak flood (top) and ebb (bottom) mid-depth velocities for existing conditions from the SELFE model for Central Bay.

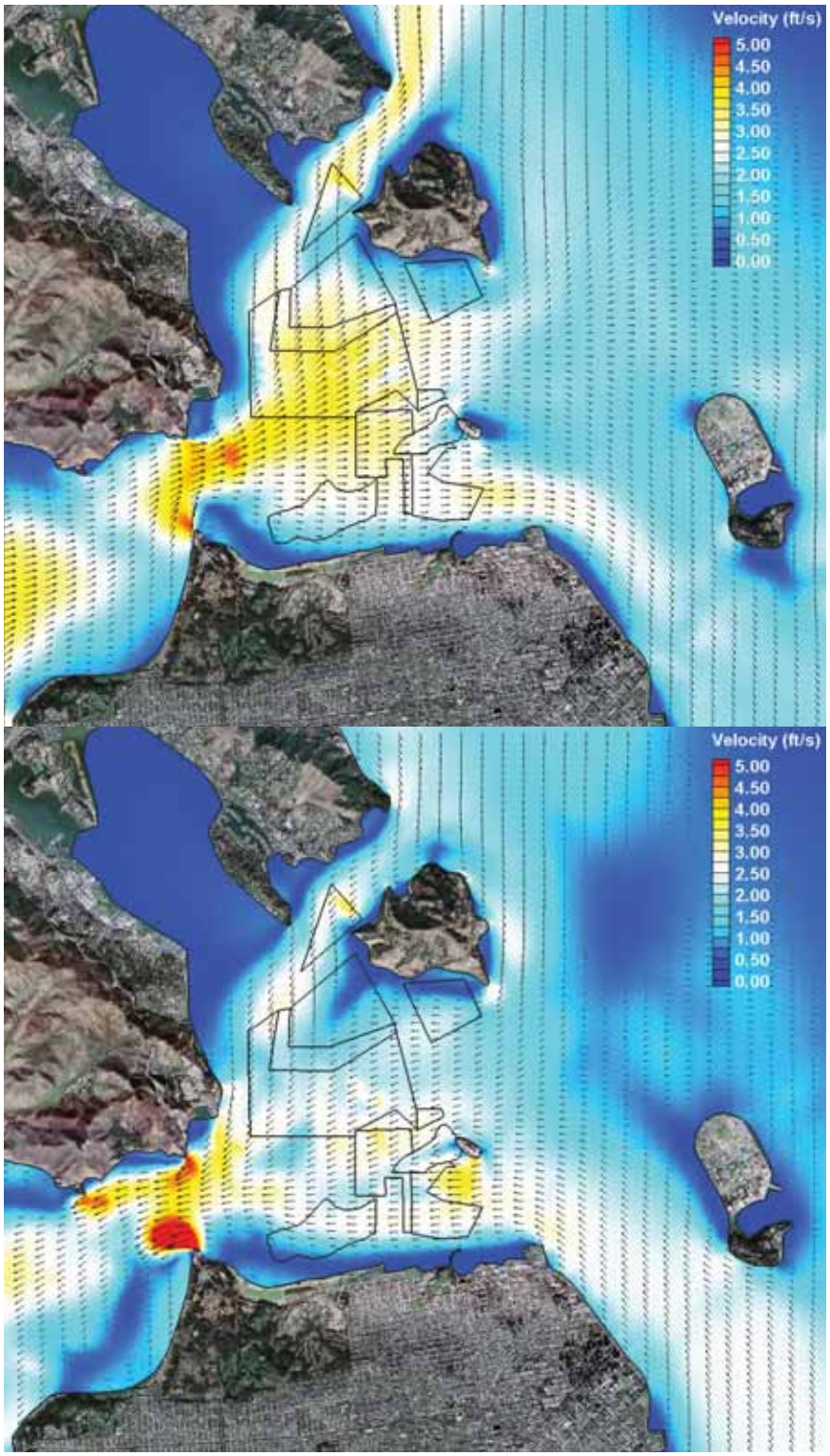

Figure 4-11. Typical flood (top) and ebb (bottom) mid-depth velocities for existing conditions

In order to detect changes in velocities, current speed difference maps were prepared. Figures 4-12 and 4-13 shows mid-depth current speed differences caused by Scenario 1 and Scenario 2, respectively, as compared to existing conditions. Analysis indicates that in general the velocity patterns surrounding the lease areas are very similar between Scenarios 1 and 2 compared to existing conditions, with only small velocity changes noticeable in the immediate vicinity of the lease areas.

Changes in mid-depth current speeds are less than approximately 1.0 feet/sec, even when measured over the most heavily mined lease areas. Changes are generally not measurable at mid-depth for distances away from the lease areas that are as large as the lease areas themselves.

It should be noted that comparison of existing conditions and after-mining conditions by direct velocity subtraction at the exact same moment in time is a highly conservative analysis approach, because introduction of project features has been known to cause small shifts in the timing of peak velocities. This produces changes in plan view that are not significant in a time history of velocity from a specific location.

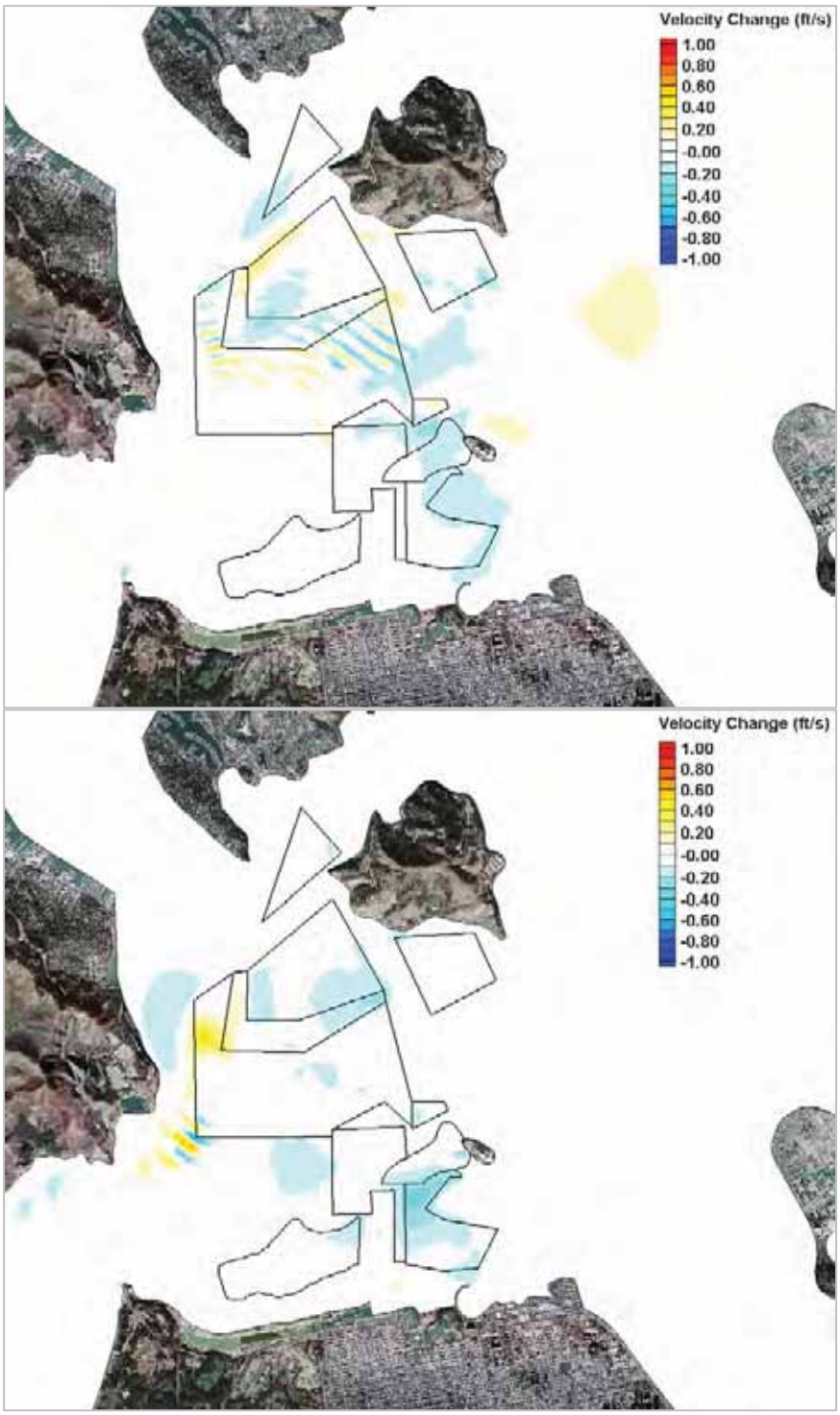

Figure 4-12. Mid-depth flood (top) and ebb (bottom) current speed differences caused by Scenario 1

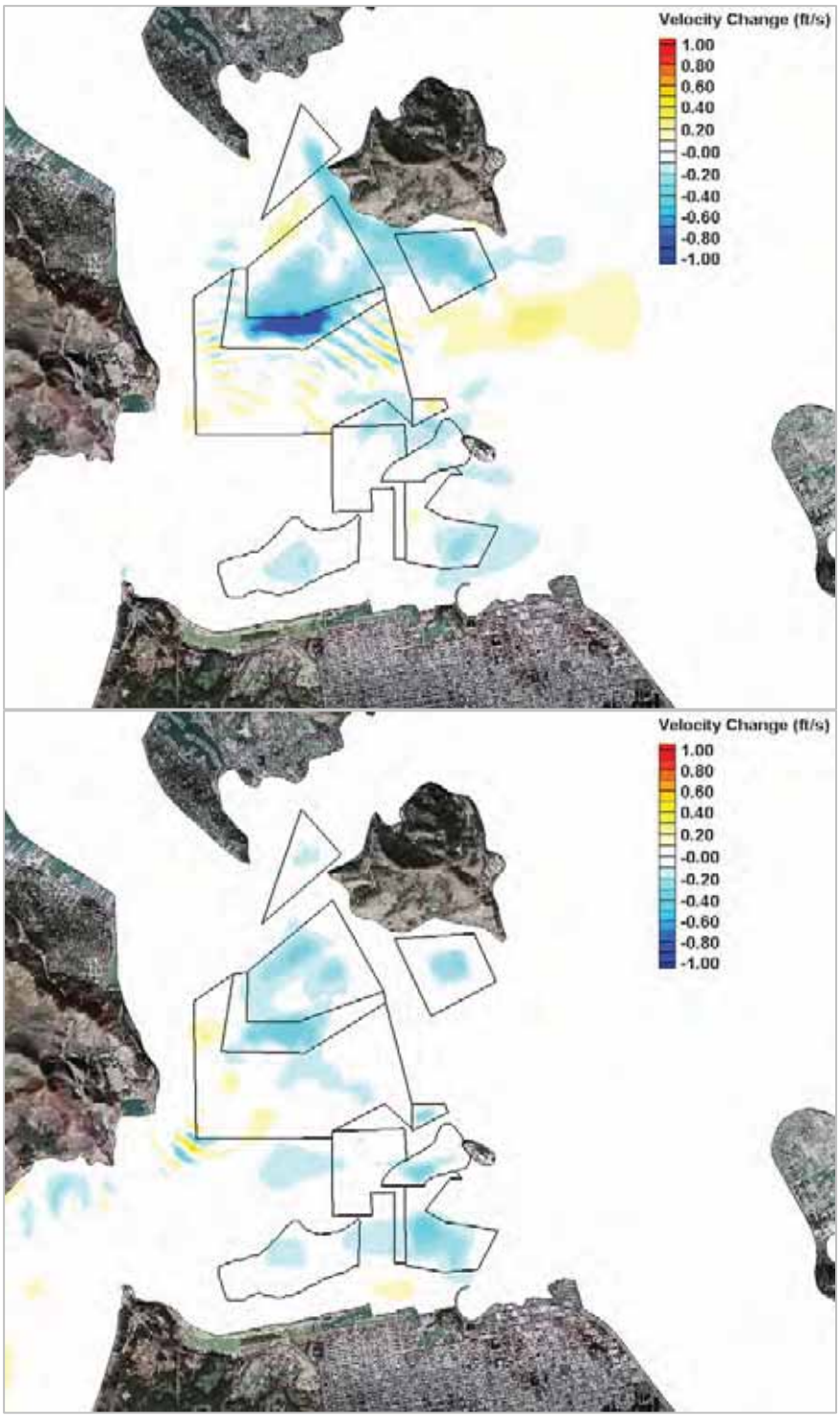

Figure 4-13. Mid-depth flood (top) and ebb (bottom) current speed differences caused by Scenario 2

A time series analysis of mid-depth velocities surrounding the lease areas was also performed at Points 1 - 21 shown in Figures 4-9. Figure 4-14 shows time histories of mid-depth velocity at Points 4 (left) and 10 (right) in Central Bay. The velocity time histories for Scenario 1 and Scenario 2 for existing conditions are not distinguishable

in the figure, indicating that bathymetry changes due to sand mining do not measurably change the overall current speed regime at these locations. The maximum current speed difference present at any Central Bay analysis location (see Figure 4-9) for both alternatives was approximately 0.05 feet/sec. In general, the current speed differences caused by the sand mining at the locations used for analysis are not expected to be measurable.

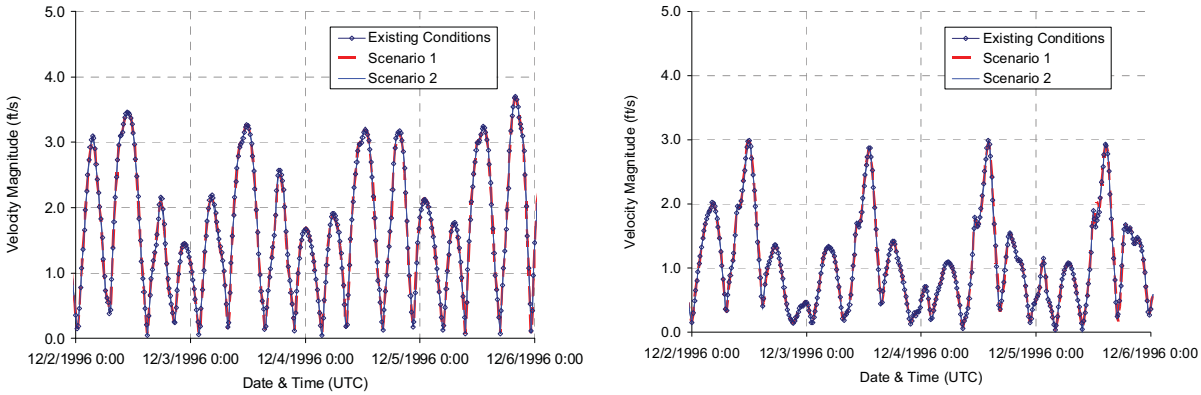

Figure 4-14. Mid-depth current speed at Point 4 (left) and Point 10 (right) for existing conditions, Scenario 1 and Scenario 2 (point locations in Figure 4-11)

Full-year simulations were performed with the SELFE model using hydrologic and tide data forcing from the period between December 1996 and December 1997. Existing conditions, Scenario 1 and Scenario 2 were simulated and hydrodynamic statistics, net values, and averages were developed to represent the longer-term conditions for each alternative. Potential impacts of sand mining were primarily evaluated using changes in net (tidally averaged) current velocities. Appropriate averaging periods were determined through sensitivity analysis.

Figure 4-15 shows the one-year net (long-term average) flows for existing conditions in Central Bay. Figure 4-16 shows the changes in net flows induced by Scenarios 1 and 2 (top and bottom, respectively). The color contours represent changes in net flow magnitudes and the vectors represent the net flows for existing conditions. As with short-term hydrodynamics, the full-year net flows in Central Bay are not measurably affected in areas outside the immediate vicinity of the lease areas.

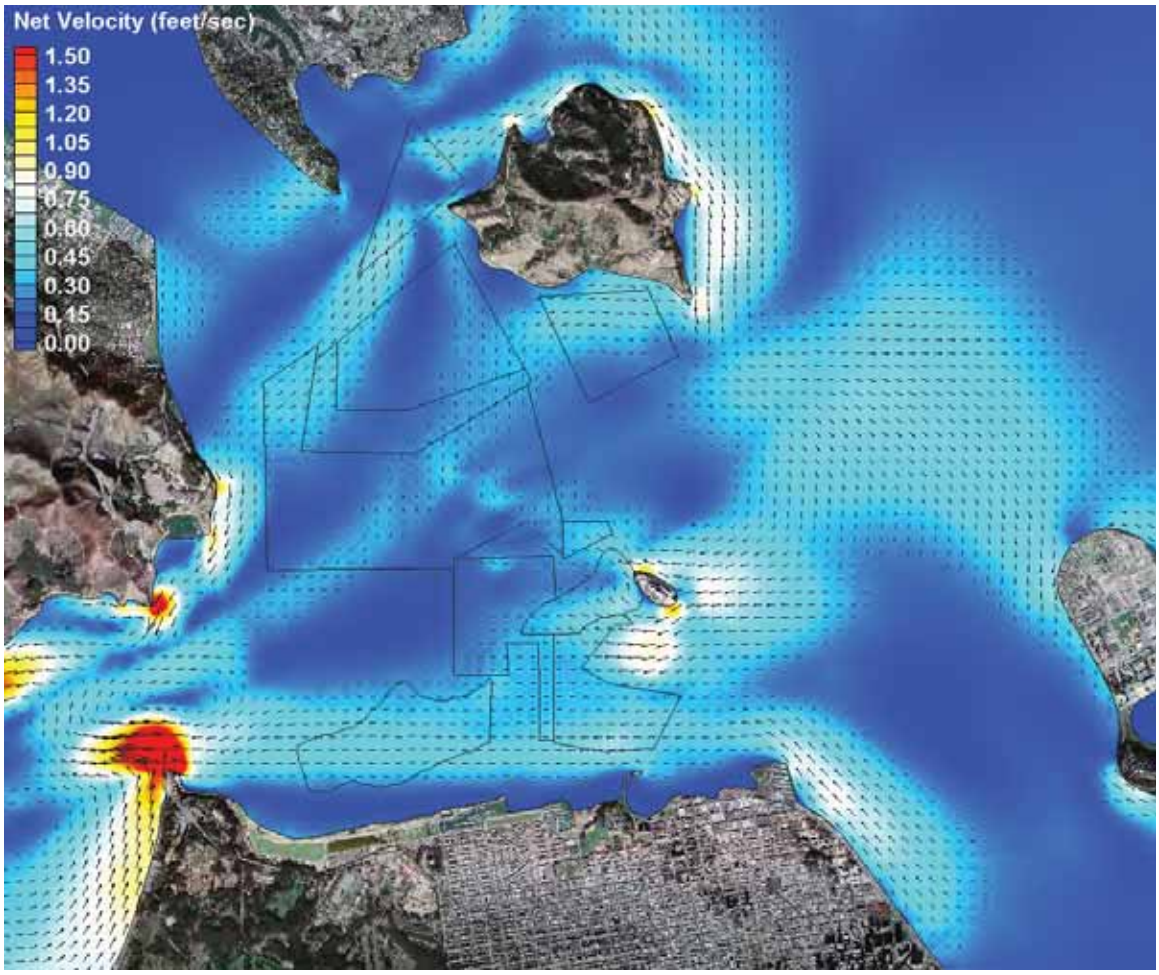

Figure 4-15. Net current velocities (December 1996 to December 1997) in Central Bay for existing conditions

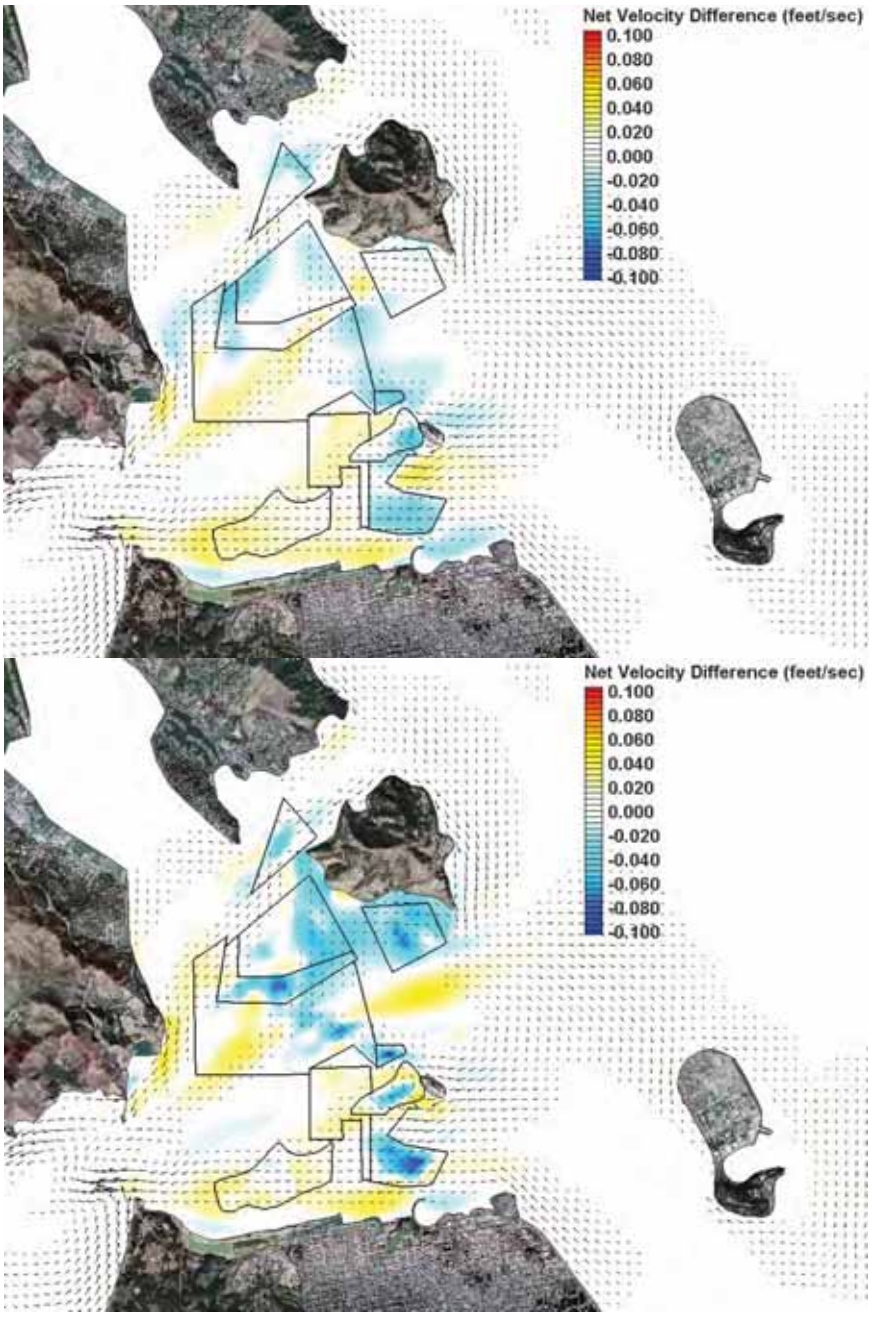

Figure 4-16. Changes in net current velocities (December 1996 to December 1997) in Central Bay caused by Scenario 1 (top) and Scenario 2 (bottom).

Figures 4-17 shows typical Suisun Bay peak flood (top) and ebb (bottom) mid-depth velocities for existing conditions from the SELFE model.

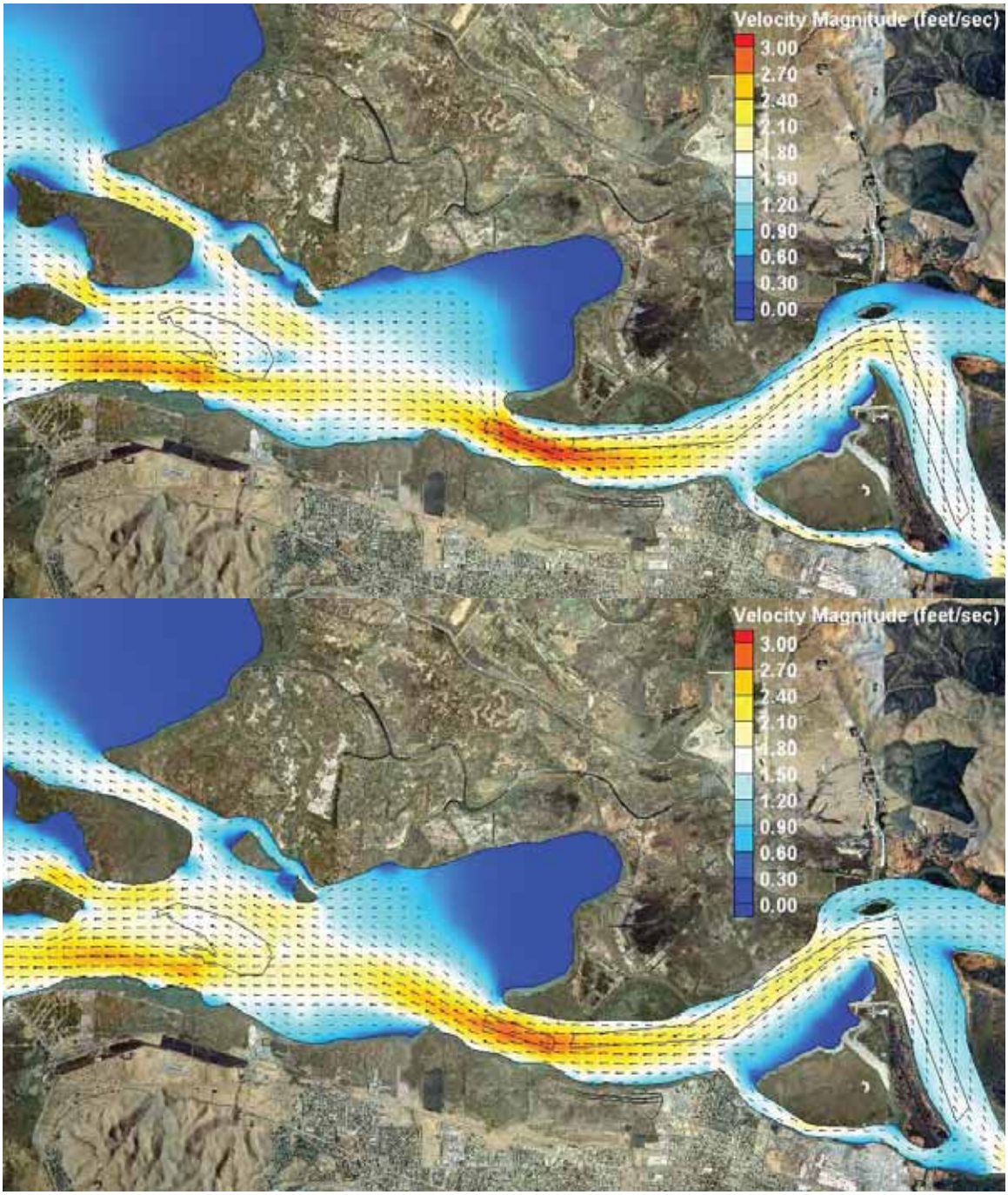

Figure 4-17. Typical flood (top) and ebb (right) mid-depth velocities in Suisun Bay for existing conditions

Current speed difference maps were also prepared for Suisun Bay. Figures 4-18 and 4-19 show mid-depth current speed differences in Suisun Bay caused by Scenarios 1 and 2, respectively, compared to existing conditions. Analysis indicates that in general the velocity patterns surrounding the lease areas are very similar between existing conditions, Scenario 1 and Scenario 2. Changes in mid-depth current speeds are less than approximately 0.5 feet/sec, even when measured over the most heavily

mined lease areas. Changes are not measurable away from the lease areas, generally at distances away from the lease areas that are similar to the sizes of the lease areas themselves.

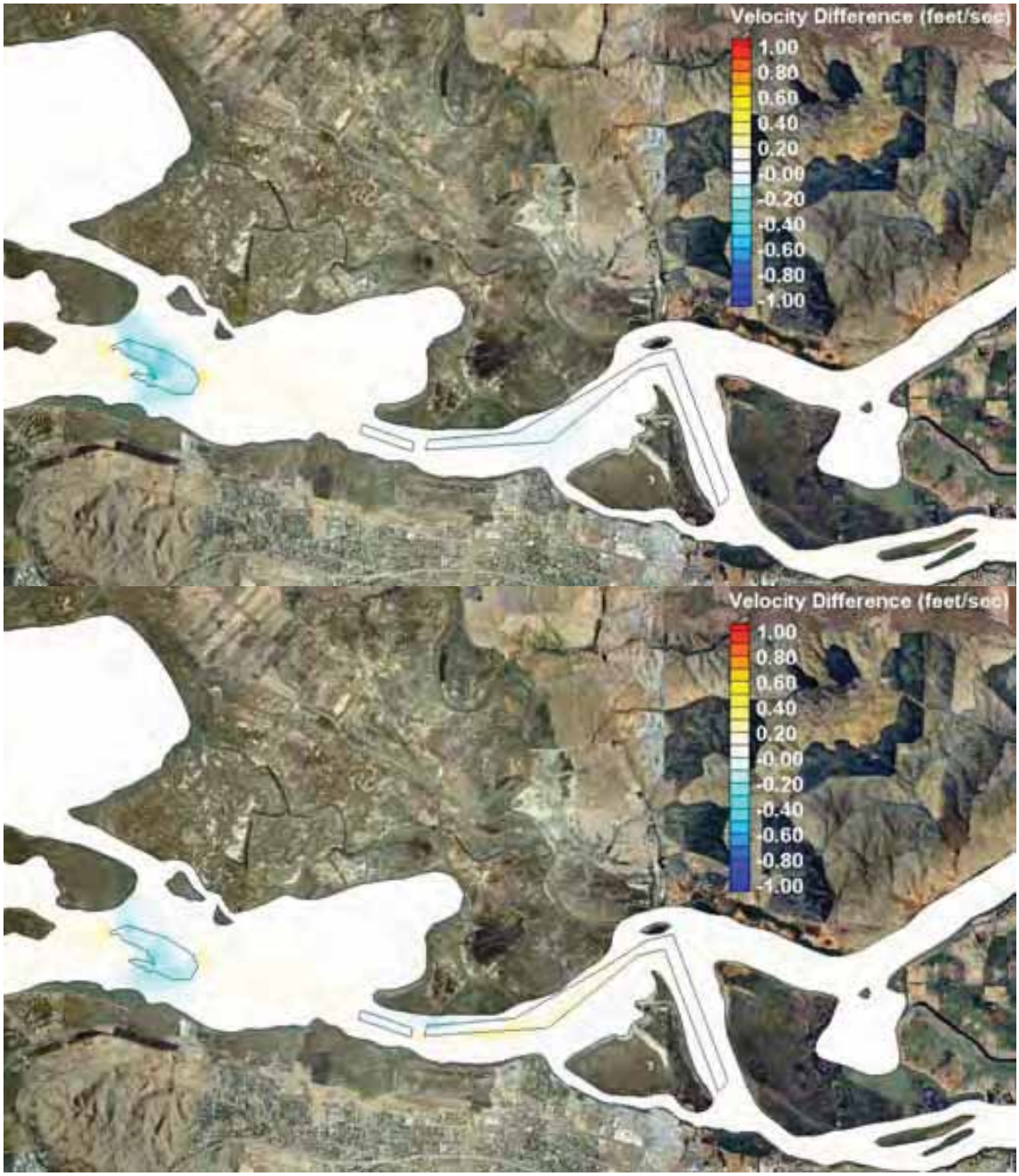

Figure 4-18. Mid-depth flood (top) and ebb (bottom) current speed differences in Suisun Bay caused by Scenario 1

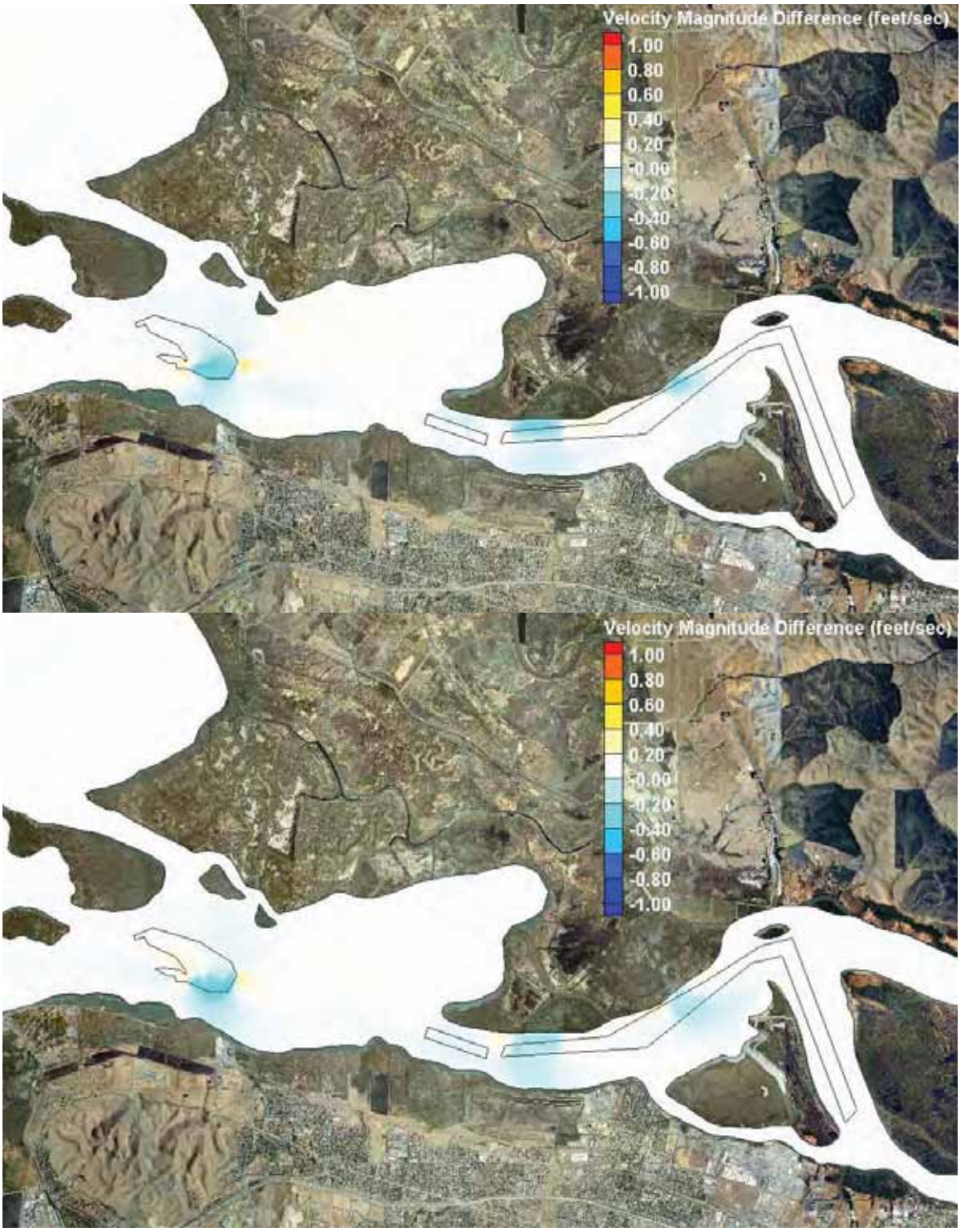

Figure 4-19. Mid-depth flood (top) and ebb (bottom) current speed differences in Suisun Bay caused by Scenario 2

A time series analysis of mid-depth velocities surrounding the lease areas was also performed at Points 22-41 shown in Figure 4-10. Figure 4-20 shows time histories of mid-depth velocity at Points 24 (left) and 29 (right) in Suisun Bay. The velocity time histories for existing conditions, Scenario 1 and Scenario 2 are almost

indistinguishable in the figure, indicating that bottom changes due to sand mining do not measurably change the overall current speed regime at these locations.

The maximum current speed difference present at any Suisun Bay analysis location (see Figure 4-10) for both alternatives was approximately 0.05 feet/sec. In general, the current speed differences caused by the sand mining at the locations used for analysis are not expected to be measurable.

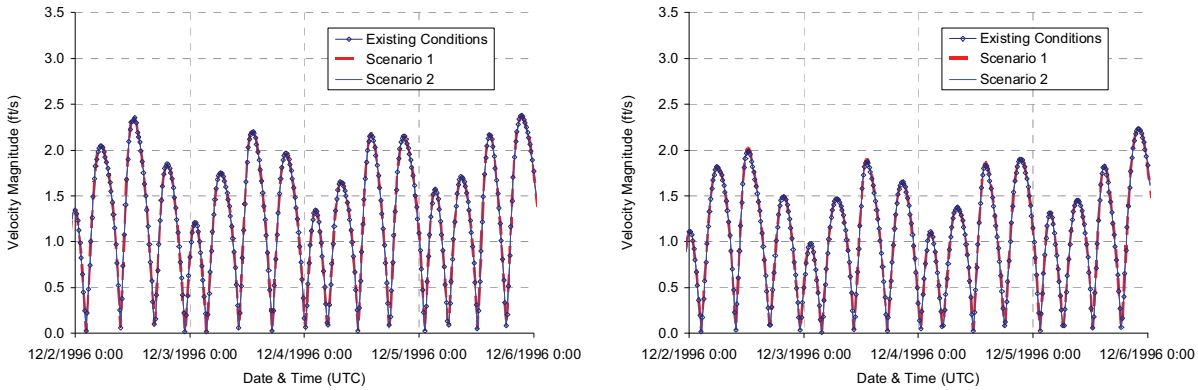

Figure 4-20. Mid-depth current speed at Point 24 (left) and Point 29 (right) for existing conditions, Scenario 1 and Scenario 2 (Point Locations in Figure 4-10)

Figure 4-21 shows the one-year net velocities for existing conditions in Suisun Bay. Figure 4-22 shows the changes in net velocities induced by Scenario 1 (top) and Scenario 2 (bottom). Suisun Bay net current velocities are much stronger than Central Bay net velocities in the lease areas due to the presence of unidirectional river discharge. Analysis indicates that the full-year net current velocities in Suisun Bay are not affected in areas outside the vicinity of the lease areas. The areas over which net flows are affected more than 0.05 feet/sec is approximately as large as the lease areas themselves.

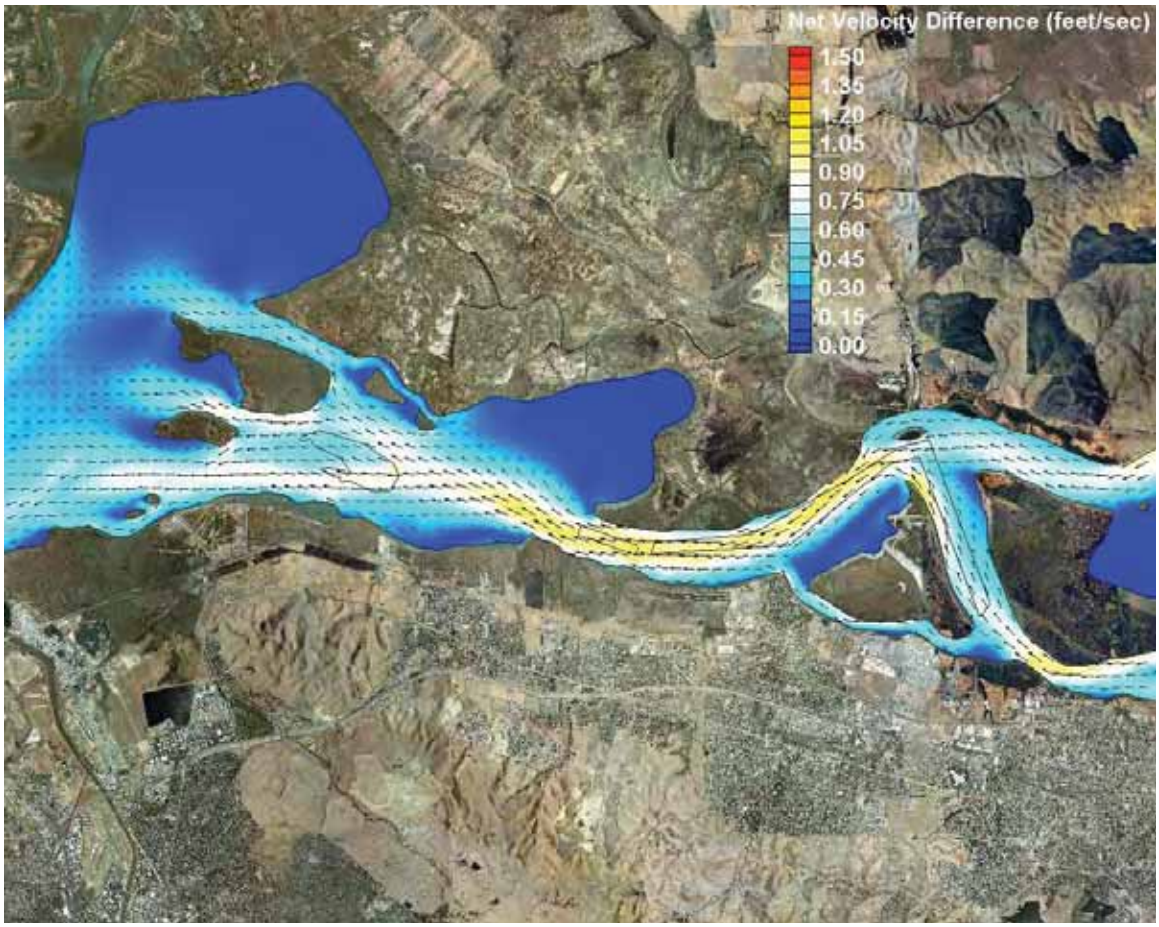

Figure 4-21. Net current velocities (December 1996 to December 1997) in Suisun Bay for existing conditions

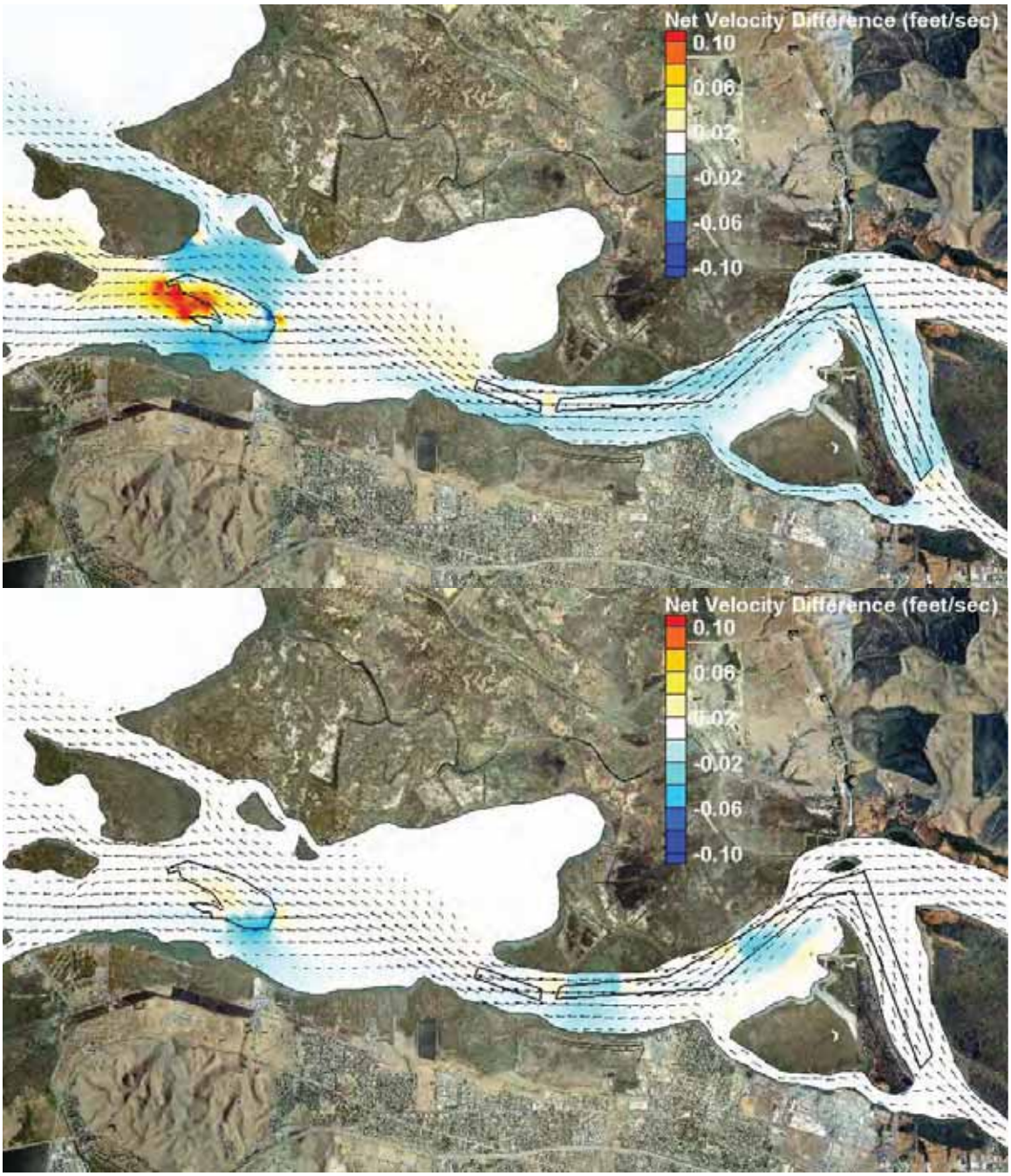

Figure 4-22. Changes in net current velocities (December 1996 to December 1997) in Suisun Bay caused by Scenario 1 (top) and Scenario 2 (bottom)

Circulation modeling results from both short-term and full-year simulations in both Central and Suisun Bays indicate that tidal and river current flows are not likely to be affected by the sand mining activities except in the vicinity of the mining areas. The vicinity of measurable changes is generally similar in size to the lease areas themselves.

4.2.5. Changes to Salinity due to Sand Mining

Salinity was also evaluated with the SELFE model within the short-term simulation to determine if the sand mining is likely to result in changes to the salinity patterns surrounding the project area. Figures 4-23 and 4-24 show plan views of bottom salinity for existing conditions during typical peak flood and ebb currents, respectively, in Central Bay. These two figures also each show vertical profiles of salinity during peak currents for existing and after-mining conditions.

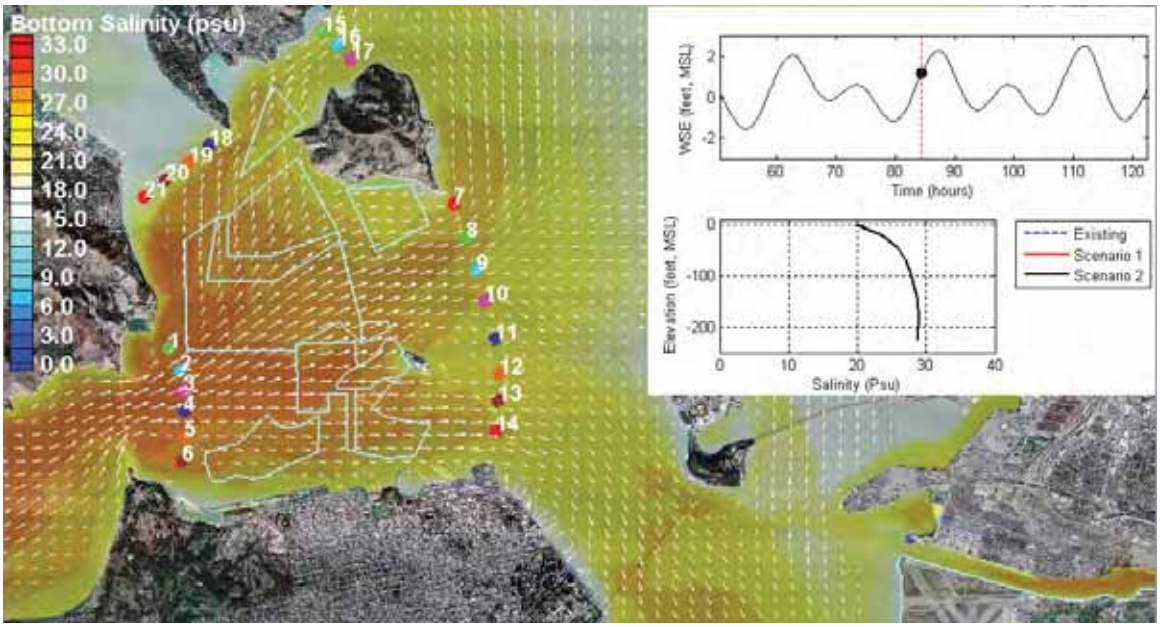

Figure 4-23. Bottom salinity (color contours) and vertical profiles of salinity at Point 4 in Central Bay for all scenarios during peak flood velocities

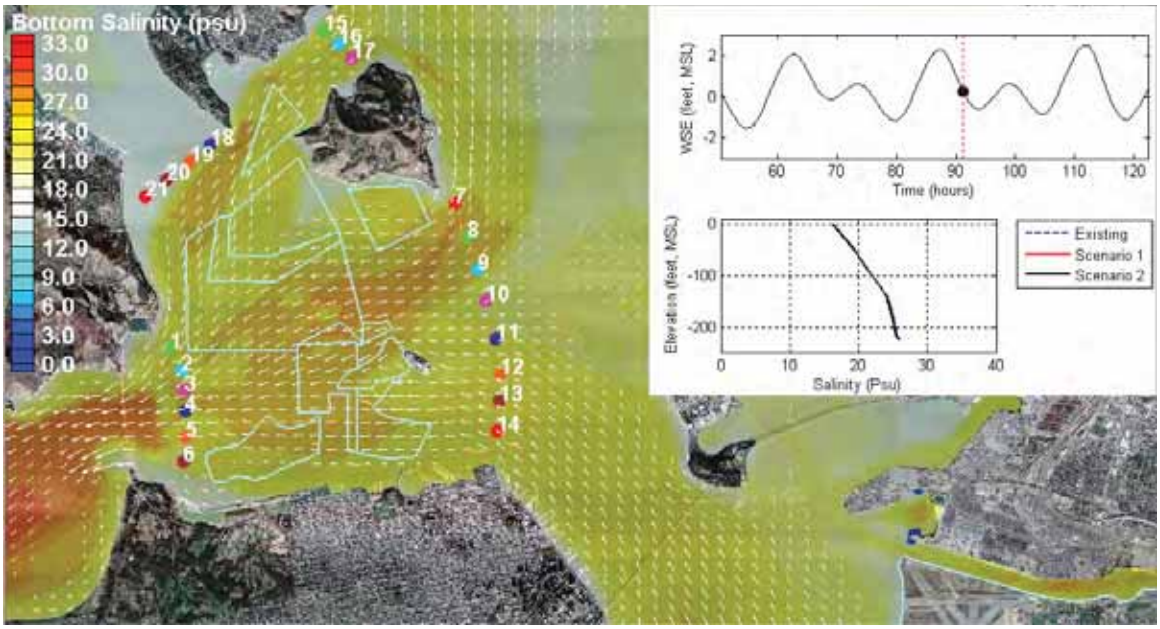

Figure 4-24. Bottom salinity (color contours) and vertical profiles of salinity at Point 4 in Central Bay for all scenarios during peak ebb velocities

Results indicate no measurable differences in salinity profiles at the locations used for analysis. However, at some times during the simulations, small salinity changes can be noticed in the near-bottom areas. The salinity differences are only temporary during periods of weaker currents (higher salinity in the mining holes), and salinity levels return to surrounding levels when stronger currents return. It should be noted that although care was taken to reasonably represent the dredging holes caused by mining, the system-wide scale of the analysis prevents highly detailed flow modeling surrounding the mining holes. Therefore, it should be expected that some slightly increased salinity levels could be present in the deeper holes if salinity levels are reduced in Central Bay from river discharge, particularly if Scenario 2 were put into practice (deepening up to 35 feet in some areas).

Salinity was also evaluated in Suisun Bay with the SELFE model. However, the salinity values measured by USGS (data that were used as initial conditions) were negligible in Suisun Bay. Since near-zero values existed in the modeling results a quantitative comparison was not made; however, results and conclusions similar to those from Central Bay should be expected for periods when salinity is higher in Suisun Bay.

Modeling results from the short-term salinity simulations indicate that salinity levels are not likely to be affected by the sand mining activities except during brief periods of time within the mining holes, where some small, short-term bottom salinity increases may occur, particularly for Scenario 2.

4.2.6. Changes to Sediment Transport due to Sand Mining

Numerical modeling of sand transport and bottom morphology for both short-term simulations (15 days) and full-year simulations (using December 1996 to December 1997 hydrologic/tide data input) was performed with the two-dimensional LAGRSED model (Maderich *et al.,* 2004). The LAGRSED model used hydrodynamics from the SELFE model as input. The sediment transport model description, setup, and input data are provided in Appendix D.

The LAGRSED model is a Lagrangian (particle-tracking) sediment transport model that computes suspended and bedload sediment transport fluxes and bed changes for a variety of sediment sizes distributed around the Bay. In order to best utilize the 3D hydrodynamic results, the shear stress values calculated by the SELFE model were input directly into the 2D LAGRSED model for calculation of transport rates and morphology. In the short-term simulations, patterns of sediment transport rates were compared to determine if any changes in hydrodynamics are likely to cause changes in instantaneous transport. Transport rates are highly variable due to the large variation in sediment sizes, highly variable pattern of near-bottom velocity and highly variable bathymetry.

Figure 4-25 shows Central Bay total sediment transport (bedload plus suspended load) during typical peak flood (top) and ebb (bottom) velocities for existing conditions. Figures 4-26 and 4-27 show changes in total transport relative to existing conditions for Scenarios 1 and 2, respectively, during typical flood (top) and ebb (bottom) currents. The color contours represent changes in total transport and vectors represent total transport for existing conditions. Total sediment transport time series were also extracted at the points shown in Figure 4-9 for all scenarios.

Figure 4-28 shows time histories of the total sediment transport rate (bedload plus suspended load) at the selected extraction points. Time histories at Points 4 and 10 in Central Bay show no measurable transport rate differences. Results indicate that total sediment transport is not likely to be measurably altered outside the immediate vicinity of the lease areas.

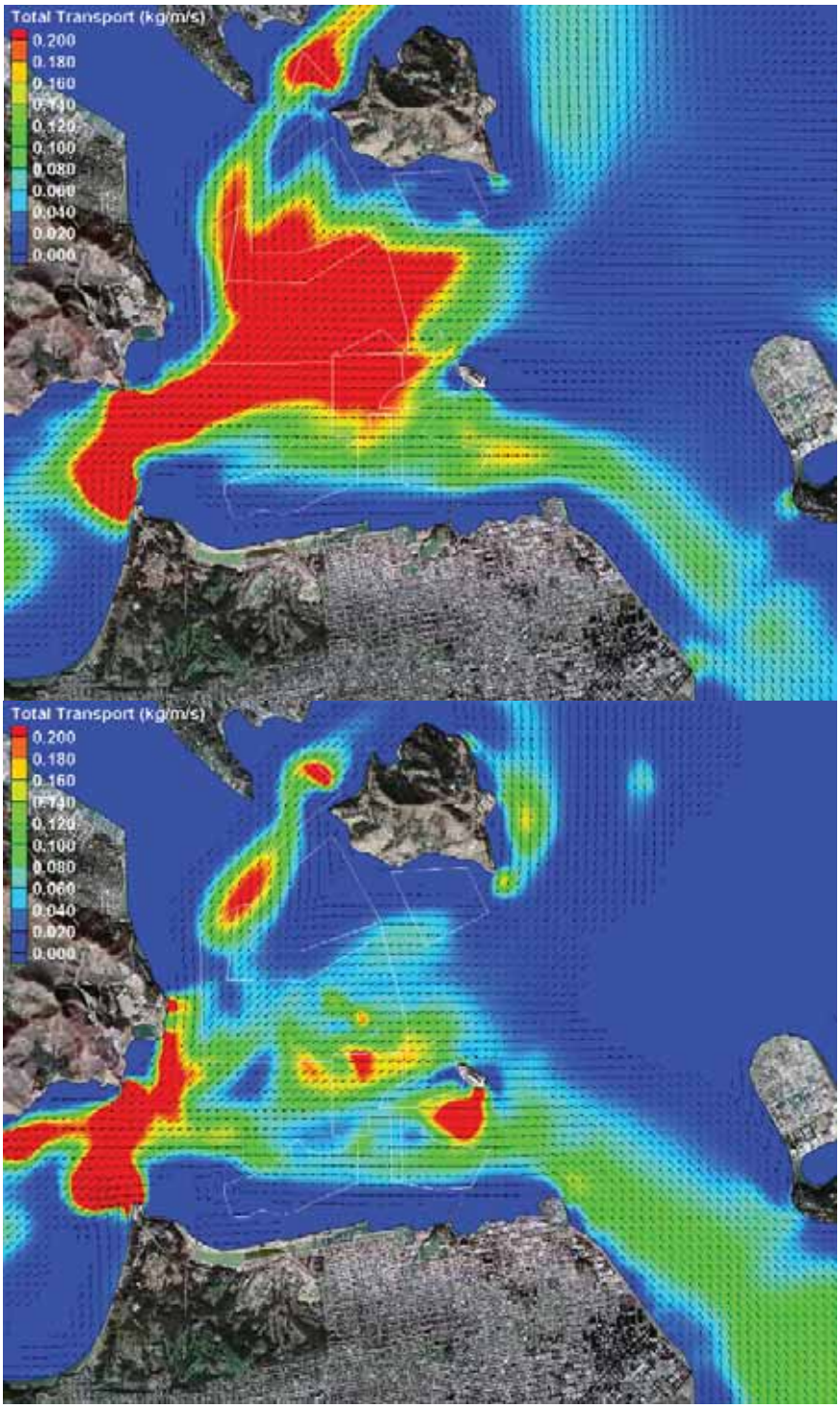

Figure 4-25. Total transport in Central Bay for existing conditions during typical flood (top) and ebb (bottom) currents

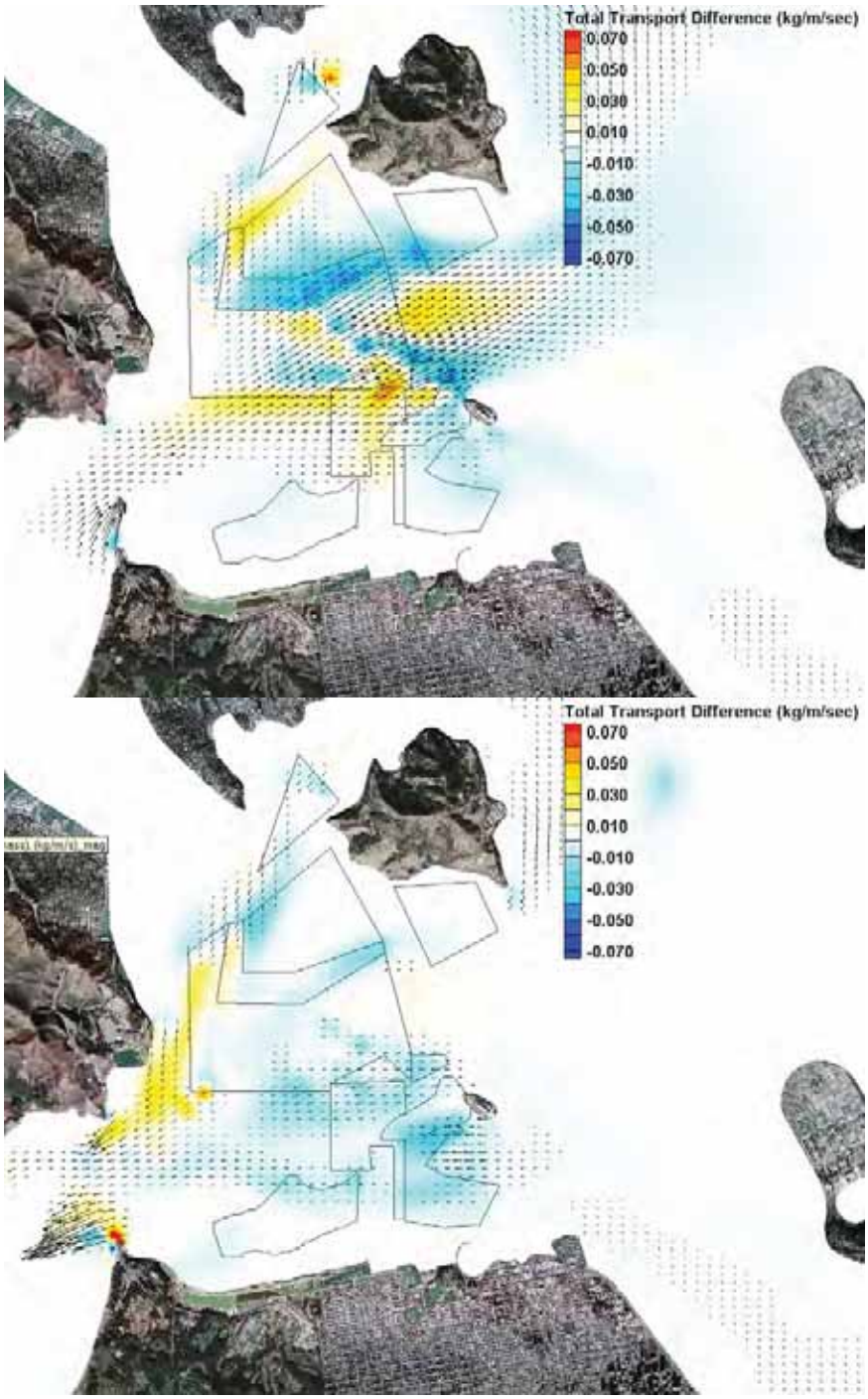

Figure 4-26. Scenario 1 changes in total transport in Central Bay for existing conditions during typical flood (top) and ebb (bottom) currents

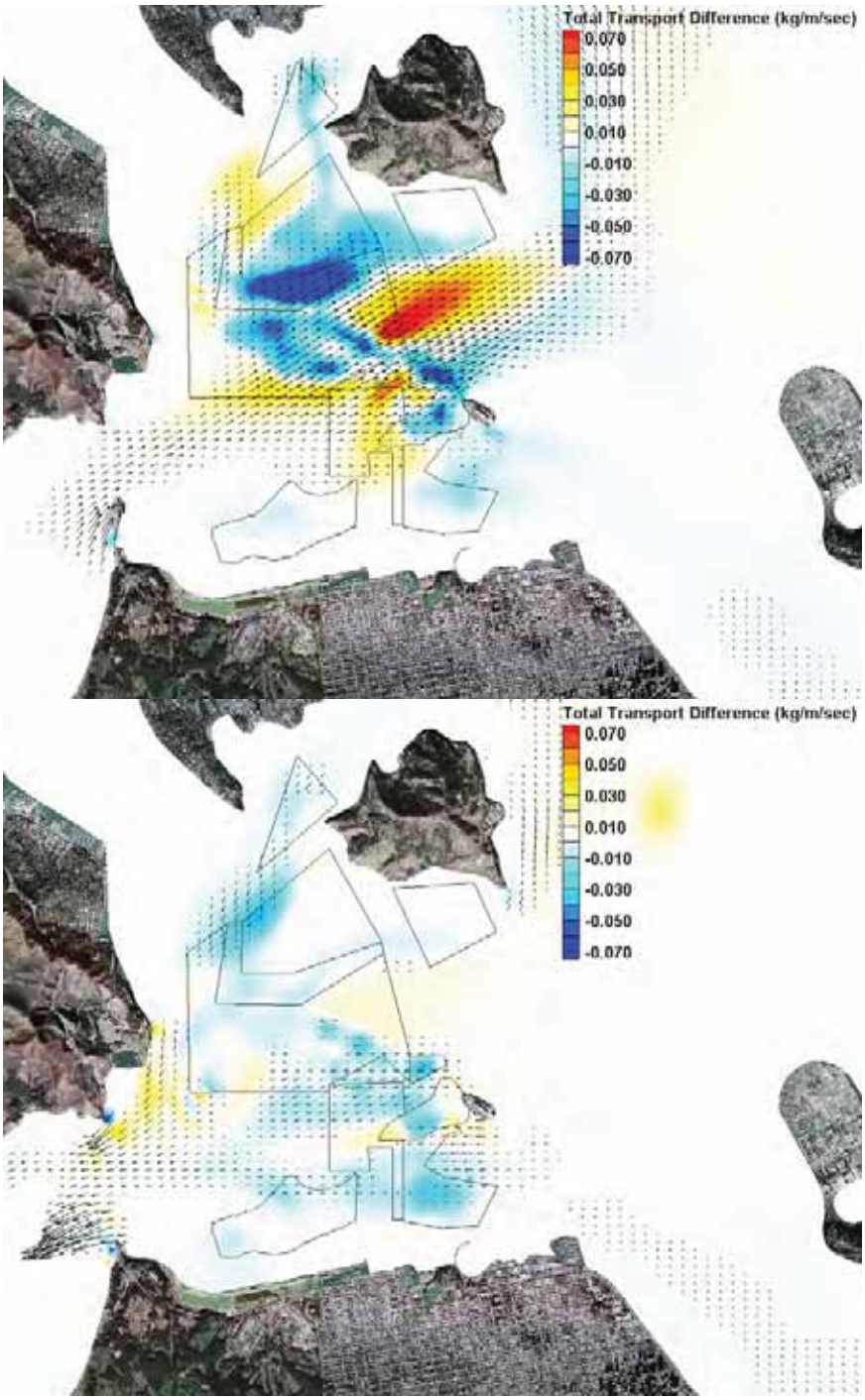

Figure 4-27. Scenario 2 changes in total transport in Central Bay for existing conditions during typical flood (top) and ebb (bottom) currents

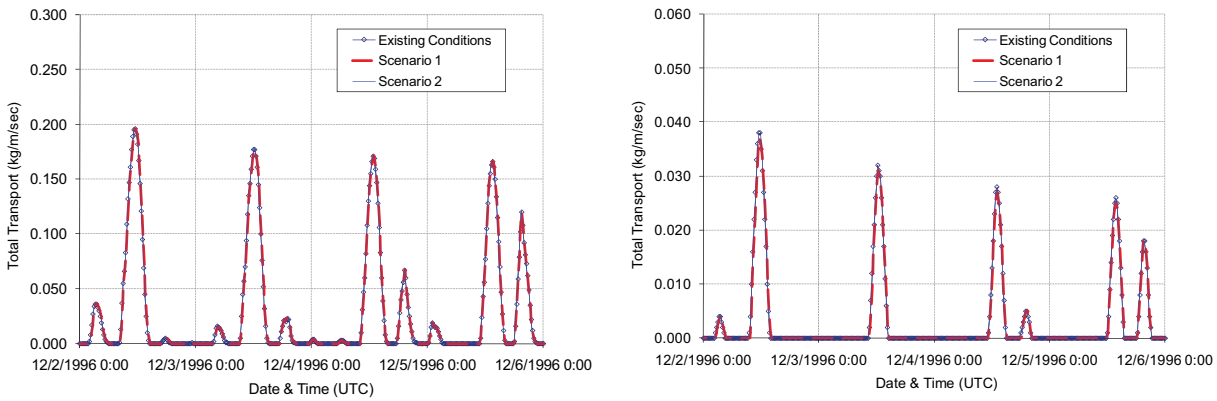

Figure 4-28. Time history of total transport at Points 4 (left) and 10 (right) in Central Bay

One-year sediment transport simulations were also performed using the LAGRSED model to capture high-flow effects. Figure 4-29 shows the net sediment transport from the one-year simulation for existing conditions in Central Bay. The net transport patterns are typically small except in areas that tend to have largely unidirectional flows, or a consistently large difference between ebb and flood current speeds.

Figures 4-30 and 4-31 show differences in net bedload sediment transport caused by sand mining relative to existing conditions for Scenarios 1 and 2, respectively. LAGRSED model results indicate that full-year (net) bedload sand transport patterns are not likely to be affected by the mining activities except in the vicinity of the mining areas. In areas farther than approximately the size of the lease areas, the changes are less than 5%.

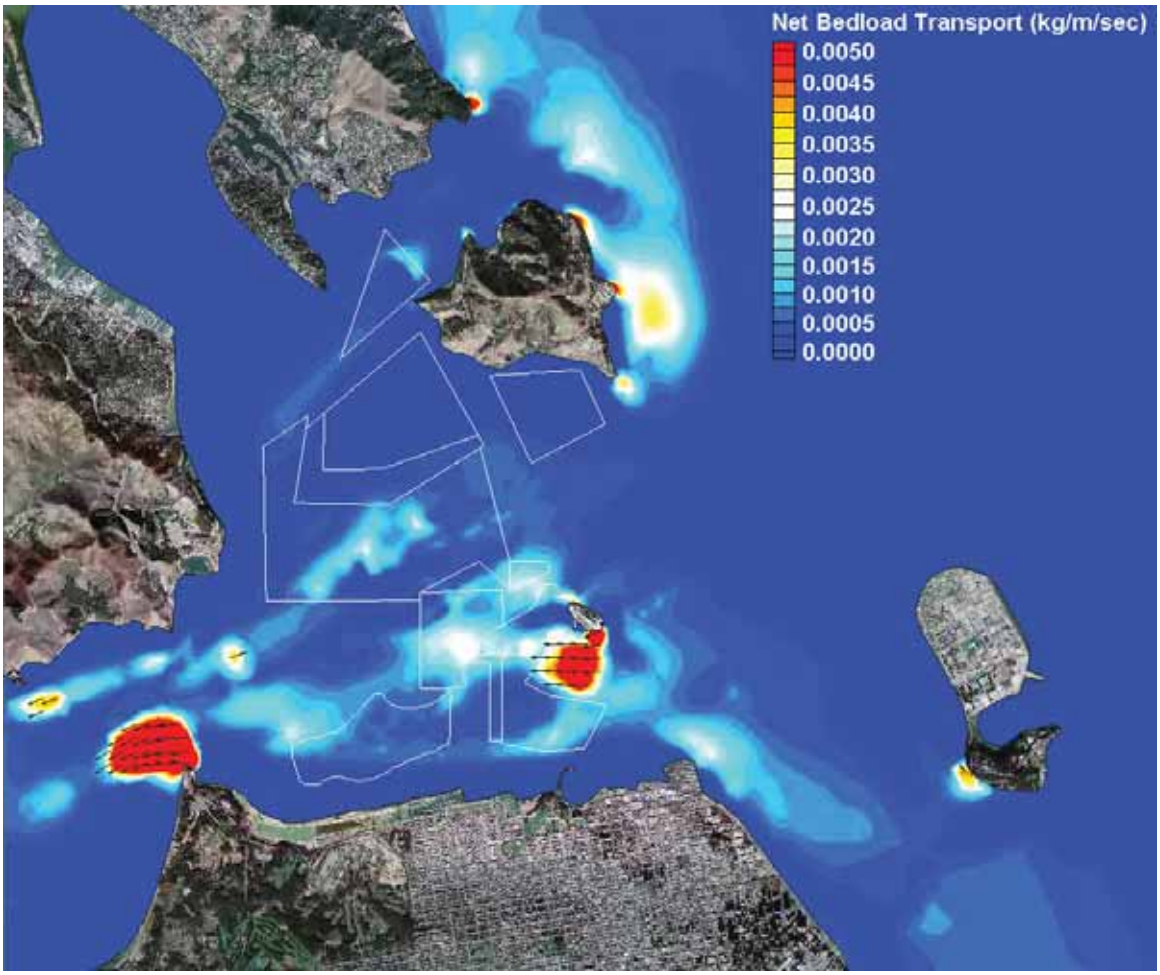

Figure 4-29. Net bedload transport in Central Bay for existing conditions

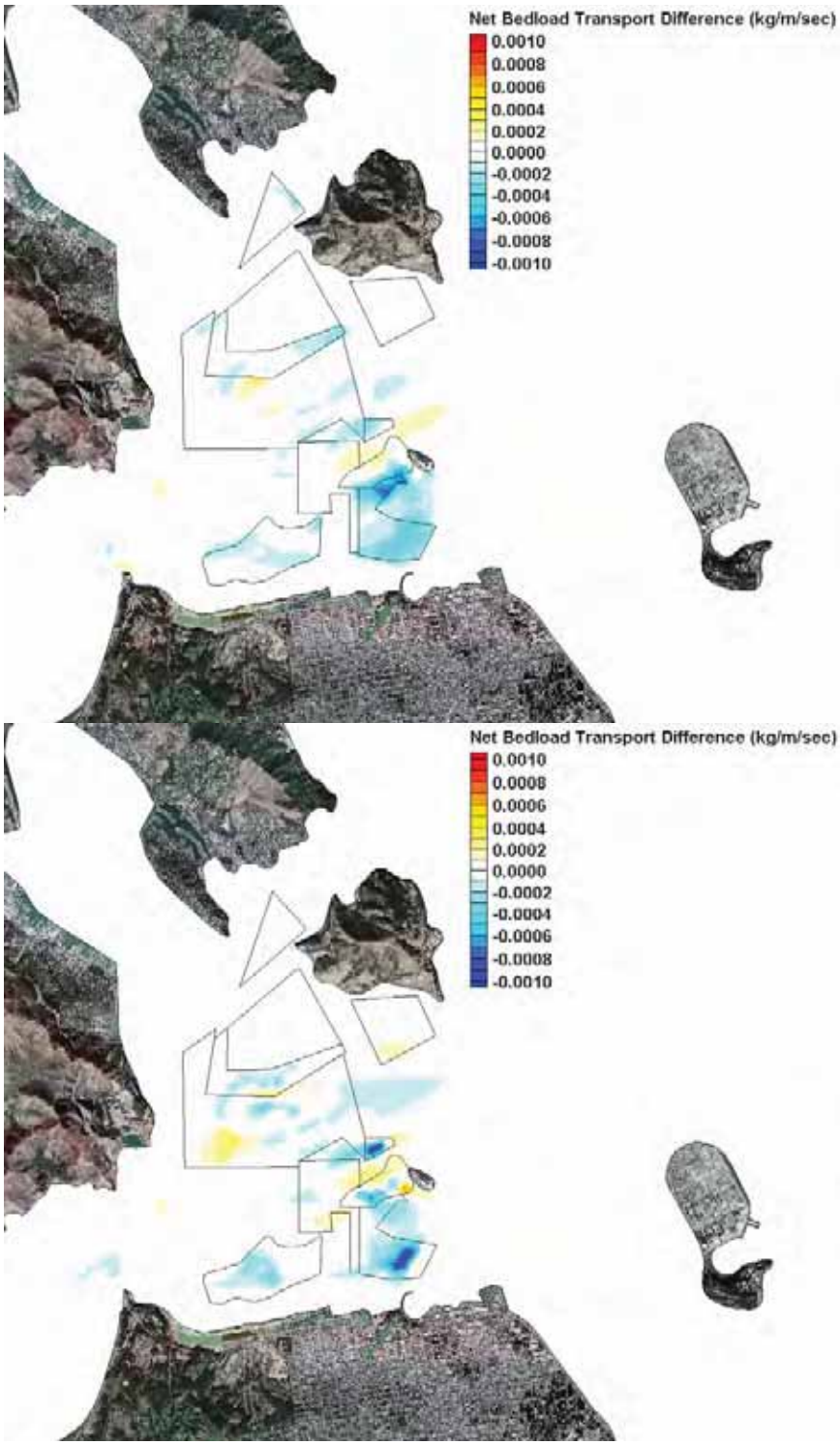

Figure 4-30. Scenario 1 (top) and Scenario 2 (bottom) changes in full-year net bedload transport in Central Bay

Figure 4-31 shows upper Suisun Bay total sediment transport (bedload plus suspended load) during typical peak flood (top) and ebb (bottom) velocities for

existing conditions during the short-term simulation. Figures 4-32 and 4-33 show changes in total transport relative to existing conditions for Scenarios 1 and 2, respectively, during typical flood (top) and ebb (bottom) currents.

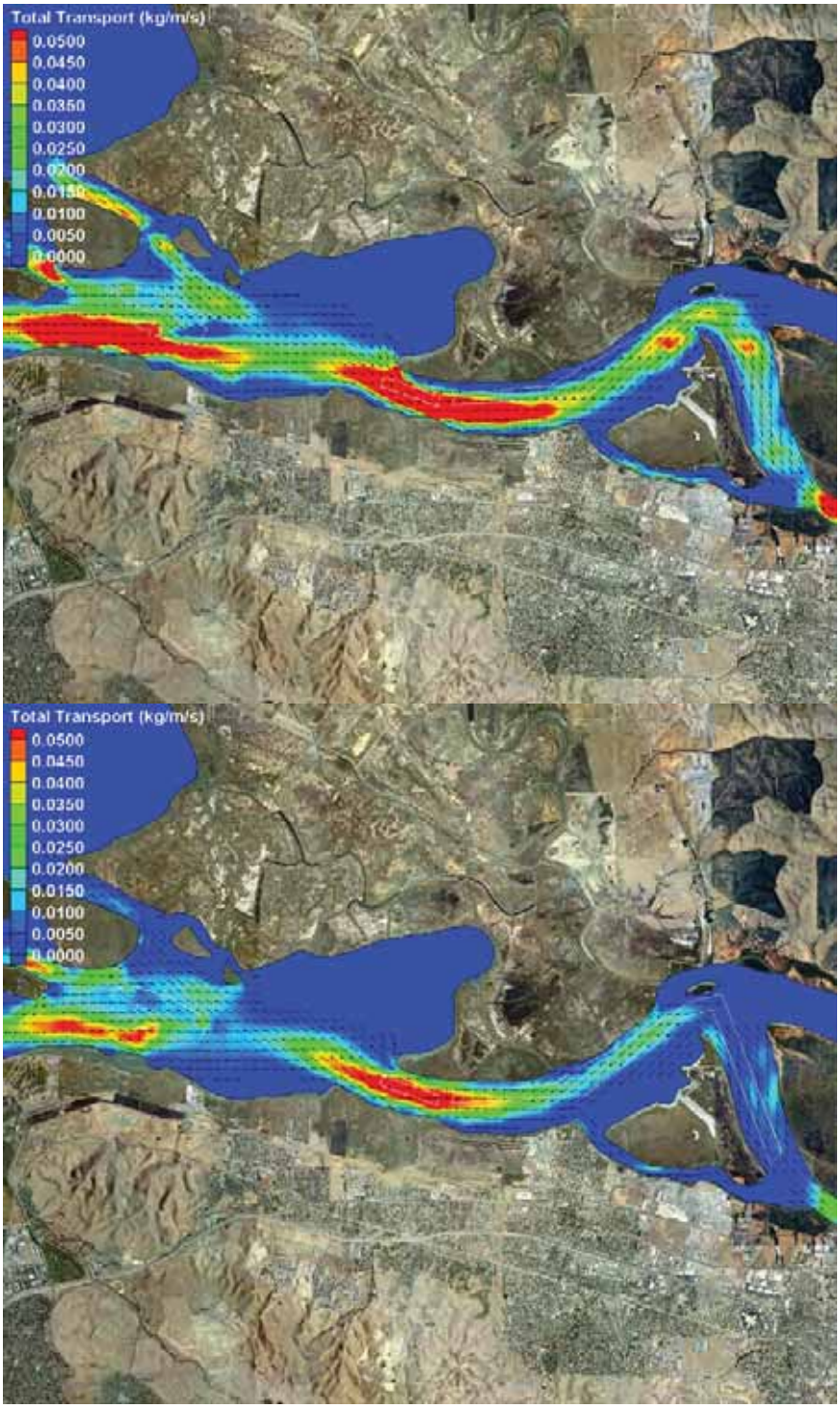

Figure 4-31. Total sediment transport in Suisun Bay for existing conditions during typical flood (top) and ebb (bottom) currents

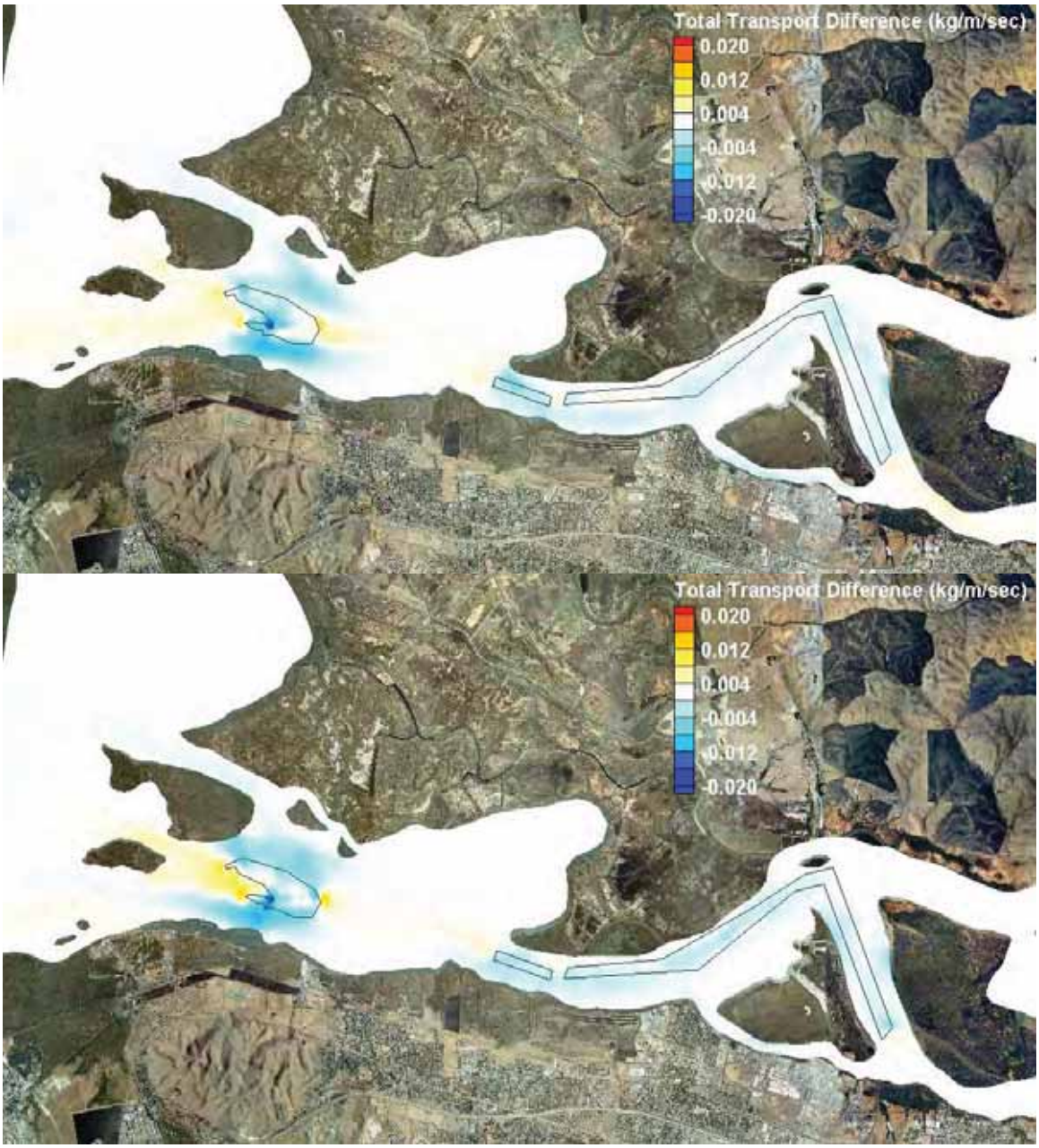

Figure 4-32. Scenario 1 changes in total transport in Suisun Bay for existing conditions during typical flood (top) and ebb (bottom) currents

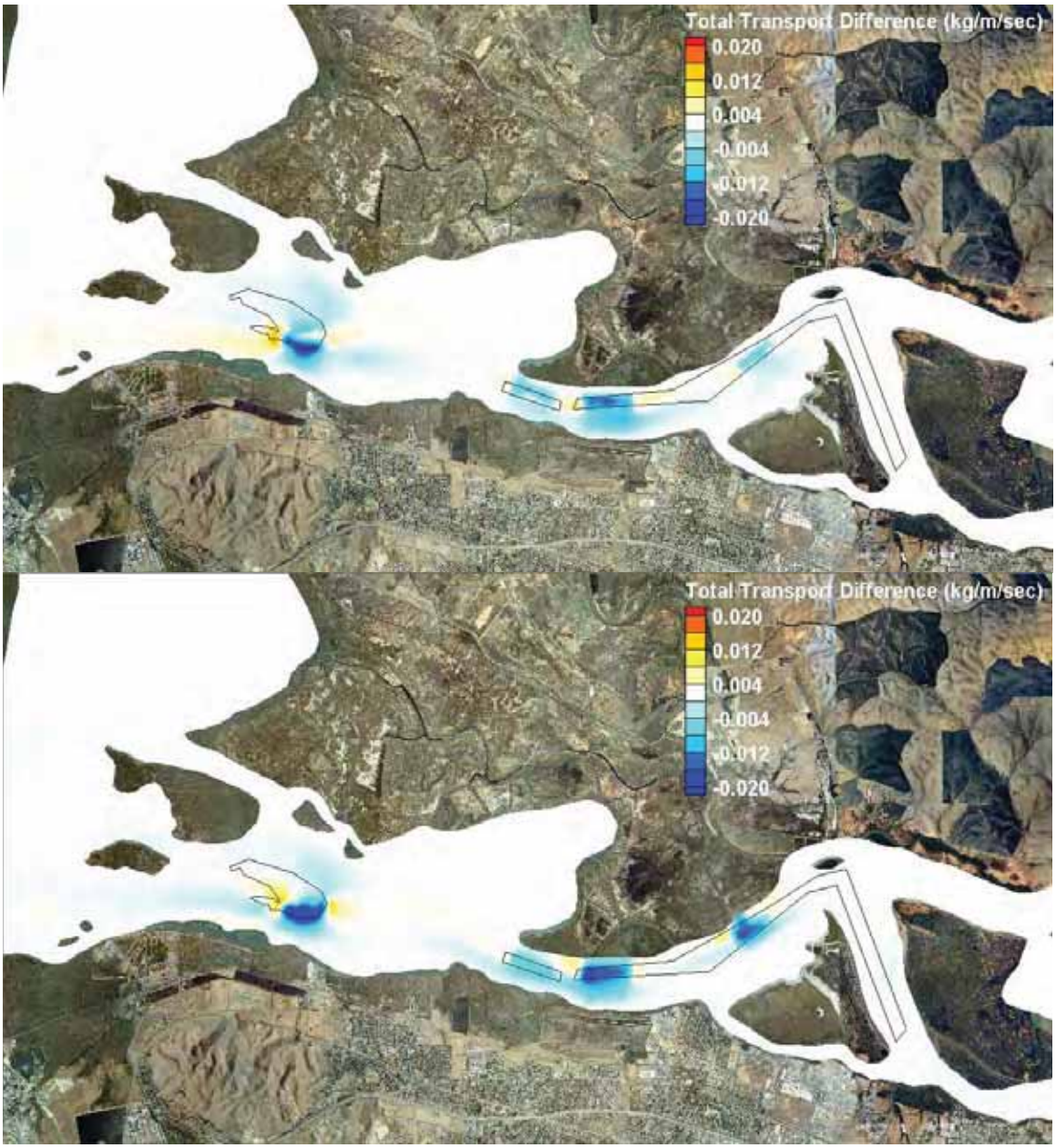

Figure 4-33. Scenario 2 changes in total transport in Suisun Bay for existing conditions during typical flood (top) and ebb (bottom) currents

A total sediment transport time series was also extracted at the points shown in Figure 4-11 for all scenarios. Figure 4-34 shows time histories of the total sediment transport rate (bedload plus suspended load) at the selected extraction points. Time histories at Points 24 and 29 in Suisun Bay show no measurable transport rate differences.

Figure 4-35 shows the net bedload sand transport from the one-year simulation for existing conditions. Figures 4-36 shows the differences in net bedload sand transport

relative to existing conditions for Scenarios 1 (top) and 2 (bottom). LAGRSED results indicate that full-year net bedload sand transport patterns are not likely to be affected by the mining activities except in the immediate vicinity of the mining areas. In areas farther away than approximately the size of the lease areas, the changes are less than 5%.

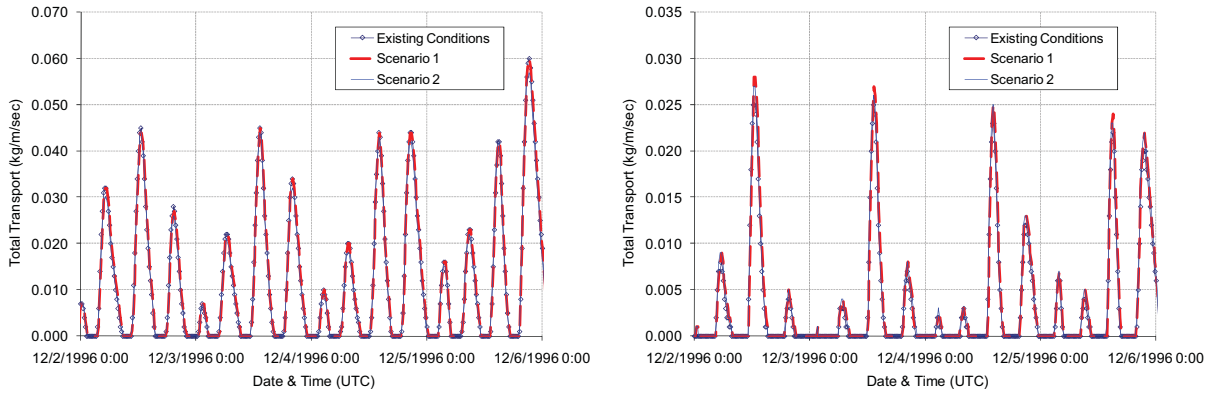

Figure 4-34. Time history of total transport at Points 24 (left) and 29 (right) in Suisun Bay

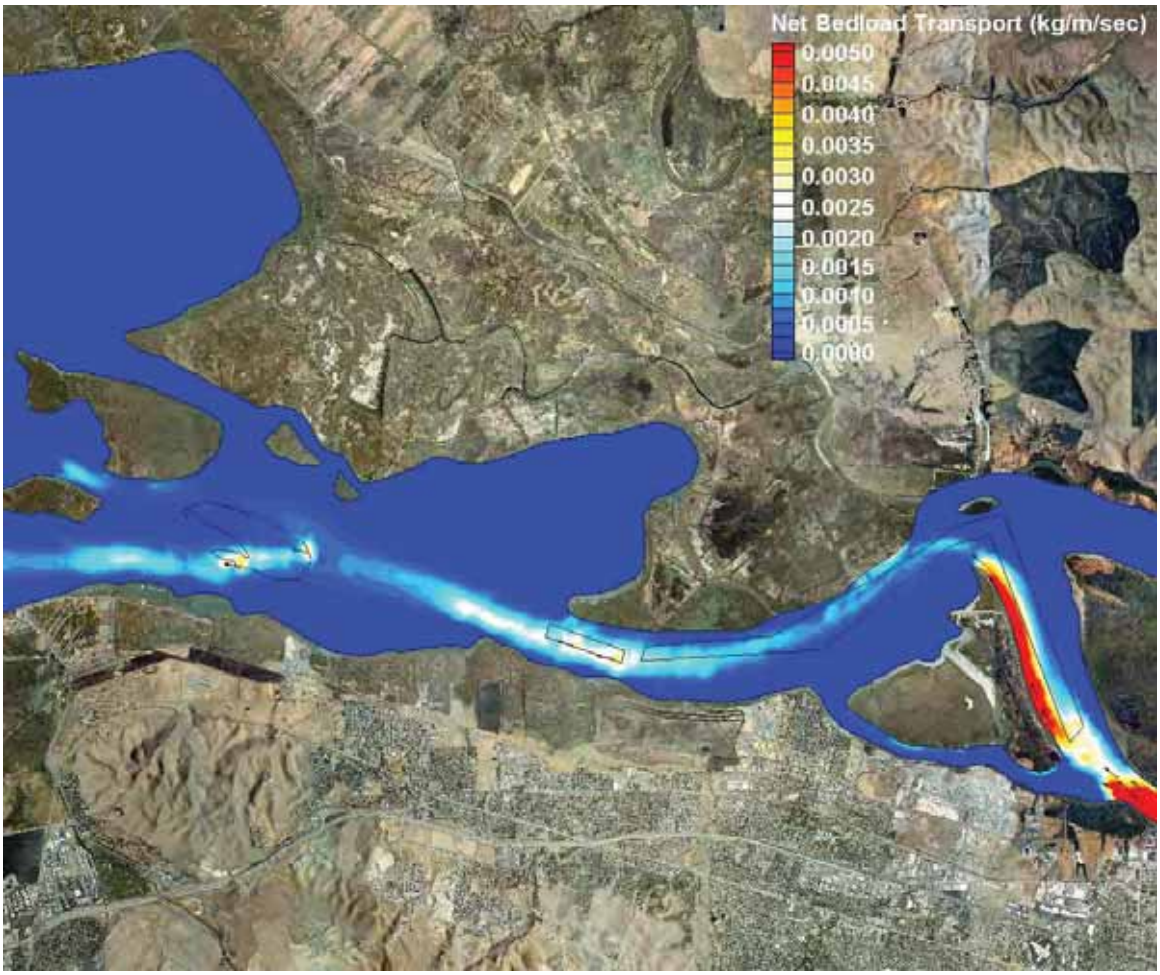

Figure 4-35. Net bedload transport in Suisun Bay for existing conditions

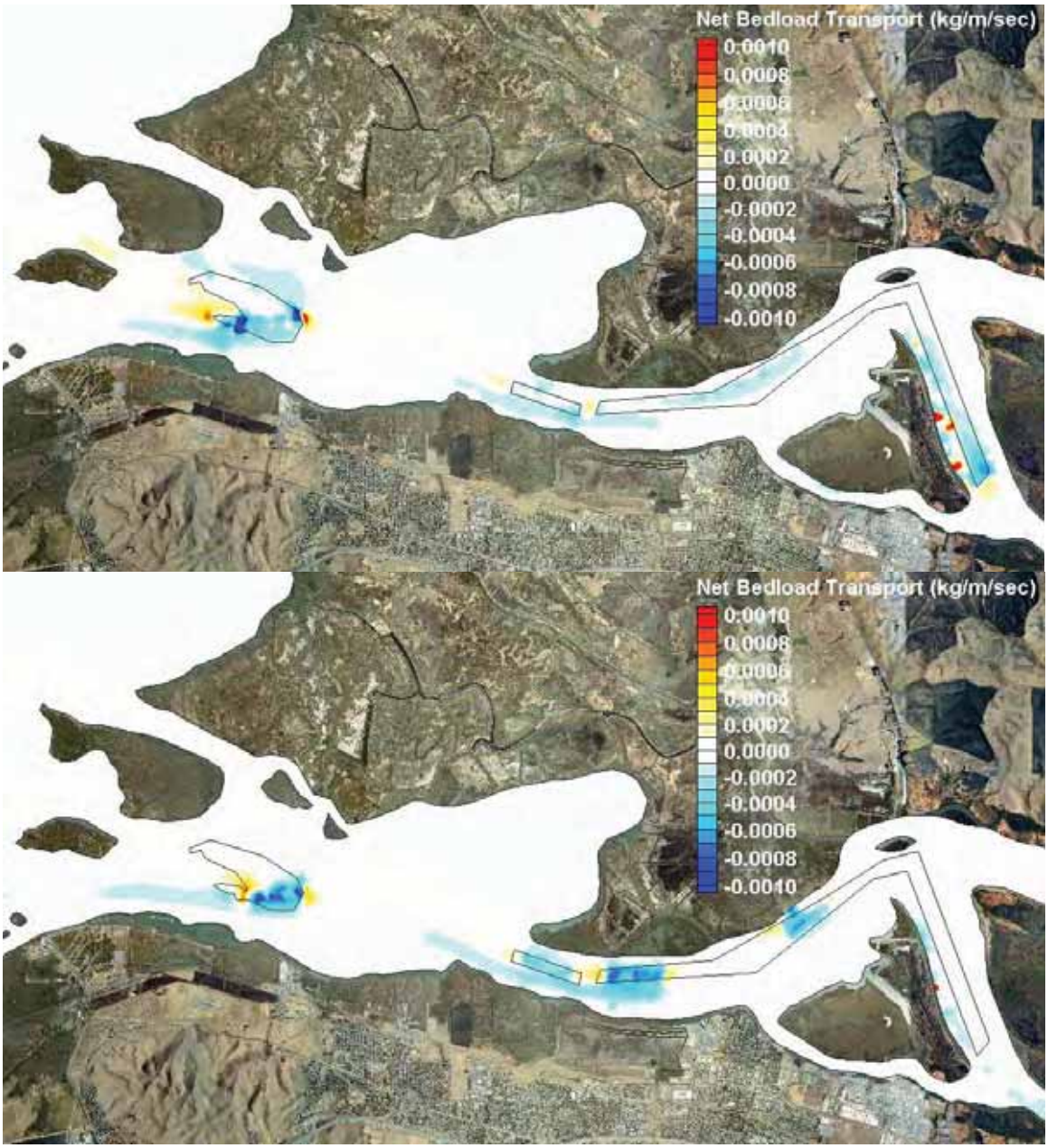

Figure 4-36. Scenario 1 (top) and Scenario 2 (bottom) changes in net bedload transport in Suisun Bay

4.2.7. Changes to Bottom Morphology due to Sand Mining

The LAGRSED model was used to predict bed changes occurring after the full one-year transport simulation using hydrologic/tide data from December 1996 to December 1997 and 2008 bathymetry conditions. Quantitative bed changes from the existing conditions simulation were not used in the analysis because hydrologic and tide data from the 1990s were used in combination with 2008 bathymetry, and many assumptions were required in development of the bottom sand distribution. It should

be noted that no effort has been made to match observed bed changes with the predicted bed changes.

Figure 4-37 shows the predicted one-year sand bed changes for Central Bay (top) and Suisun Bay (bottom) for existing conditions. Potential morphological impacts of sand mining (sand bed changes) were evaluated only using the relative bed changes; specifically, only the differences in bed change between existing and after-mining conditions were evaluated.

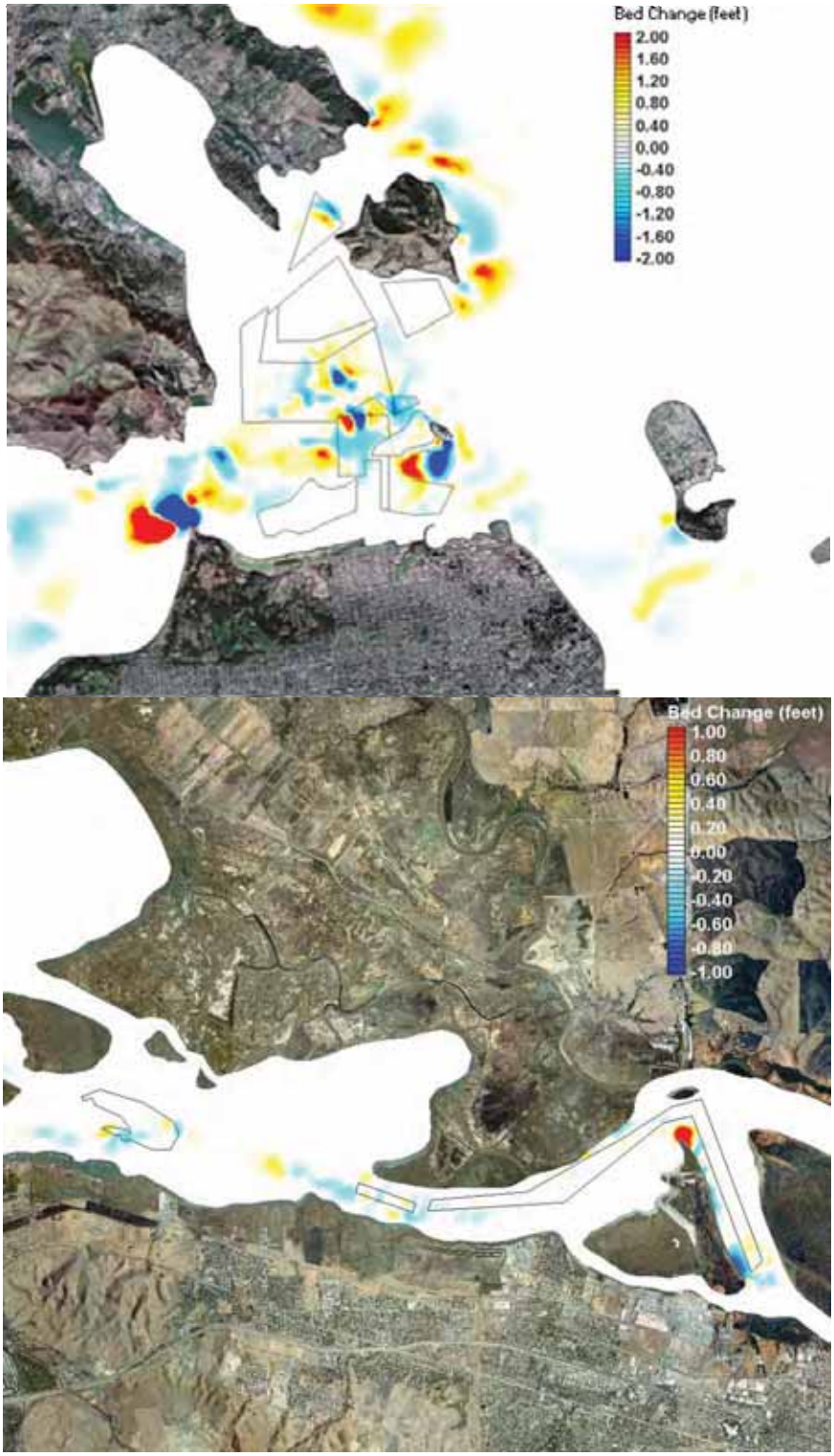

Figure 4-37. One-year existing conditions sand bed changes for Central Bay (top) and Suisun Bay (bottom)

Figure 4-38 shows the relative sand bed changes caused by Scenario 1 (top) and Scenario 2 (bottom) for Central Bay. The relative sand bed changes caused by both scenarios are only measurable within the immediate vicinity of the lease areas.

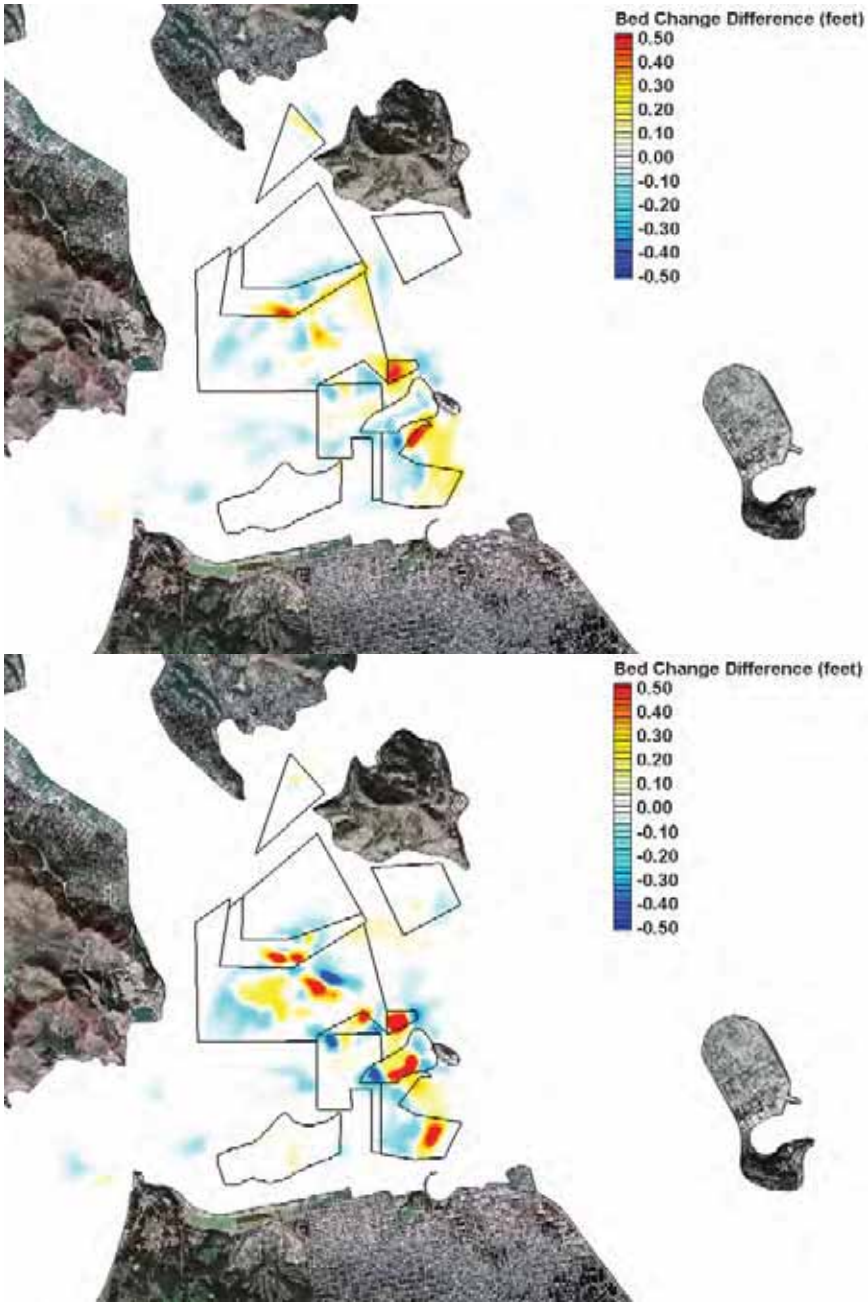

Figure 4-38. One-year sand bed change differences between Scenario 1 and existing conditions (top) and Scenario 2 and existing conditions (bottom) for Central Bay

Figure 4-39 shows the relative sand bed changes caused by Scenario 1 (top) and Scenario 2 (bottom) for Suisun Bay. The relative sand bed changes caused by both scenarios are only measurable within the immediate vicinity of the lease areas.

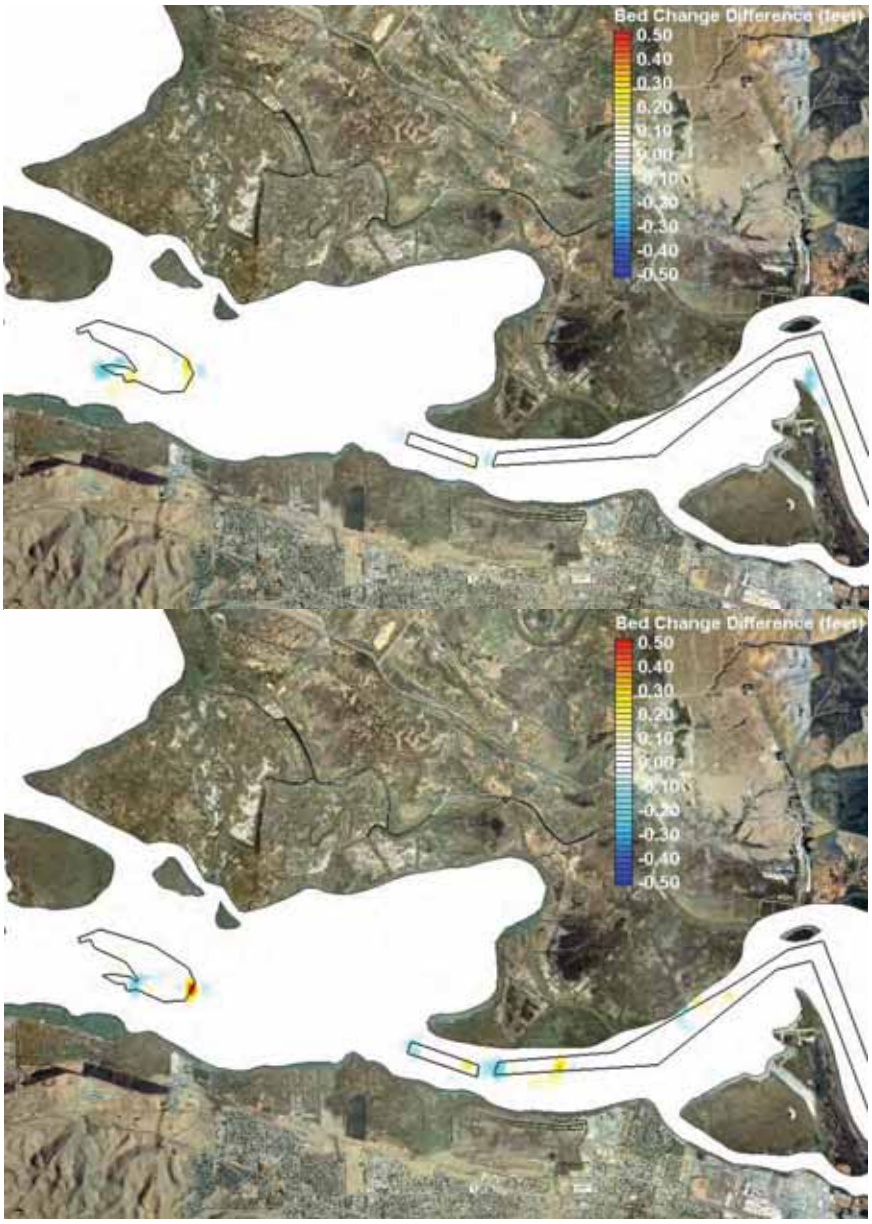

Figure 4-39. One-year sand bed change differences between Scenario 1 and existing conditions (top) and Scenario 2 and existing conditions (bottom) for Suisun Bay

Sediment transport modeling results from both short-term and full-year simulations indicate in a primarily qualitative sense that sand transport and bottom morphology conditions are not likely to be affected by the sand mining activities except in the immediate vicinity of the mining areas.

5. General Conclusions

Conclusions from the coastal engineering analysis are provided in two categories: 1) future sand resources in the mining areas; and 2) impacts to the bay circulation, water quality, and sediment transport/morphology.

5.1. Sand (Sediment) Resources in the Lease Areas

Analysis of bathymetry data and previous mining activities indicates the following with regard to future sand (sediment) resources likely to be present within the lease areas:

- Central Bay: after consideration of actual mining locations and other factors (such as expected bulking after mining), the reported mining volumes are approximately equal to the measured erosion from 1997-2008. This indicates that at least for the purposes of the proposed 10 years of additional mining, Central Bay mining resources are basically limited to sand already in place.
- Suisun Bay: sand mining resources appear to be limited in the deeper areas of Middle Ground, but have not been significantly reduced in West or East Suisun Associates. Sand appears to be primarily arriving in the mining areas under transport from the surrounding areas. The large surrounding areas of ongoing sand transport and lack of observed change in surrounding morphology during the study period indicate that deposition in the mining areas is likely to continue at similar rates.

5.2. Impacts to Bay Circulation, Water Quality and Sediment Transport/Morphology

Analysis of bathymetry data and previous mining activities indicates the following with regard to potential impacts of the proposed 10 years of future sand mining:

- Central Bay: since the vast majority of material removed from Central Bay is still absent from the lease areas and adjacent areas, in general sand impoundment in the mining area holes did not occur. Therefore, the mining areas are not likely to capture sand and induce deficits in other areas resulting in erosion. Analysis of the multibeam survey data indicates that observed bottom erosion migration is limited to the immediate vicinity of the mining areas.
- Suisun Bay: erosion and accretion patterns for most lease and control areas fluctuate with magnitudes larger than the mining volumes; therefore, potential impacts of mining are unclear using survey data alone. Erosion measured in all of the reference sites downstream of the Sacramento River following a large flood event indicates, however, that a steady stream of river sediment is not completely re-supplying the lease areas (hence, the supply is mostly local), and therefore mining impacts to nearby morphology should be re-evaluated following the next 10-year period.

Results of numerical modeling, including hydrodynamics, salinity, and sediment transport/morphology indicate the following with regard to potential impacts of the proposed 10 years of future sand mining:

- Hydrodynamics: Current velocity changes caused by sand mining Scenario 1 or 2 are limited to areas adjacent to the lease areas. Distances from the lease areas where changes in flows are measureable are typically similar to the sizes of the lease areas themselves.
- Salinity: Salinity changes were evaluated in a qualitative manner during short-term simulations by direct comparison of proposed and existing conditions. Some short-term increases in bottom salinity within the mining holes may occur relative to existing conditions. Results indicate that salinity changes outside the immediate vicinity of the lease areas are not likely to occur. Since salinity is directly driven by hydrodynamics, the changes cover roughly the same areas.
- Sediment Transport/Morphology: Sediment transport was evaluated in a qualitative manner through direct comparison of proposed and existing conditions using short-term and full-year simulations. Short-term simulations indicate that the changes in instantaneous transport patterns during both ebb and flood currents are limited to areas immediately adjacent to the lease areas. Full-year simulations indicate that the changes in net transport patterns are also limited to areas immediately adjacent to the lease areas. In addition, comparison of bed changes between existing and after-mining conditions indicates that no morphological impacts (erosion or accretion) are likely outside the immediate vicinity of the mining areas.

6. References

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APPENDIX A

Representative Project Hydrographic Survey Data Sets

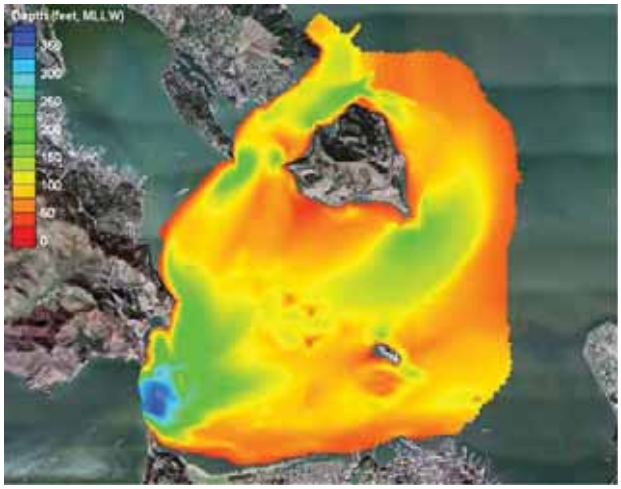

Figure A-1. 2008 USGS multi-beam bathymetry in Central Bay

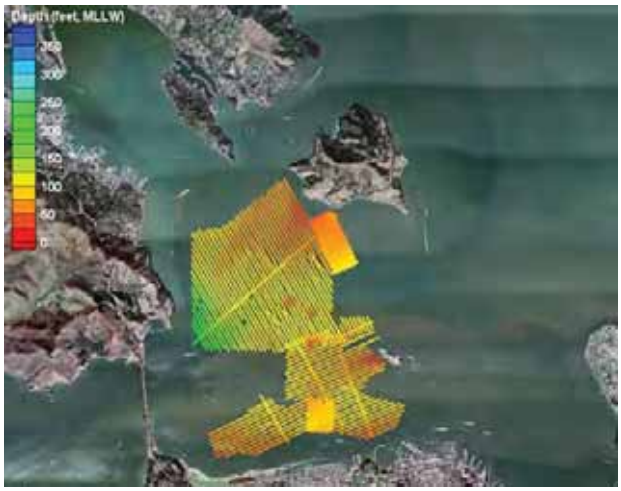

Figure A-2. 2007 E-Trac single-beam bathymetry in Central Bay

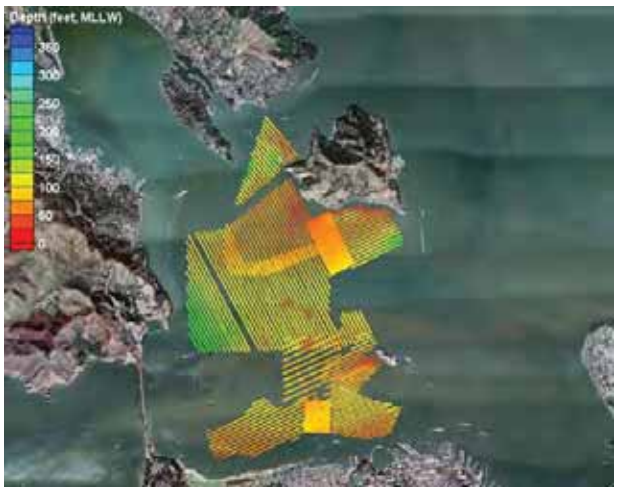

Figure A-3. 2005 PLS single-beam bathymetry in Central Bay

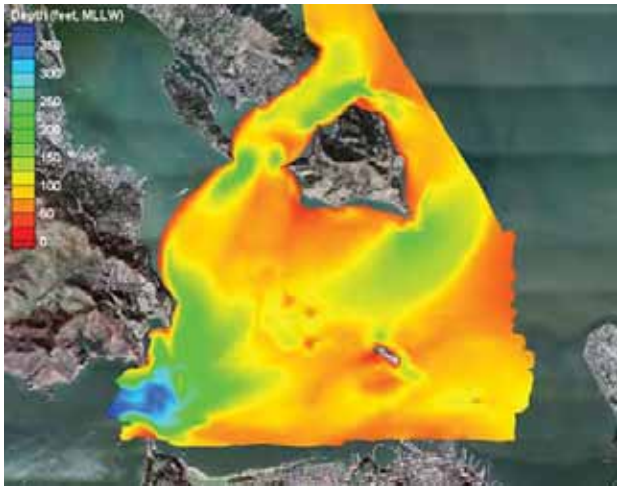

Figure A-4. 1997 USGS single-beam bathymetry in Central Bay

Figure A-5. 2008 USGS multi-beam bathymetry in Suisun Bay

Figure A-6. 2007 E-Trac single-beam bathymetry in Suisun Bay

Figure A-7. 2005 PLS single-beam bathymetry in Suisun Bay

APPENDIX B

Volumes of Available Sediment above -90 ft MLLW and below -3 ft (MLLW) from PLS Surveys for Lease Areas and Control Sites of Central Bay

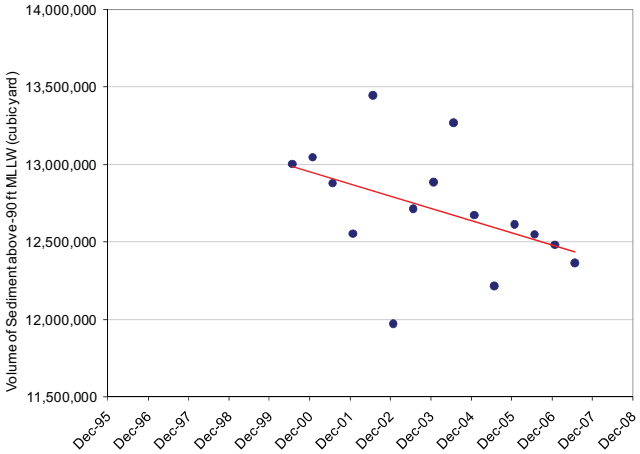

Figure B-1. Volume of available sediment above -90ft MLLW and below -3ft MLLW for Lease Area 709 South

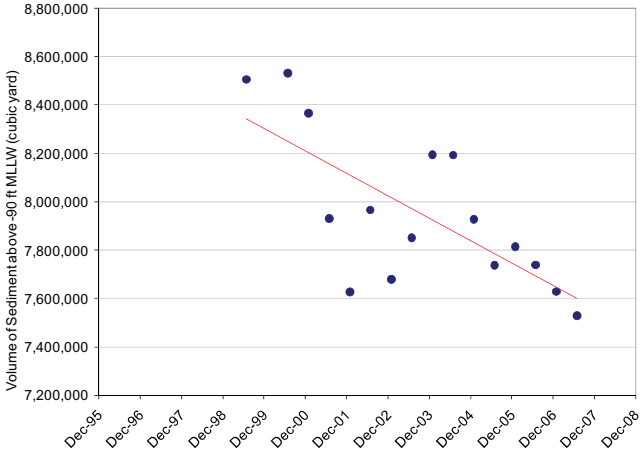

Figure B-2. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 5871

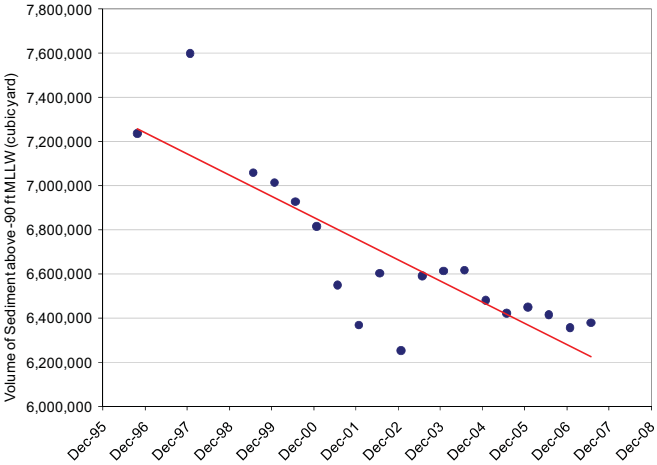

Figure B-3. Volume of Available Sediment above -90ft MLLW and below -3ft MLLW for Lease Area 709 East

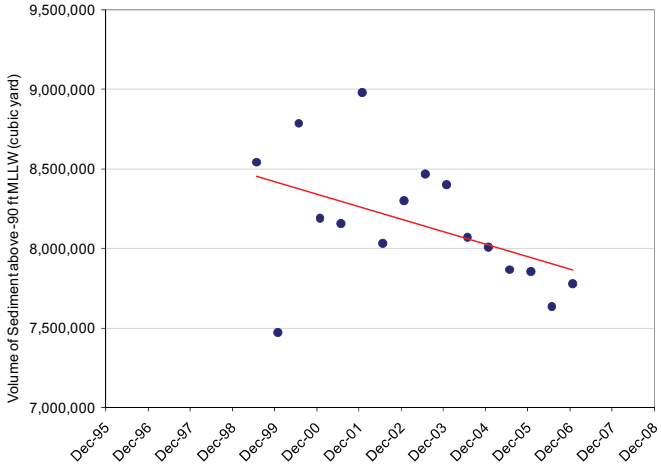

Figure B-4. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 7780 South

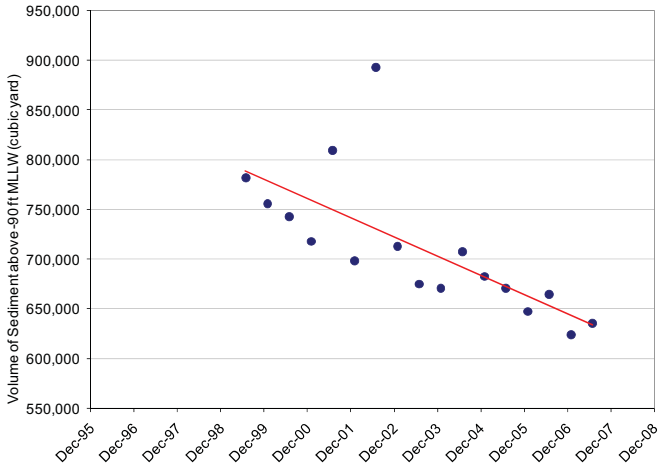

Figure B-5. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 7780 North

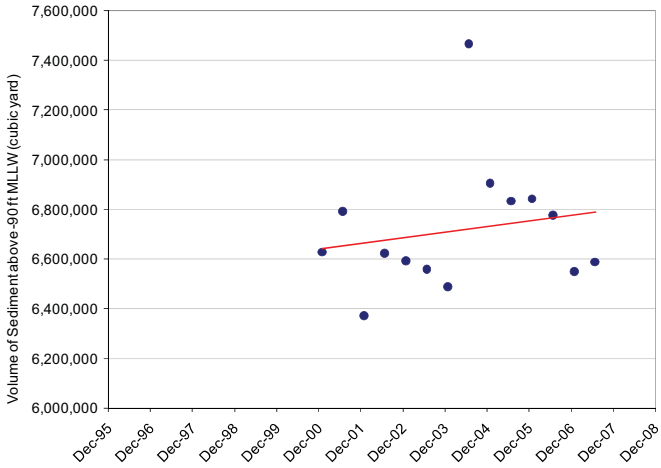

Figure B-6. Volume available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 7779 West

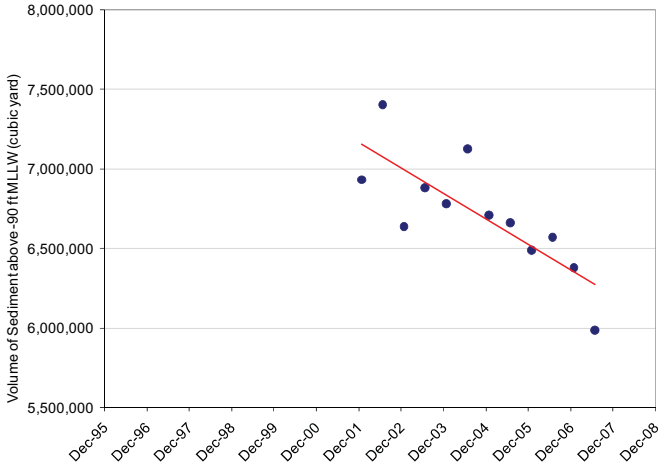

Figure B-7. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 2036

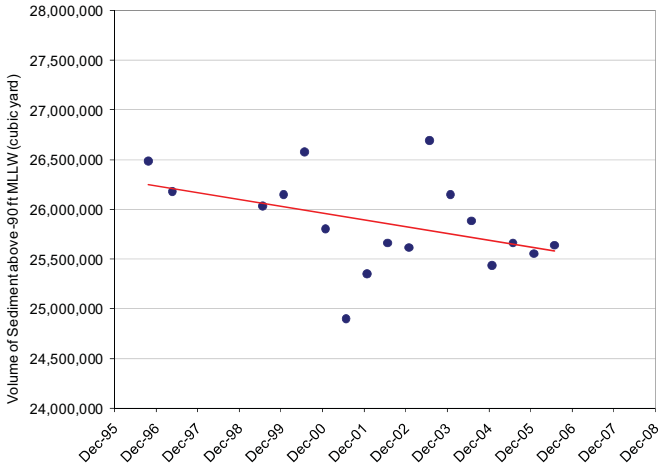

Figure B-8. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 709 North

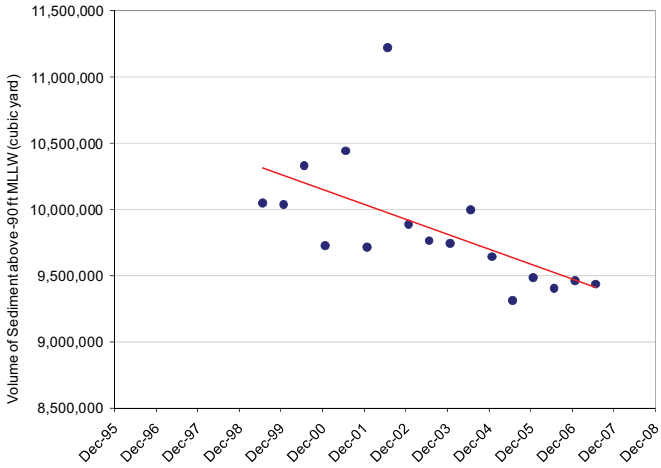

Figure B-9. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area 7779 East

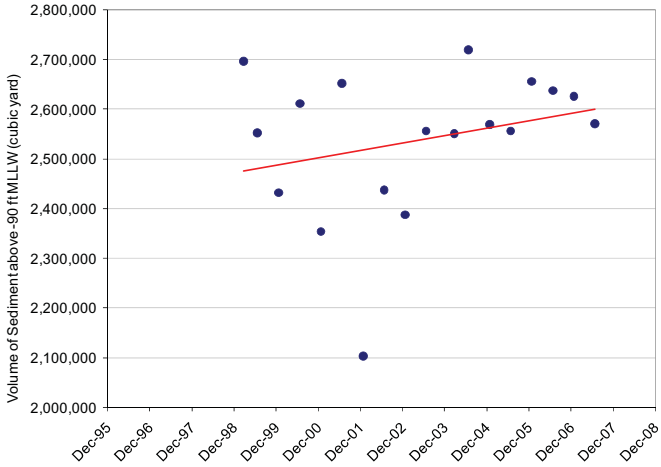

Figure B-10. Volume of available sediment above -90ft MLLW and below -3ft MLLW for Lease Area 7779 North

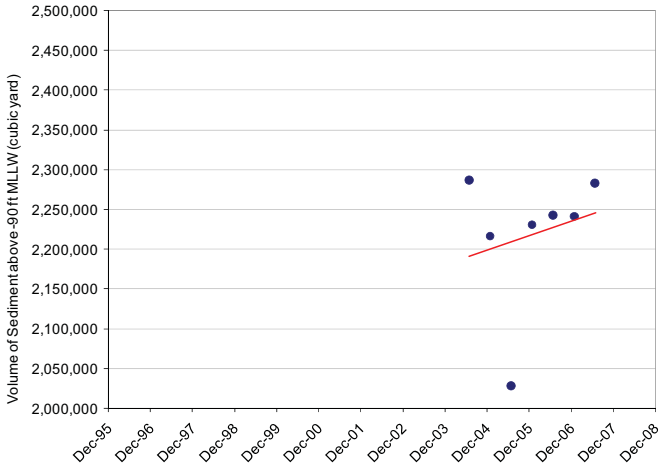

Figure B-11. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site North

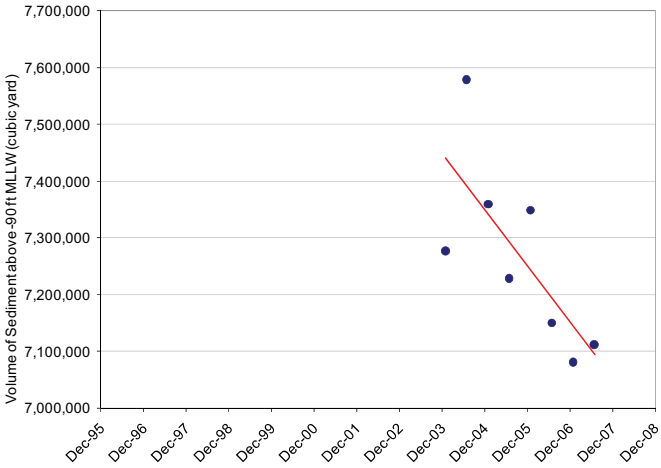

Figure B-12. Volume of Available Sediment above -90 ft MLLW and below -3 ft MLLW for Control Site South

APPENDIX C

Volume of Available Sediment above -90 ft MLLW and below -3 ft MLLW from PLS Surveys for Lease Areas and Control Sites of Suisun Bay

Notes:
Vertical scales of volume plots vary.
Trendlines represent unmodified linear fit.

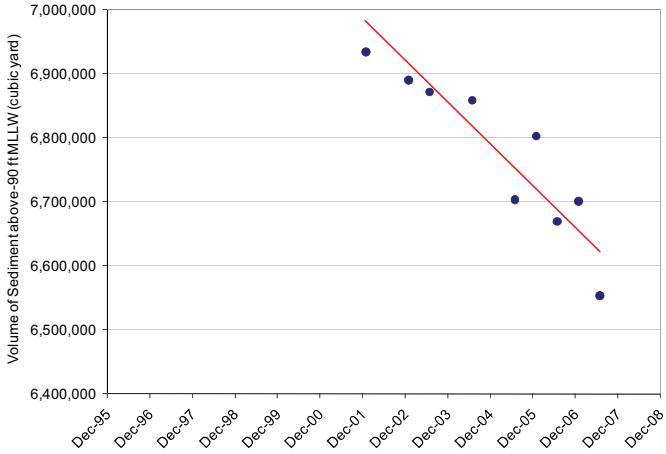

Figure C-1. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area Middle Ground

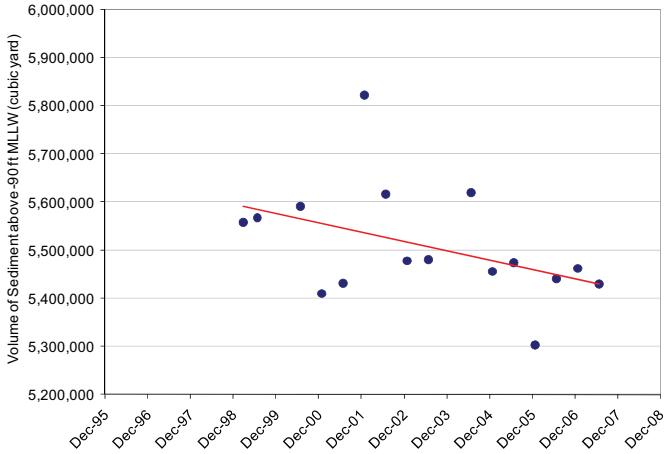

Figure C-2. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area West Suisun Associates

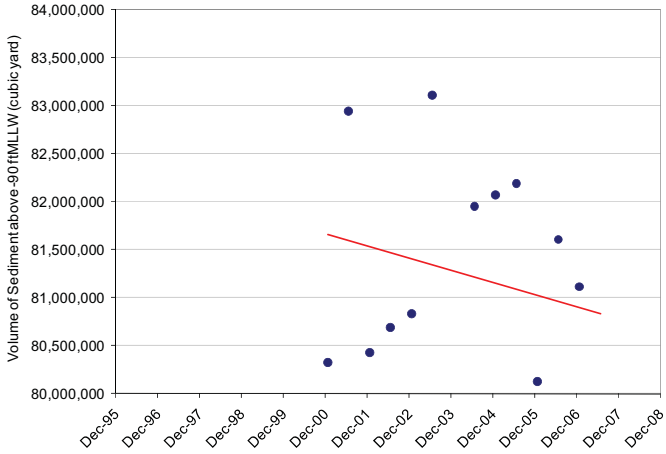

Figure C-3. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Lease Area East Suisun Associates

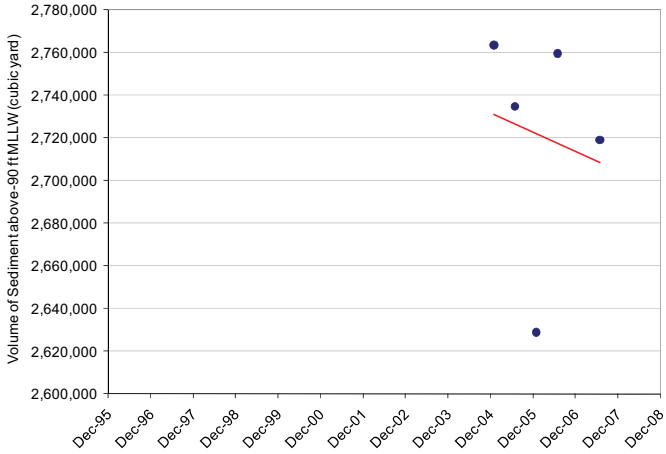

Figure C-4. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 1

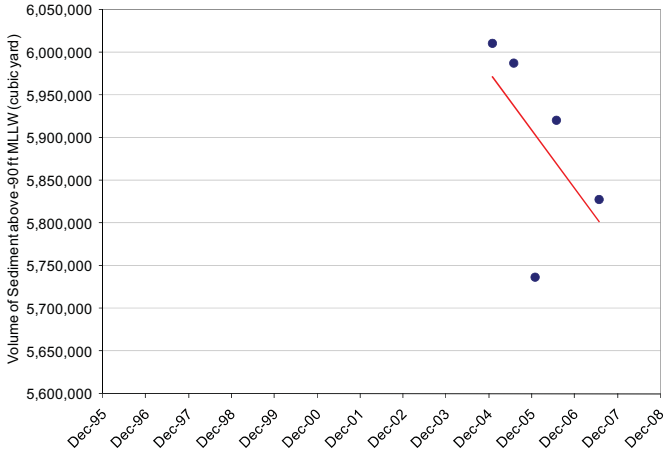

Figure C-5. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 2

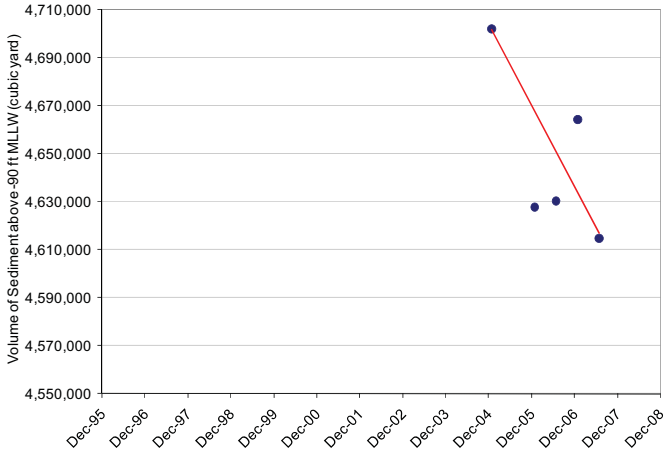

Figure C-6. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 3

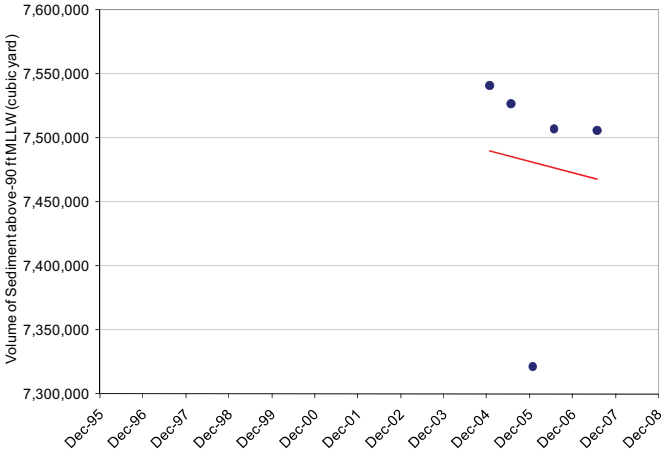

Figure C-7. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 4

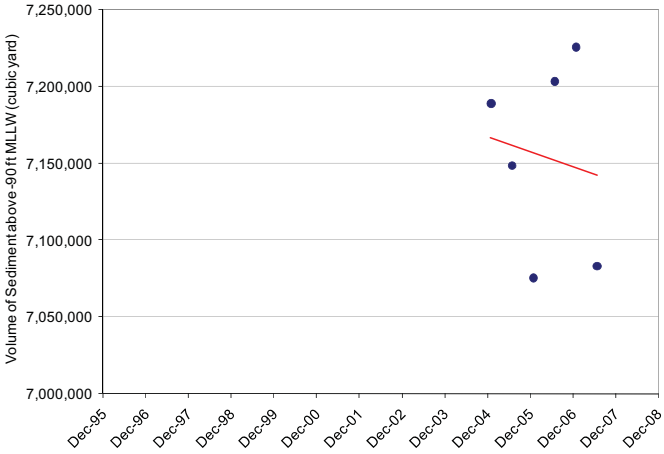

Figure C-8. Volume of available sediment above -90 ft MLLW and below -3 ft MLLW for Control Site 5

APPENDIX D

Numerical Model Development and Verification

D1. Comparison of Results from Numerical Models

Circulation in the Bay is controlled largely by tidal currents and river currents. Changes in circulation are the most important potential impact because circulation in the Bay controls salinity and water quality, as well as sediment transport and bottom morphology in areas outside wave influence. Therefore, analysis of Bay circulation was performed and analyzed with four widely respected numerical modeling tools:

- SELFE (Zhang *et al.*, 2005)
- FVCOM (Chen *et al.*, 2006)
- ADCIRC (Luettich *et al.*, 1992)
- MORPHO-UN (Kivva *et al.*, 2007)

Efforts have been made to use modeling parameters and input data that are as consistent as possible between the modeling tools; however, owing to their fundamentally different theoretical bases and numerical approaches some differences should be expected. Figure D-1 shows velocities computed by SELFE, FVCOM, ADCIRC and MORPHO-UNS during typical flood currents near the Central Bay lease areas. Figure D-2 shows velocities computed by the models during typical ebb currents.

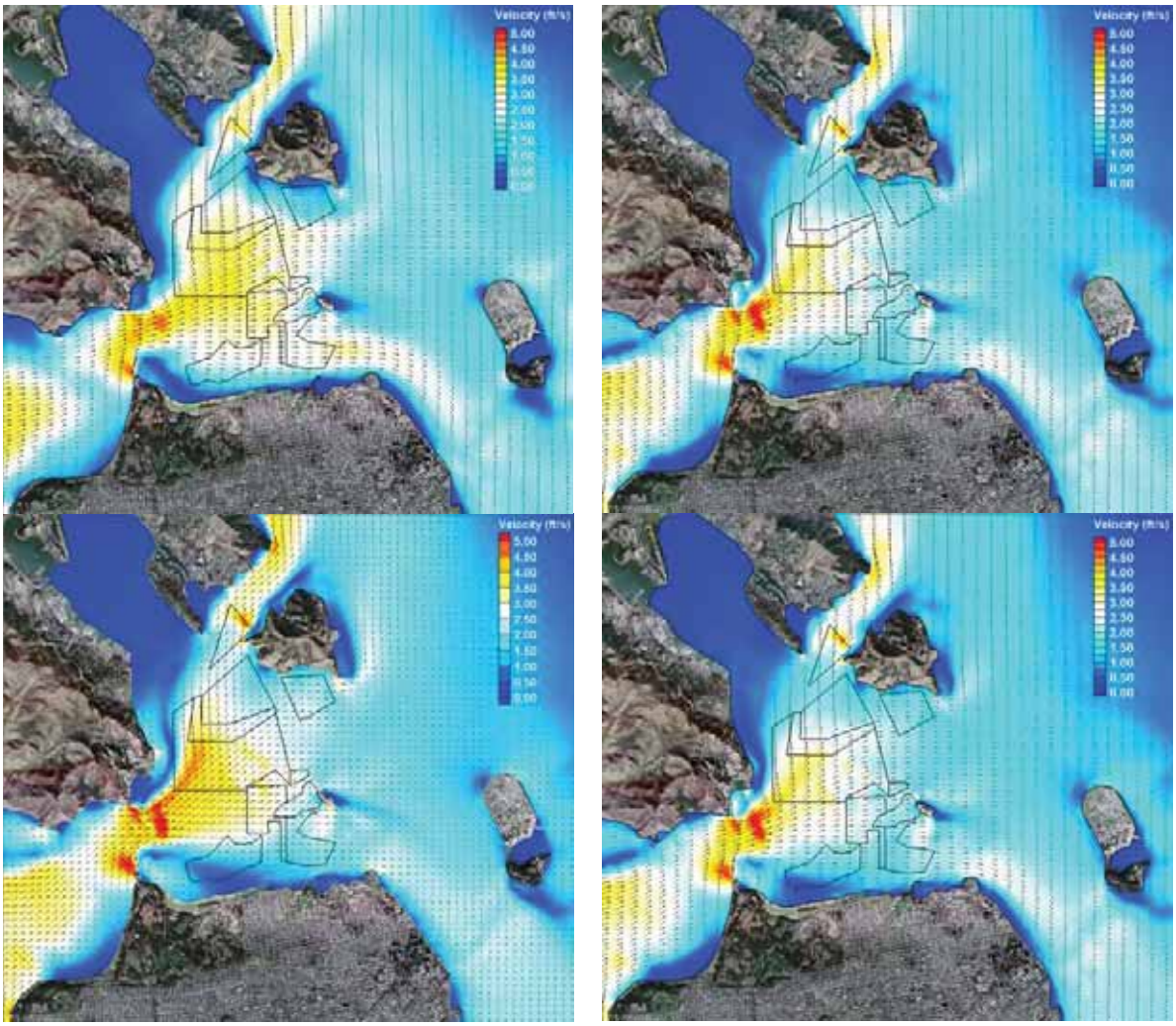

Figure D-1. Typical flood current velocities in Central Bay for SELFE (top left), FVCOM (top right), ADCIRC (bottom left) and MORPHO-UNS (bottom right). SELFE and FVCOM velocities taken at mid-depth, ADCIRC and MORPHO-UNS velocities are depth-averages

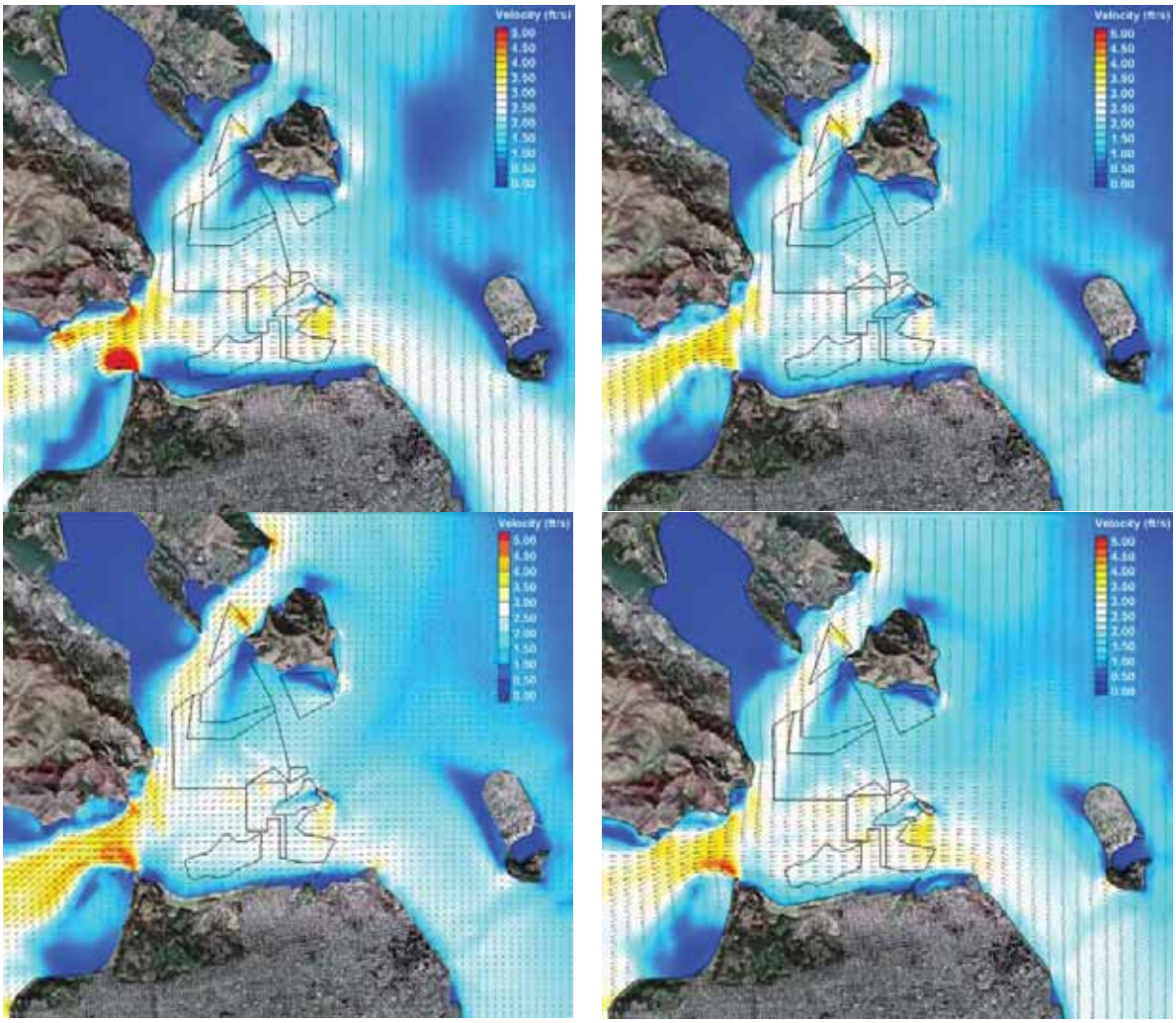

Figure D-2. Typical ebb current velocities in Central Bay for SELFE (top left), FVCOM (top right), ADCIRC (bottom left) and MORPHO-UNS (bottom right). SELFE and FVCOM velocities taken at mid-depth, ADCIRC and MORPHO-UNS velocities are depth-averages

Figures D-3 and D-4 shows the locations where time series of velocities were extracted from the results of all four modeling codes in Central Bay and Suisun Bay, respectively. Figure D-5 shows time histories of mid-depth velocities (for the 3D models) and depth-averaged velocities for the 2D models at Central Bay extraction points 4 (left) and 10 (right) using hydrologic and tide data from early December 1996. The comparison of the four modeling tools indicates that the models provide very similar results, particularly at Point 4 where stronger flows are present. At Point 10, the comparison is reasonable, with SELFE providing the largest current velocities.

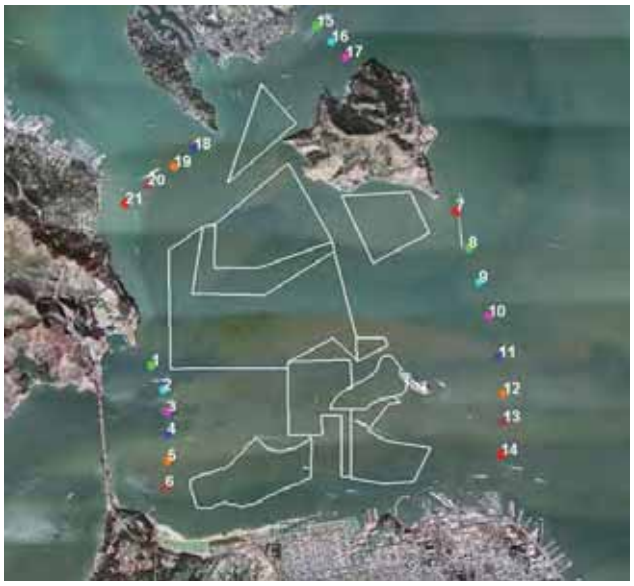

Figure D-3. Locations of time history extraction in Central Bay

Figure D-4. Locations of time history extraction in Suisun Bay

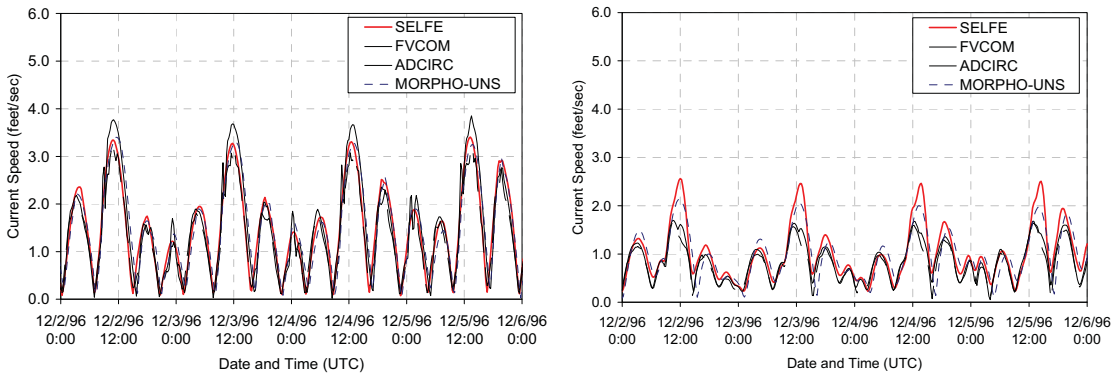

Figure D-5. Velocity time histories in Central Bay at Point 4 (left) and Point 10 (right)

Figure D-6 shows time histories of mid-depth velocities for the 3D models and depth-averaged velocities for the 2D models at Suisun Bay extraction points 24 (left) and 29 (right). The comparison of the four modeling tools indicates that the models provide similar results at both locations, including the phasing and magnitudes of the currents. At Point 24, SELFE often shows the largest current velocities, while at Point 29, ADCIRC shows the largest current velocities.

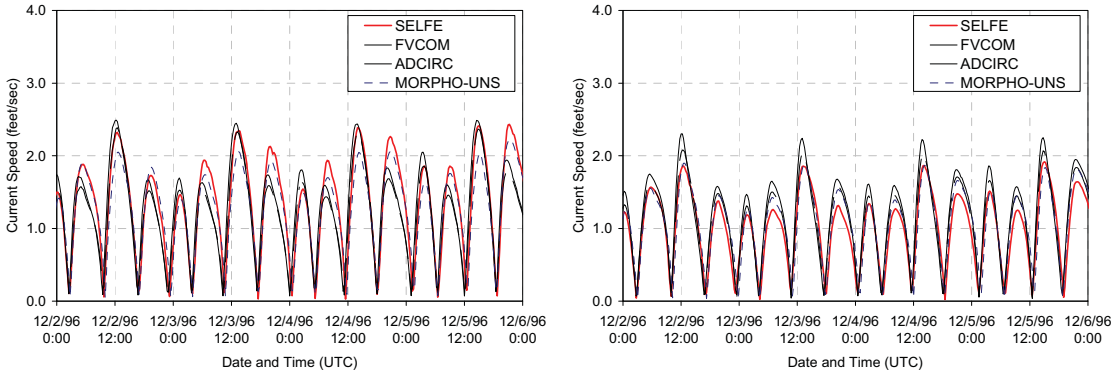

Figure D-6. Velocity time histories in Suisun Bay at Point 24 (left) and Point 29 (right)

The comparison of numerical modeling tools indicated that the four models tested here were likely to provide similar analysis results with regard to potential changes to San Francisco Bay hydrodynamics, and therefore similar conclusions regarding the potential impacts of sand mining. The SELFE model was utilized for all further analysis of potential sand mining impacts due to its good validation with measured currents, concurrent simulation of salinity, and ability to efficiently simulate a full-year period within the project timeframe.

D2. SELFE Model Bathymetry and Domain

Circulation caused by tidal fluctuations within San Francisco Bay is complex. Evaluation of tidal currents within most areas of San Francisco Bay requires modeling the propagation and transformation of tides under the Golden Gate Bridge and through the various channels and shallows of the Bay. The model bathymetry was compiled from various sources, including the following:

- United States Army Corps of Engineers, miscellaneous surveys 1980-present
- United States Geological Survey (USGS), miscellaneous surveys 1990-present
- Coast & Harbor Engineering, Inc. (2000, 2002)
- USGS Multi-beam (1997, 2004, 2008)

The bathymetry data for areas surrounding the lease areas were obtained from the 2008 USGS Multi-beam survey. Inclusion of some rivers entering the estuary, particularly the Petaluma and Napa Rivers, were shown to have a negligible effect on results near the lease areas, and hence these areas were not included in the model. However, the San Joaquin and Sacramento Rivers were added since they contribute the vast majority of discharge into the Bay system. Figure D-7 shows the hydrodynamic modeling domain (left) with bathymetry contours and finite element mesh (right).

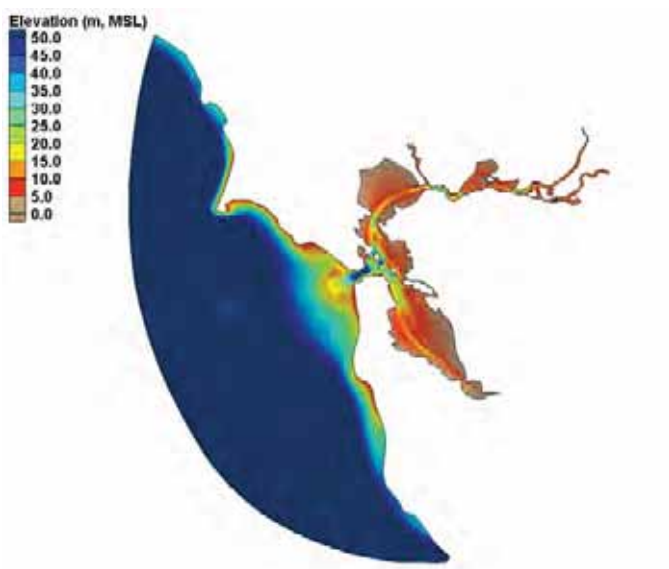

Figure D-7. Bay-wide modeling domain used for SELFE, FVCOM, ADCIRC and MORPHO-UNS simulations (areas inside the Bay shown)

D3. SELFE Model Verification

The bay-wide circulation model was validated using measured currents from the NOAA PORTS station previously in place at the Richmond-San Rafael Bridge. Therefore, only current velocities and water levels were validated for the purposes of the sand mining impact analysis.

Forcing of the San Francisco Bay model requires detailed tidal constituent data at each calculation node along the offshore boundary of the model. Tidal constituent data consists of unique amplitude and phase data for each tidal constituent at each offshore node. For the present analysis, these amplitude and phase data for the largest 13 tidal constituents were obtained from a worldwide database (Le Provost *et al.,* 1994).

Measured current data were available from an Acoustic Doppler Current Profiler (ADCP) deployed from 1999-2002 near the Richmond-San Rafael Bridge (I-580), located at 37°55'45.5"N, 122°25'30.0"W. The ADCP was deployed by NOAA under the PORTS real-time observation network (http://sfports.wr.usgs.gov/SFPORTS/). Predicted tide data were extracted from NOAA data for the Point San Pedro Station (NOAA Station ID 641), located at 37°59'40"N, 122°26'80"W.

The simulation period chosen for validation was a 14-day period beginning on December 18th, 1999 at 00:00 (UTC). No additional boundary conditions were prescribed for the validation period because river flows into the bay were low during this period, and therefore had a negligible effect on current velocities at the Richmond Station location. Modeling parameters such as drag coefficient (0.002) were not altered from previous San Francisco Bay model calibration and verification efforts.

Figure D-8 shows the winter measured and SELFE mid-depth current speeds at the Richmond Gauge, as well as the predicted (NOAA) and SELFE tidal fluctuations at the Point San Pedro Station. The velocities on ebb and flood tide and tidal fluctuations are well predicted by the SELFE model. The SELFE model developed for the project was therefore determined to be a reliable tool for analysis of project circulation, sediment transport, and water quality impacts of the proposed sand mining.

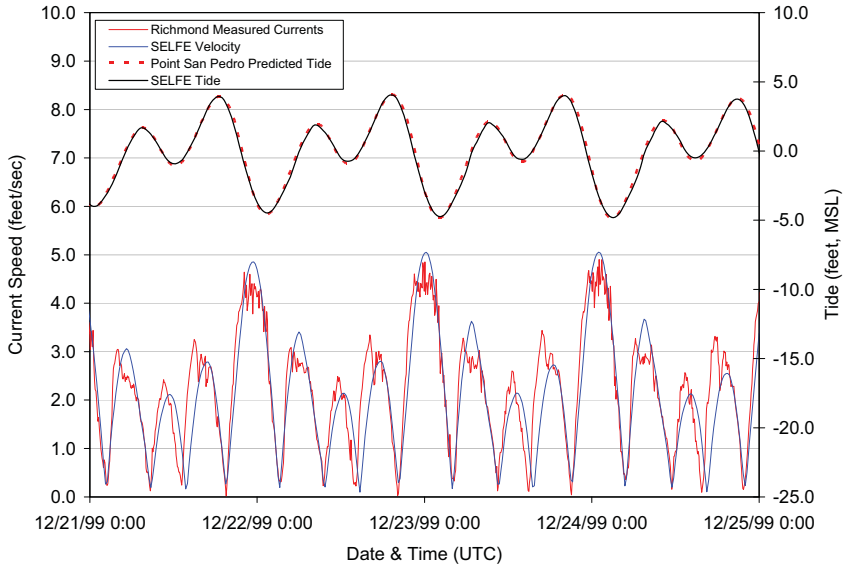

Figure D-8. Measured and predicted (SELFE) tides and currents at Richmond gauge and Point San Pedro gauge (NOAA)

D4. SELFE Model Boundary and Initial Conditions

Boundary conditions relevant to the analysis of sand mining impacts include river discharges (primarily from San Joaquin and Sacramento Rivers), tidal constituents at the Pacific Ocean boundary, and temperature/salinity values at the river/offshore boundaries. Initial conditions consisted of bay-wide temperature and salinity distributions. Temperature and salinity initial and boundary conditions were developed from measurements along a bay-wide longitudinal transect by United States Geological Survey (http://sfbay.wr.usgs.gov/access/wqdata/). Temperature and salinity conditions offshore were taken from concurrent measurements at the San Francisco Buoy by the National Data Buoy Center (Buoy #42068). Temperature and salinity at both the river and offshore boundaries were assumed to be constant during the simulation. Figure D-9 shows the measured salinity and temperature longitudinal transect taken by USGS that was used for modeling initial conditions.

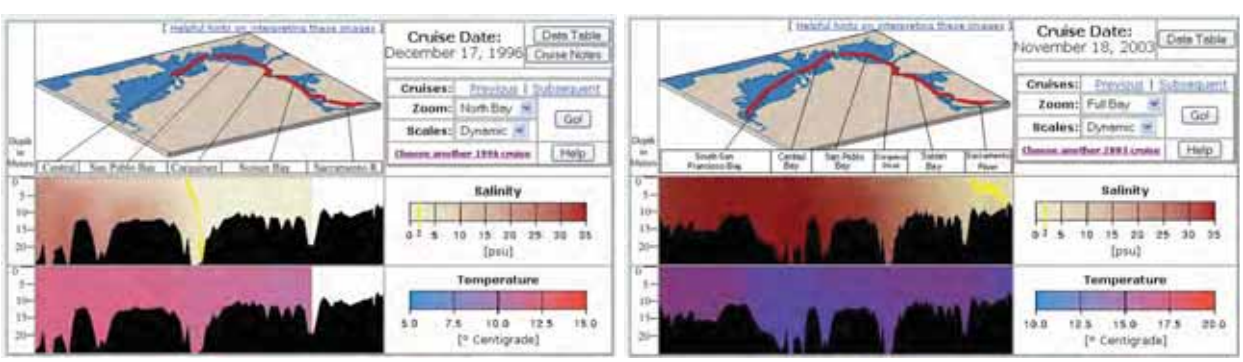

Figure D-9. Measured salinity and temperature used as initial conditions in the simulation; left, 1996 simulation; right, 2003 simulation (www.USGS.gov)

Tidal constituents were taken from the database of Le Provost as described in Section A.1 above. River discharges were taken from the DAYFLOW model (California Department of Water Resources 1978). Total discharge inputs were consolidated into the Sacramento and San Joaquin Rivers which were represented in the model.

D5. Sediment Transport Model Description

Sediment transport in the Bay-Delta estuary was simulated using hydrodynamic data from the 3D SELFE model as input into the LAGRSED model (Maderich *et al.*, 2004). The LAGRSED model is a 2D Lagrangian sediment transport model that was extended by incorporating bottom shear stresses directly from the 3D SELFE model results into calculations of transport. The LAGRSED model was chosen because it can simultaneously simulate multiple grain sizes and utilizes state-of-the-art formulations for transport under various flow conditions. Only sand known to exist in various locations around the Bay was simulated. Areas known to consist of largely Young Bay Mud or rock did not contribute sediment into the simulations but could be used by migrating sand. The LAGRSED model covered the same modeling domain extents as the 3D SELFE model.

D6. Sediment Transport Model Setup and Sediment Information

Multiple different types of boundary conditions were used as input into the LAGRSED model during initial testing, particularly near the river boundaries. Eventually, the boundaries were determined to be sufficiently far from the project site that bedload and suspended load transport develops inside the domain, and no sediment boundary conditions were required. The model was used to calculate transport and morphology for the full one-year simulation starting in December 1996. In order to construct the initial sediment transport modeling domain, numerous sources of sand grain sizes were collected and evaluated (Hanson Environmental 2004, Rubin et al 1979). Figure D-10 shows grain sizes reported in Rubin et al (1979) as an example.

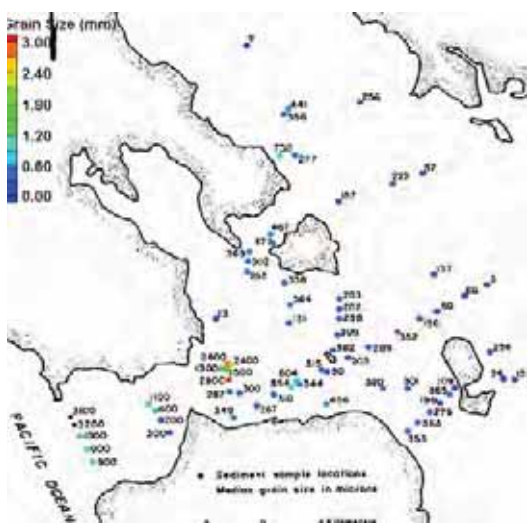

Figure D-10. Central Bay grain sizes (Source: Rubin et al 1979)

Based on evaluation of these data sources and digitization of sampled grain size plots from mining operations provided in Hanson Environmental (2004), CHE developed a bay-wide sediment grid that contains sand type zones in areas known to be sand resource areas. Each of these zones contains a certain gradation of sediment, developed as a set of thousands of individual particles whose sizes are set according to the specified gradation. Figure D-4 shows the sand type zones. Each gradation was assumed to consist of three sediment sizes, centered about the median diameters shown in Figure D-11.

It is immediately clear that significant differences exist in measured sediment sizes even in the same exact location, and even when samples are taken one after another in time. Therefore, it should be understood that the proposed sand distribution is intended to provide qualitative sediment transport information and reasonable predictions only for direct comparison between proposed mining scenarios and existing conditions.

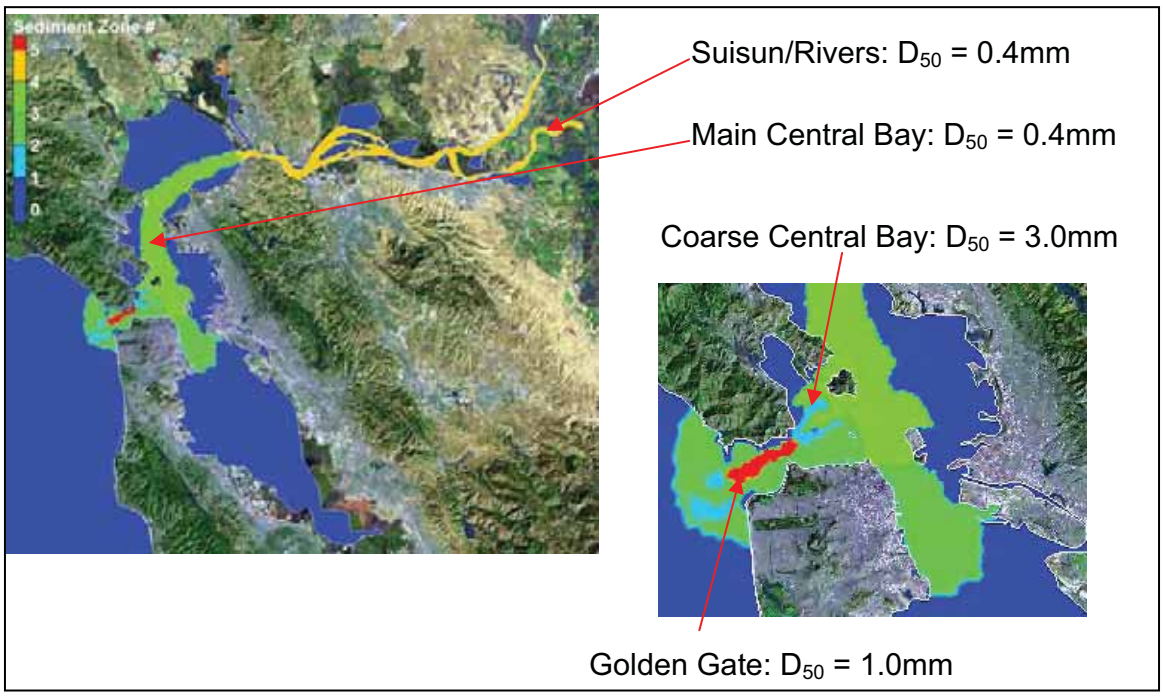

Figure D-11. Sand type zones defined in LAGRSED

D7. References

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