4. HISTORICAL CURRENT ANALYSIS

The goal of the historical current analysis was to quantify mean (depth-averaged) and peak near-bottom currents at each disposal site for use in sediment transport models. Historical current measurements from representative data sets were identified to characterize the current regime at each disposal site. Near-bottom flows were separated by numerical analysis to quantify maximum current responses within different frequency bands.

4.1. Description of Data Sets

Current velocity measurements have been collected at several locations in Long Island Sound over the last 15 years. Available historical current data sets were identified and gathered during previous work in support of the EIS (ENSR, 2001). There were essentially four data sets to consider in evaluating the variability of currents in the surrounding regions of the four identified disposal sites, Western and Central Long Island Sound:

- ENSR conducted field measurements of currents at four locations near WLIS and CLIS for a two-month period in 2001.
- City of New York sponsored collection of current measurements at a single mooring near WLIS for approximately 10 months in 1994 and 1995.
- National Ocean Service (NOS) measured currents at three locations in western and central Long Island Sound for two to three months in 1988 and 1990.
- State University of New York (SUNY) at Stony Brook collected current data along three transects in western and central Long Island Sound for approximately one month time periods in 1988.

From March to May 2001, ENSR collected current measurements at four locations in the vicinity of the four disposal sites (STN01 through STN04 on Figure 2). Full column velocity measurements were collected by Acoustic Doppler Current Profiliers (ADCPs) in 6.5 ft (2 m) bins, starting approximately 13 ft above bottom, and near-bottom measurements were collected by Nortek Aquadopp single point current meters at approximately 3.3 ft above bottom. STN01 was located within the WLIS disposal site at 112 ft water depth. STN04 was deployed within the CLIS disposal site at 69 ft water depth. Two additional moorings were located within the vicinity of the disposal sites; STN02 was located at 75 ft depth, approximately 2 miles northwest of the WLIS disposal site and STN03 was deployed approximately 4 miles south of the CLIS disposal site at 95 ft. Current measurements were collected by ENSR for approximately 2 months and are of good quality. The records were sufficient in length to analyze flow variability on time scales of interest. Measurements collected at STN01, STN02, and STN04 were the primary data sets evaluated to quantify the variability of currents at the four disposal sites.

Mooring H was deployed for the City of New York in Western Long Island Sound (Figure 2). Currents were measured by single point current meters at 9.8 ft and 82 ft water depth. Data were collected for approximately 10 months from November 1994 to September 1995 with a one-month gap in June. Mooring H was deployed in 95 ft water depth, approximately 2.8 mi Northeast of WLIS and 15.5 mi Southwest of Bridgeport disposal site. The near-bottom measurements at Mooring H were collected 13 feet above bottom, and were likely to be greater in magnitude than currents within the bottom boundary layer. However, the longer record of current measurements collected at Mooring H was utilized to gain a more complete understanding of lower-frequency near-bottom currents at WLIS and Bridgeport disposal sites.

Three current data sets collected by NOS (NOS7, NOS8, and NOS9) were evaluated (Figure 3). ADCP were deployed at each location to collect velocity measurements throughout the water column. All three moorings were located within the axial depression of the Long Island Sound at water depths of 130 to 160 feet. NOS7 and NOS8 were placed in close proximity to ridges formed by irregularly shaped topographic features running Northwest to Southeast; respectively, Norwalk shoals and Stratford shoals. The NOS moorings were located in greater water depths than the disposal site locations and amongst irregular bathymetric features not found within the disposal sites. Therefore, NOS data were not included in the numerical analysis of currents at the disposal sites. Brief analysis of these data sets confirmed the measurements as inconsistent with measurements collected within the WLIS and CLIS disposal sites.

SUNY Stony Brook collected current measurements at four mooring locations along three north to south transects across Western and Central Long Island Sound (SUNY2, SUNY3, and SUNY4 on Figure 3). Current data were collected with single point current meters at approximately three locations in the water column; near-bottom measurements were typically 10 ft off the bottom. The data records were typically less than a month in length and of poor quality due to biofouling (Vieira, 2000). Moorings on SUNY transect 2 were positioned across Norwalk shoals and SUNY transect 3 was positioned adjacent to Stratford Shoals. The SUNY data sets were not included in the calculation of currents due to poor data quality, short duration of measurements, and location of instruments near the shoals.

4.2. Numerical Analysis

Currents observed within LIS represent the cumulative effects of many physical processes of different time scales and amplitudes. Numerical procedures, described in this section, were used to quantify current responses within different frequency bands, and identify possible forcing mechanisms at these frequencies. The goal of this numerical analysis was to separate the observations into wind-dependent and wind-independent components.

Separation of the total signal into specific components was performed using tidal harmonic decomposition as well as the application of a series of low- and high-pass filters. Numerical analysis produces subsets of individual time series that represent distinct physical processes. These separated signals are not completely distinct; but, can be considered in two parts, wind independent and wind dependent.

Wind-Independent

- Tidal currents (diurnal and semi-diurnal constituents)
- Low-frequency subtidal currents (periods > 8 days)

Wind-Dependent

- High frequency noise (with periods less than 33 hours)
- Subtidal currents (with periods of 1 to 8 days)

The first step in the separation analysis is to remove tidal currents from the raw data using harmonic analysis. The result was a separation of the total observed currents into two time series: predicted tides based on a reconstruction of individual tidal components (the summation of 21 sinusoidal functions), and a second time series of non-tidal or residual currents. Residual currents are calculated as the difference between the reconstructed tidal time series and the original signal.

The residual signal was further analyzed to separate non-tidal processes, such as wind-driven, density driven, and mean currents. Low frequency (subtidal) energy is removed by applying a PL33 low-pass filter to the residual signal. The PL33 is a standard oceanographic filter, which uses $^{1}/_{33}$ (hours) as the cutoff frequency to remove tidal energy from oceanographic time series. The low-passed time series, termed the subtidal signal, was subtracted from the non-tidal residual signal, resulting in a high frequency time series containing all non-tidal currents having periods less than approximately 33 hours. This high-frequency energy (referred to as 'noise') can be due to several sources, including flow field turbulence, wave-induced flow, rapid responses to wind shifts, as well as possible data contamination due to instrument scatter.

A second level of filtering was performed to separate the subtidal signals into two bands: 1 to 8 days, and 8 or more (8+) days. The 1 to 8 day band reveals the dominant wind-driven current flows. The 8+ day signal represents lower frequency processes, such as mean and density-driven flows, which vary at longer time scales than wind-driven currents within Long Island Sound.

Tidal currents are independent of wind and contain the most energy. The maximum tidal currents are peak (spring tide) speeds, and bi-directional along the principal (major) axes of the tidal ellipse. Subtidal (8+ day band) currents are also independent of wind. The peak subtidal current velocity was determined by projecting the subtidal currents along the axes of the maximum tidal currents. The maximum wind independent currents are a vector addition of the peak tidal currents and the lower frequency subtidal currents that enhance the tidal currents.

In Long Island Sound wind-driven flows were bi-directional, and typically oriented in the same direction as the tidal ellipses, *i.e.,* along-axis. The maximum currents in the 1 to 8 day subtidal band were calculated along the principal axes of the flow. High-frequency currents also seemed to be wind-dependent; noise levels increased typically with stronger winds. These high-frequency currents were omni-directional, thus only the magnitude was considered. The standard deviation of this signal (over the whole data set) was calculated. Statistical analysis says that 95% of random fluctuations should be less than 3 standard deviations from the mean.

The maximum wind dependent currents were calculated to be a summation of the wind-driven current speeds and the high-frequency speed at three times the standard deviation, oriented in the direction of the peak wind-driven currents.

Total maximum currents expected at each disposal site were determined as a vector addition of peak wind independent and peak wind dependent currents. While extreme wind and wave calculations for this study were reported for return periods ranging from 1 to 100 years, similar extremal analyses were not performed for wind-dependent bottom currents. Rather, current analyses were focused on peak flows that can occur at least once a month during spring tides. Peak tidal and low-frequency currents were determined independent of return period storm events. High-frequency and shorter period subtidal currents were dependent on winds, and may be estimated based on extremal wind events through a transfer function, but derivation of an accurate transfer function between winds and wind-induced bottom currents for these locations would have been difficult given the scant data sets available. In Long Island Sound, wind dependent bottom flows generally contain less than 10-15% of the total energy. For this analysis, the most conservative approach was to assume that wind-driven flows were constant for all return periods. This assumption may result in an underestimation of peak currents during extreme wind events.

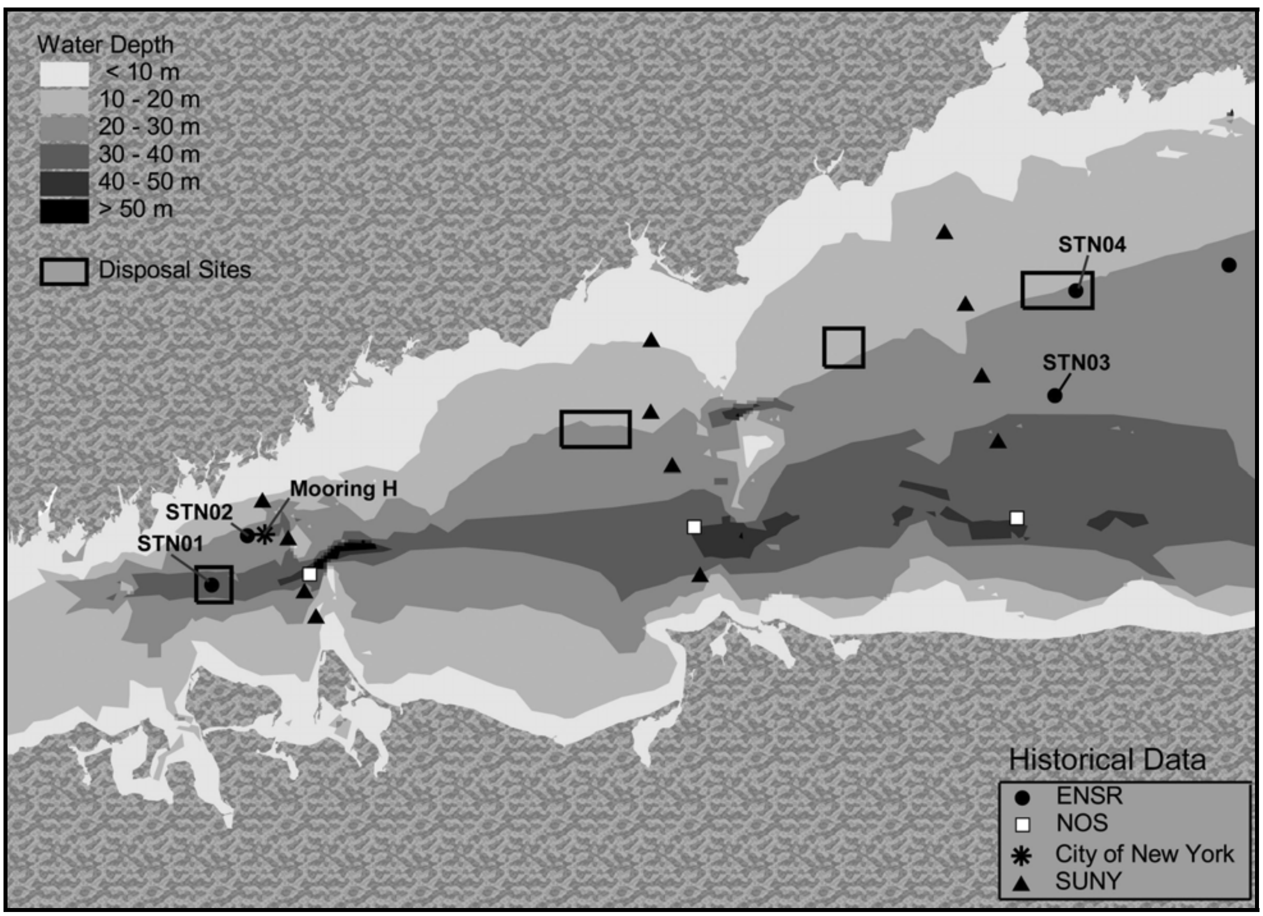

Figure 2. Bathymetric Map of Long Island Sound Showing Mooring Locations Occupied by ENSR in 2001 and Mooring H Deployed for the City of New York in 1994.

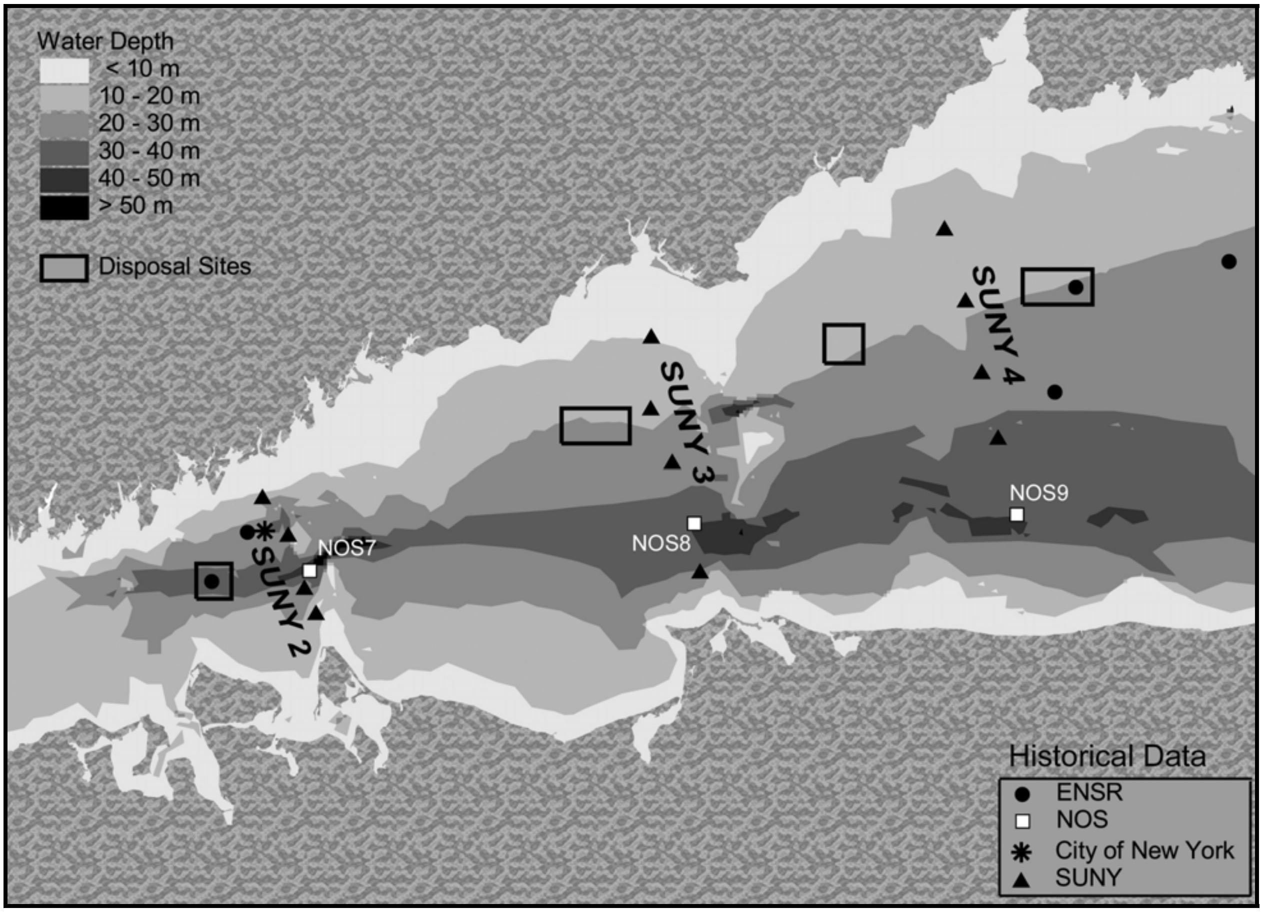

Figure 3. Bathymetric Map of Long Island Sound Showing The Locations Of Historical Current Data Collected by National Ocean Service (NOS) and State University of New York (SUNY) at Stony Brook.

4.3. Results

The ENSR data sets were the focus of the analysis; current data were collected at Station 01 (STN01), Station 02 (STN02), and Station 04 (STN04) synoptically from March to May 2001. The data were presented in rose diagrams to depict the predominant direction of each current component and the percent of the time the flow was oriented toward that direction. The results were also presented in tabular form to understand the peak near-bottom current calculation.

4.3.1. Near-bottom currents

Near-bottom currents at each disposal site were evaluated based on measurements collected by the Nortek Aquadopps at STN01, STN02 and STN04. The longer record of current measurements collected at Mooring H in 1995 was considered to determine lower frequency energy.

Western Long Island Sound

Maximum near-bottom current velocities at WLIS were determined from the ENSR Station 01 Nortek data at 3.3 ft above bottom. The wind independent components (tidal and 8+ days) were taken strictly from STN01 data. The measurements of tidal currents at Mooring H were consistent in direction with the STN01 velocities, but the magnitudes were nearly two times higher. This difference is likely due to the almost 10 ft difference in location of measurements relative to the bottom. The lower frequency density-driven flows at STN01 and Mooring H were in opposing directions. The wind-driven component (1 to 8 days) and high-frequency noise were also computed based on the data at STN01.

Total near-bottom currents at the WLIS disposal site were essentially bi-directional, running northeast and southwest driven primarily by tides (Figure 4). Tidal currents contain at least twice the energy of the other components, reaching a maximum speed of approximately 0.4 knots (Table 7), and are directed along the axis of the sound (east-northeast- to west-southwest). Density-driven currents at this location were directed northward (upslope) over 50% of the time (Figure 4). At times when these low frequency currents were directed more east-west, they slightly enhanced tidal currents, and increased the total maximum contribution of flow from wind independent sources to 0.5 kts. In WLIS, wind-driven near-bottom currents were typically along-axis as well, and reached a speed of approximately 0.18 kts. Wind-driven near-bottom flows typically form a counter-current (flowing in the opposite direction) to wind-driven surface currents. The strongest winds across LIS blow out of the northeast; therefore wind-driven near-bottom flows are strongest to the northeast. High frequency noise from flow turbulence, wave-induced flow, and other short time scale oscillations were evenly distributed across the directional spectrum (Figure 4) and can nearly double the energy of wind dependent currents. Maximum near-bottom currents were reached during spring tides combined with strong northeast wind events, reaching speeds of approximately 0.8 kts oriented towards 70° (NE) (Table 7).

Table 7. Maximum Near-bottom Current Components at Western Long Island Sound Disposal Site.

	East		West	
	Speed (knots)	Direction (deg)	Speed (knots)	Direction (deg)
Tidal	0.43	76	0.43	256
Density (8+ days)	0.09	52	0.08	303
Total Wind independent	0.51	72	0.51	263
Wind-driven (1 to 8 days)	0.18	72	0.12	260
Hi-frequency	0.12	N/A	0.12	N/A
Total Wind dependent	0.30	72	0.24	260
Total Max current	0.81	72	0.75	262

Bridgeport

Data sets within the vicinity of the Bridgeport disposal site are limited. The SUNY and NOS data sets within the region were determined to be unrepresentative of the disposal site as a result of the close proximity to Stratford Shoals (Figure 3). The SUNY transect 3 data also had additional problems as described previously. ENSR STN02 and Mooring H were evaluated to determine the maximum near-bottom current velocities at the Bridgeport disposal site. Although both data sets were collected a significant distance from Bridgeport (approximately 15 miles southwest), the bathymetry, distance to shore, and sedimentary environments are nearly the same (Figure 2). STN02 was weighted more heavily in calculating near-bottom currents, and the measurements at Mooring H were used qualitatively to determine the low-frequency flows.

The Bridgeport disposal site is located geographically within the Western portion of Long Island Sound; therefore current directions were similar to those observed at the WLIS disposal site. Tidal currents flow towards the northeast and southwest along the axis of the sound with a peak speed of 0.49 kts (Figure 5, Table 8). Lower-frequency currents at STN02 were directed south-southwest (down-slope), opposite the direction of density-driven flows at STN01. Density-driven flows at Mooring H confirmed the southerly flow observed at STN02, and showed the occurrence to be approximately 90% of the time (Figure 6). The contribution of low-frequency flows to wind independent currents was nearly negligible due to the low magnitudes and off-axis alignment. Wind-driven flows at the Bridgeport disposal site were significantly lower in magnitude, and were oriented slightly more north-south than east-west (Figure 5). Hi-frequency currents contribute the most energy to wind dependent flows (Table 8). The Bridgeport disposal site is in relatively shallow water (59 ft), near the coastline and subject to higher wave energy (high-frequency flow) than the other disposal sites. The combination of wind-driven and high frequency currents results in wind dependent currents of approximately 0.2 kts (Table 8). Peak near-bottom currents were strongest to the southwest at 0.76 kts due to stronger density-driven flows to the west.

Table 8. Maximum Near-bottom Currents at Bridgeport Disposal Site.

	East		West	
	Speed (knots)	Direction (deg)	Speed (knots)	Direction (deg)
Tidal	0.49	64	0.49	244
Density (8+ days)	0.02	20	0.09	211
Total Wind independent	0.50	62	0.56	239
Wind-driven (1 to 8 days)	0.06	49	0.05	231
Hi-frequency	0.15	N/A	0.15	N/A
Total Wind dependent	0.21	49	0.20	231
Total Max current	0.71	59	0.76	237

Milford

There were no existing data sets in the vicinity of the Milford disposal site. The tidal driven currents and mean flows were interpolated from the data sets to the east and the west of the site. The wind-driven velocities were computed based on data collected at STN04 within the CLIS disposal site (Figure 2). At this location, maximum tidal current speeds were estimated to reach 0.39 kts (20 cm/s) during spring tide conditions (Signell *et al.*, 1998). This value falls within the range of maximum tidal current speeds measured at STN02 and STN04 in 2001. Measured density-driven flows vary greatly in direction between adjacent sites in LIS, but are small in magnitude. A minor contribution of 0.04 kts was estimated to slightly enhance the total wind independent component (Table 9). In the absence of data at the Milford disposal site, it was

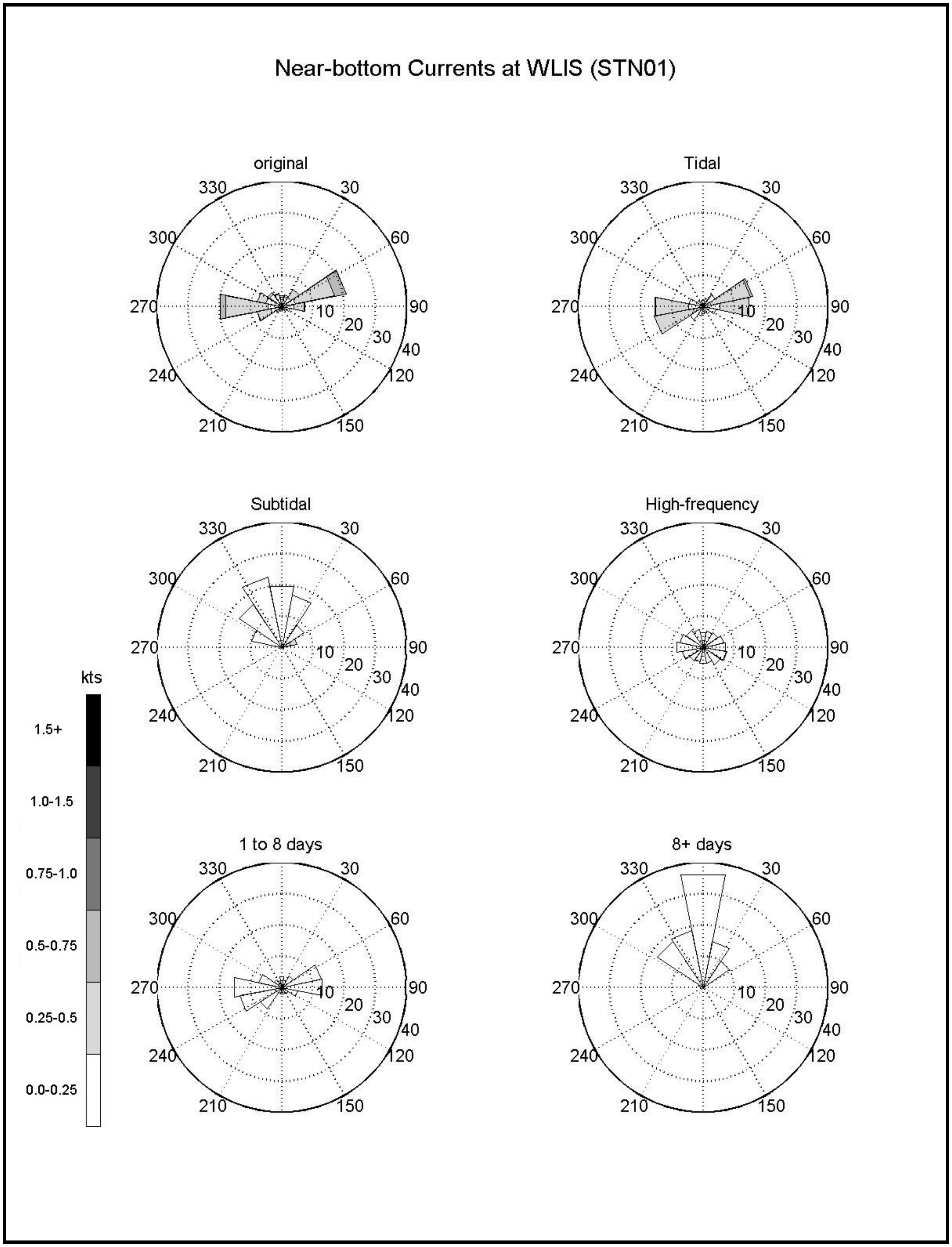

Figure 4. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction of Near-bottom Currents, Measured at STN01 from March to May 2001.

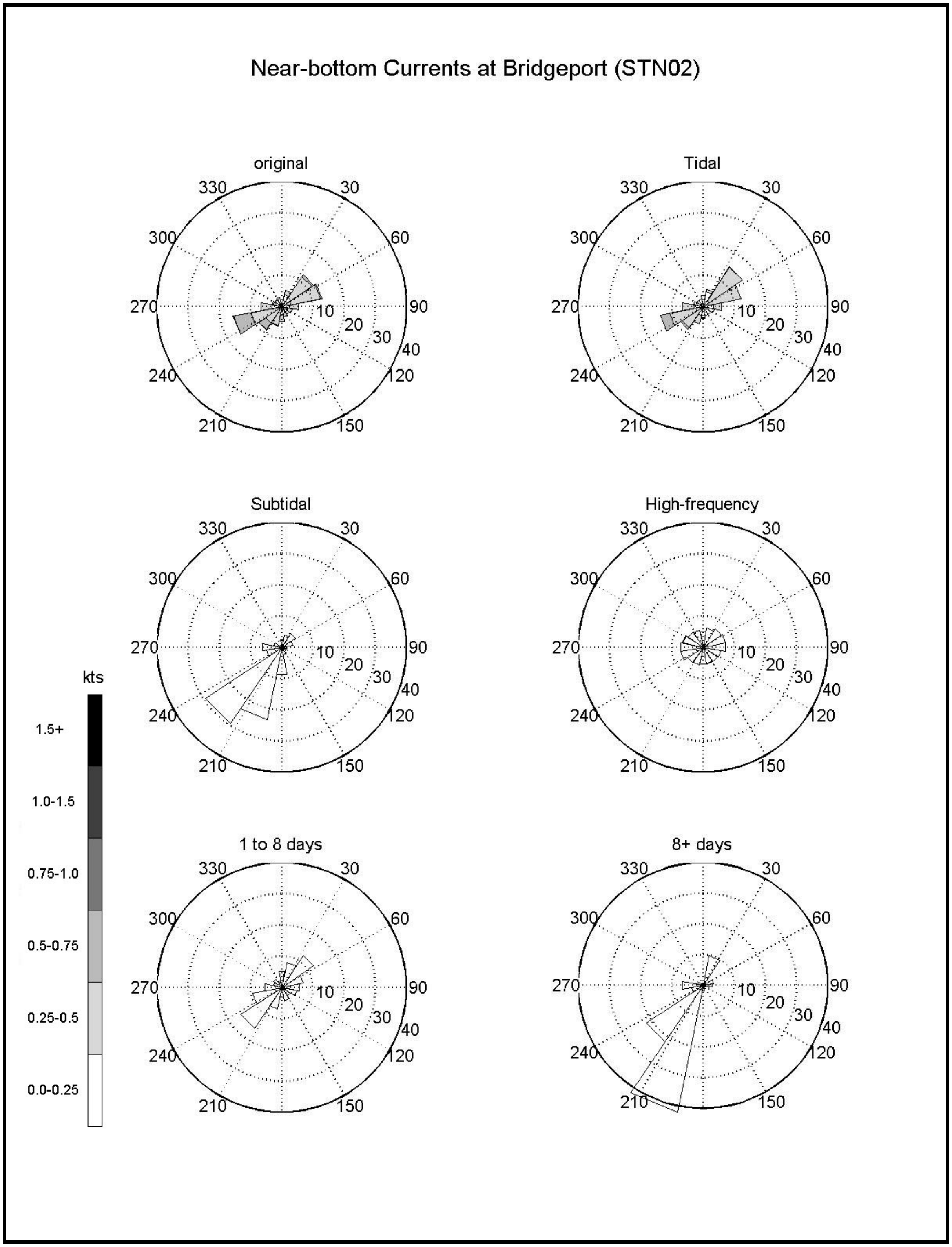

Figure 5. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction Measured at STN02 from March to May 2001.

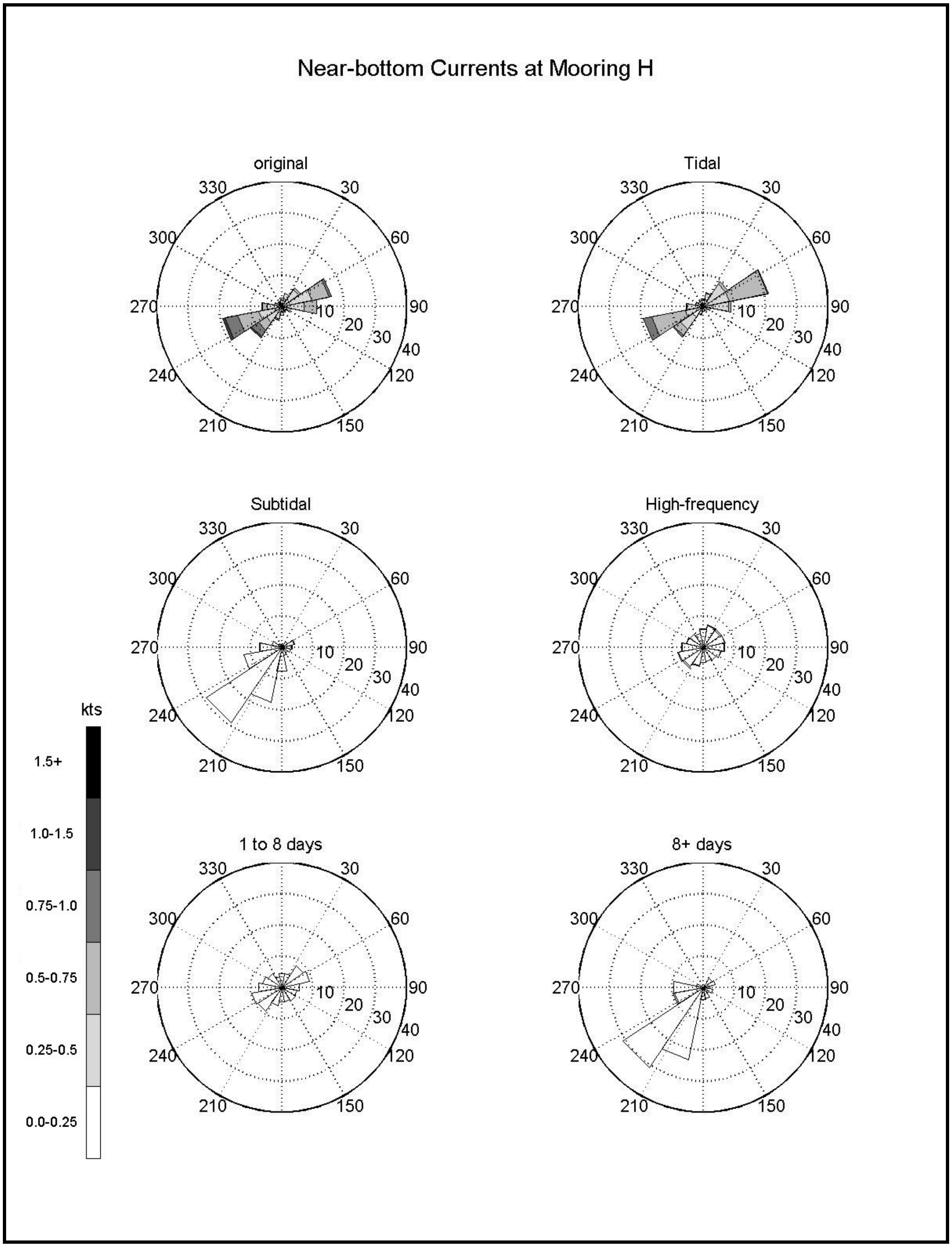

Figure 6. Rose Diagrams of Near-bottom Currents, Measured at Mooring H from November 1994 to September 1995.

assumed that wind-driven flows would be consistent across the Central Long Island Sound region. At STN04, wind-driven currents were measured at approximately 0.06 kts in the northwest and southeast directions (Figure 7). High-frequency noise was estimated at 0.12 kts from slightly higher values at STN02 and slightly lower values at STN04. These estimates total a maximum near-bottom current of approximately 0.45 kts in the east and west directions (Table 9).

Table 9. Maximum Near-bottom Current Components at Milford Disposal Site.

	East		West	
	Speed (knots)	Direction (deg)	Speed (knots)	Direction (deg)
Tidal	0.39	80	0.39	260
Density (8+ days)	0.04	30	0.04	330
Total Wind independent	0.41	76	0.40	265
Wind-driven (1 to 8 days)	0.06	165	0.06	350
Hi-frequency	0.12	N/A	0.12	N/A
Total Wind dependent	0.18	165	0.18	350
Total Max current	0.45	99	0.45	287

Central Long Island Sound

Maximum near-bottom current velocities at CLIS were determined from the ENSR Station 04 Nortek data at 3.3 ft above bottom (Figure 2). This was the only available data set for this site. As mentioned previously, the SUNY transect 4 and NOS site 9 were determined to be unrepresentative of the disposal site as a result of location of the moorings (Figure 3). Peak tidal currents were calculated to be slightly lower than tidal currents at Western Long Island Sound sites at peak speeds of less than 0.4 kts oriented due east and west (Table 10). Density-driven currents varied in direction, increasing the ability to enhance tidal currents in both directions (Figure 7). The summation of wind-driven currents and high-frequency flows produced wind dependent velocities at approximately 0.17 kts in the northwest and southeast directions (Table 10). Due to the more northerly and southerly direction of wind-driven flows, they only contribute minorly to the total maximum currents (Figure 7). Peak near-bottom currents at CLIS are estimated to be 0.51 knots east-southeast and 0.48 knots west-northwest (Table 10).

Table 10. Maximum Near-bottom Current Components at Central Long Island Sound Disposal Site.

	East		West	
	Speed (knots)	Direction (deg)	Speed (knots)	Direction (deg)
Tidal	0.38	92	0.38	272
Density (8+ days)	0.05	139	0.04	339
Total Wind independent	0.42	97	0.40	278
Wind-driven (1 to 8 days)	0.06	165	0.06	350
Hi-frequency	0.11	N/A	0.11	N/A
Total Wind dependent	0.17	165	0.17	350
Total Max current	0.51	115	0.48	298

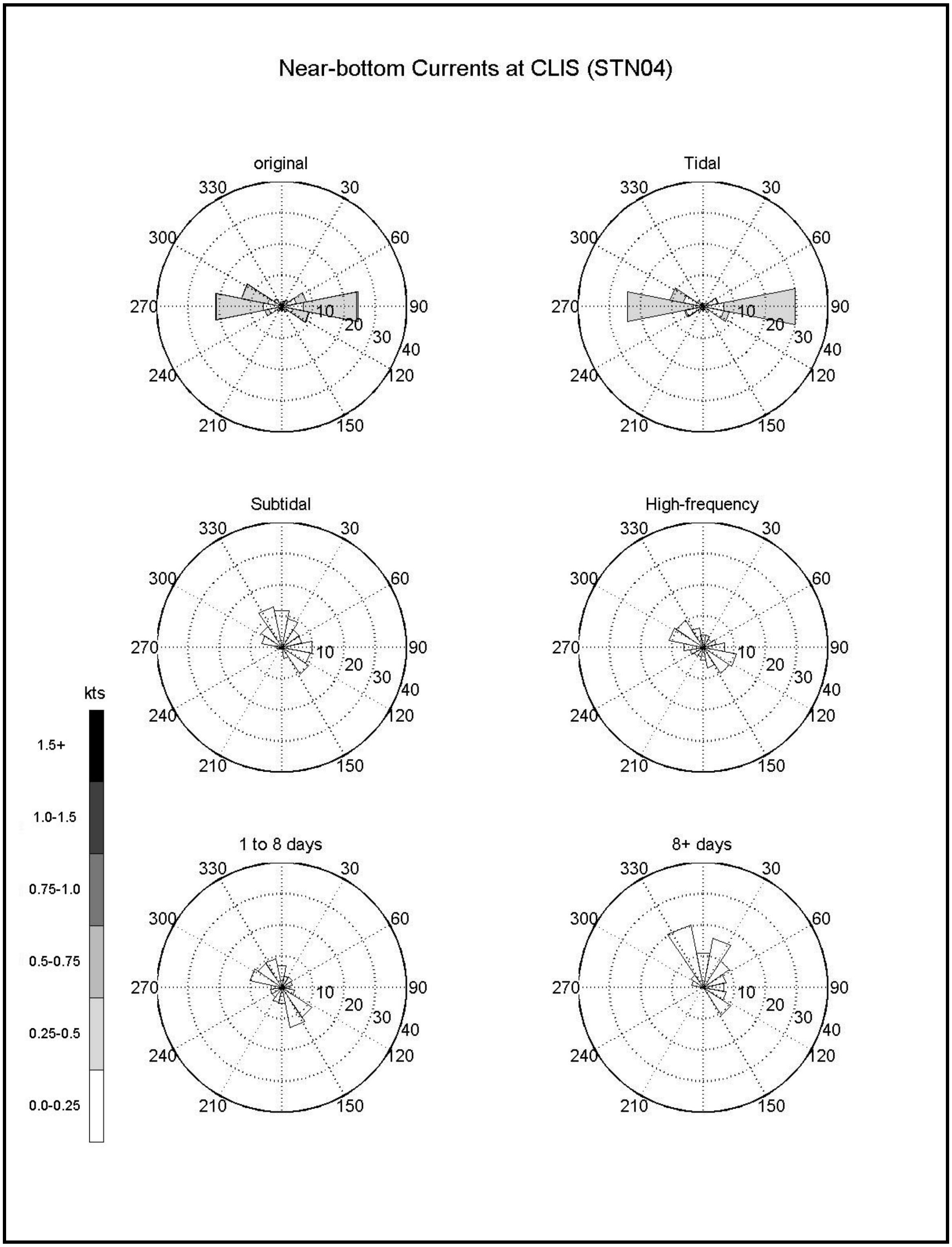

Figure 7. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction of Near-bottom Currents, Measured at STN04 from March to May 2001.

Near-bottom currents were strongest at the WLIS disposal site (Table 11), when tidal, density-induced, and wind-driven currents all flow strongly in the same direction (northeast or southwest). This site is in relatively deep water of the axial depression and is subject to enhancement of mean flows by wind-driven currents. Peak current velocities at Bridgeport were similar in magnitude; swift tidal currents at this location were increased by high-frequency noise from flow turbulence due to wave-induced orbital velocities. The two disposal sites in Central Long Island Sound (Milford and CLIS) exhibit weaker near-bottom currents. Tidal currents flow east to west, while peak wind-driven currents were small in magnitude and flowed northwest to southeast.

Table 11. Summary of Maximum Near-bottom Currents at the Four Disposal Sites.

	East		West	
Site	**Speed (knots)**	**Direction (deg)**	**Speed (knots)**	**Direction (deg)**
WLIS	0.81	72	0.75	262
Bridgeport	0.71	59	0.76	237
Milford	0.45	99	0.45	287
CLIS	0.51	115	0.48	298

4.3.2. Mean currents

Mean currents were calculated from the ADCP records at each of the four disposal site locations. The data was evenly spaced in 6.5 ft (2 m) bins through out the water column. The data were depth-averaged, resulting in a single mean current speed and direction for each 20-minute sample period. A scalar-averaged speed and direction was calculated from the depth-averaged current time series, representing the mean current. Rose diagrams of the depth-averaged currents show tidal, wind-driven and density-driven flow components (Figure 8 to Figure 10).

Depth-averaged tidal currents show similar flow patterns to near-bottom tidal currents; oriented northeast-southwest at WLIS (Figure 8 and Figure 9) and due east-west at CLIS (Figure 10). Tidal currents flow in one of two directions approximately 90% of the time, and rarely exceed 1.5 knots. Wind-driven near bottom currents tended to follow bathymetric contours, similarly to tidal currents, in Western Long Island Sound. Depth-averaged wind-driven currents, although more widely distributed in direction, show an east-west flow at all three measurement locations. Density gradients typically produce mean westward flows in Western and Central Long Island Sound as depicted in Figure 8 and Figure 9. Total mean depth-averaged currents are strongest at CLIS (Table 12).

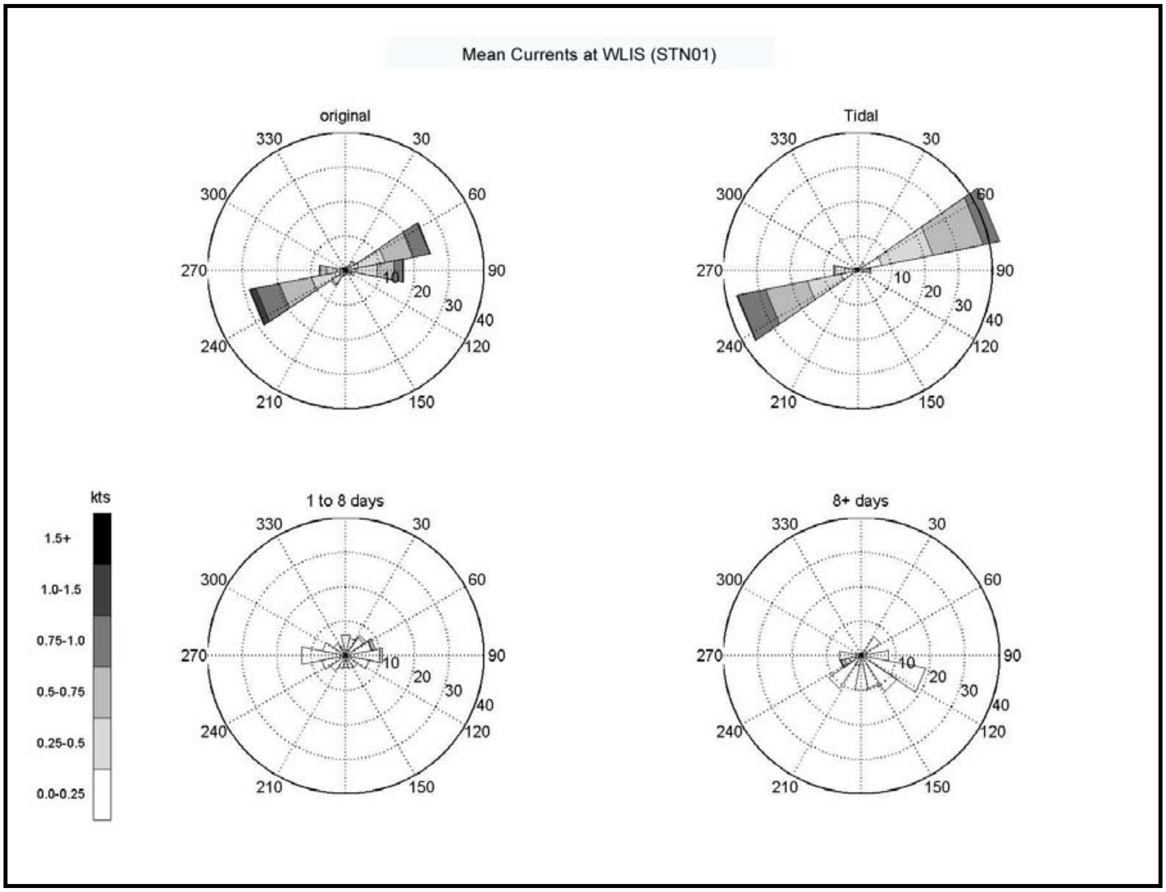

Figure 8. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction of Depth-averaged Currents, Measured in Western Long Island Sound (WLIS) at STN01 from March to May 2001.

Table 12. Summary of Mean Depth-averaged Currents at the Four Disposal Sites.

Disposal Site	Data	Average Speed (knots)
WLIS	ENSR Stn01	0.36
Bridgeport	ENSR Stn02	0.37
Milford	ENSR Stn04	0.45
CLIS	ENSR Stn04	0.45

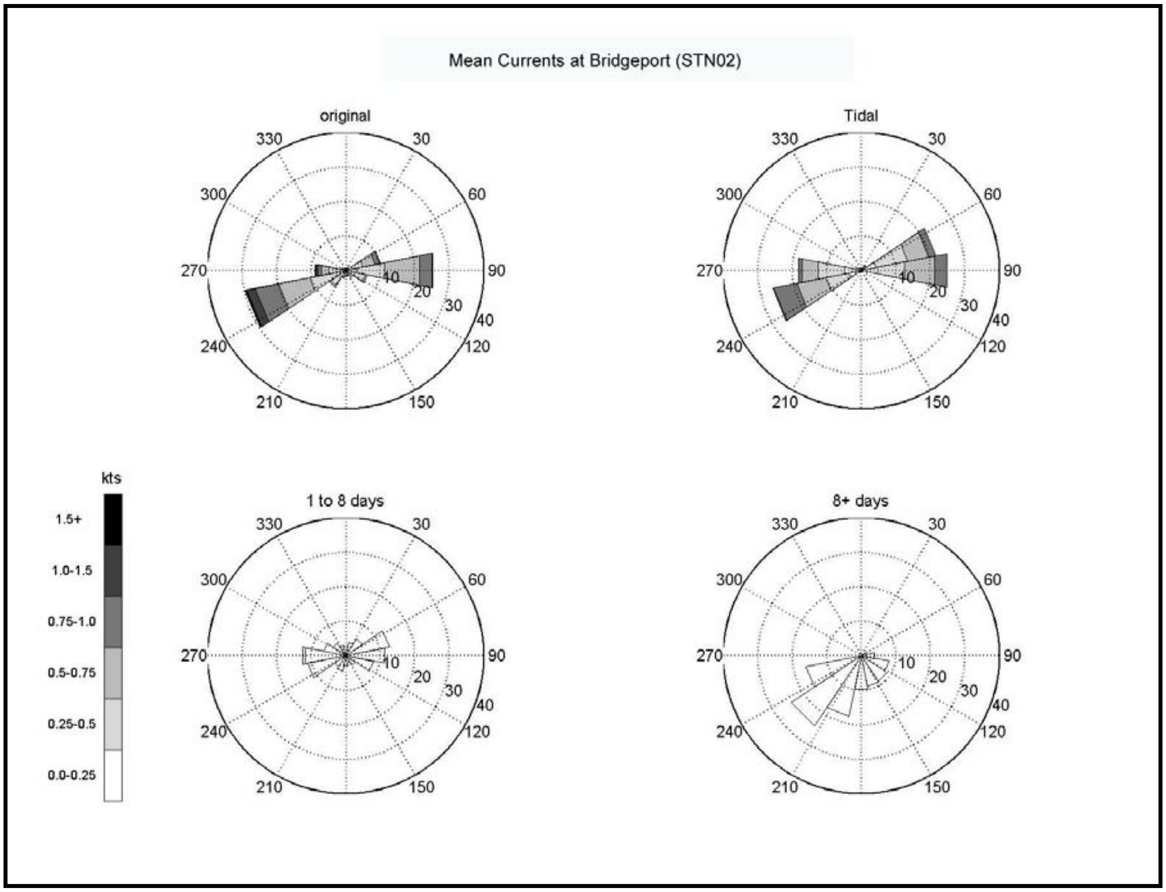

Figure 9. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction of Depth-averaged Currents, Measured near the Bridgeport Disposal Site at STN02 from March to May 2001.

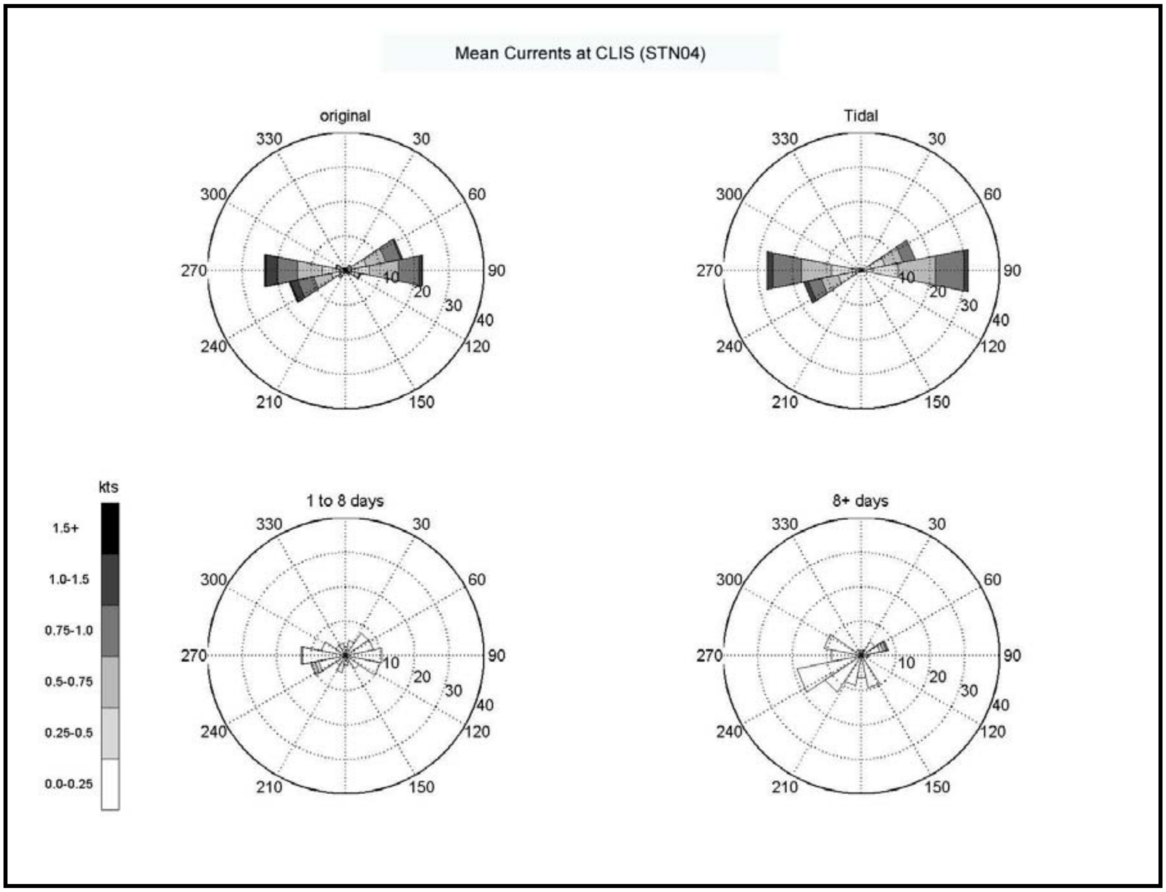

Figure 10. Rose Diagrams Depicting Percent Occurrence of Current Speed and Direction of Depth-averaged Currents, Measured in Central Long Island Sound (CLIS) at STN04 from March to May 2001.

5. DISPOSAL PLUME MODELING (STFATE)

Most of the sediments disposed in Long Island sound consist of very fine sand to silt and clay (USACE, 1994). While the bulk of the dredged material will settle to the bottom in the first few minutes after release, low concentrations of fine particles may persist for several hours in the water column, during which time they may be moved by the currents and diffused. For example, Rhodes (1994) suggests that up to 6 percent of the dredged material (dry mass) can remain suspended in the water column as a turbid plume to be transported away from the disposal point (extrapolating from measurements at the Rockland disposal site reported in SAIC, 1988). This is consistent with estimates by Tavolaro (1984) and Dragos and Lewis (1993) based on disposal events at the New York Mud Dump Site in the New York Bight (water depth approximately 92 feet [28 meters]) and with sophisticated laboratory experiments (Adams, 2002).

5.1. STFATE Model Description

The Corps of Engineers' Short Term Fate (STFATE) dredged material disposal model was applied at each of the alternative sites to predict disposal plume behavior. STFATE was developed to model disposal plume behavior including physical mixing, transport, settling and contaminant dilution in and around the disposal site during the first few hours after the release of dredged material. It is based on the work of Brandsma and Divorky (1976) and Koh and Chang (1973) and models the behavior of the plume as a dense liquid (since the concentration of discharged dredged material in the plume is usually low), applying conservation of mass, momentum, buoyancy, and particle fall velocities. The results can be used to establish conditions in the permit for management and monitoring of disposal in accordance with Corps regulations.

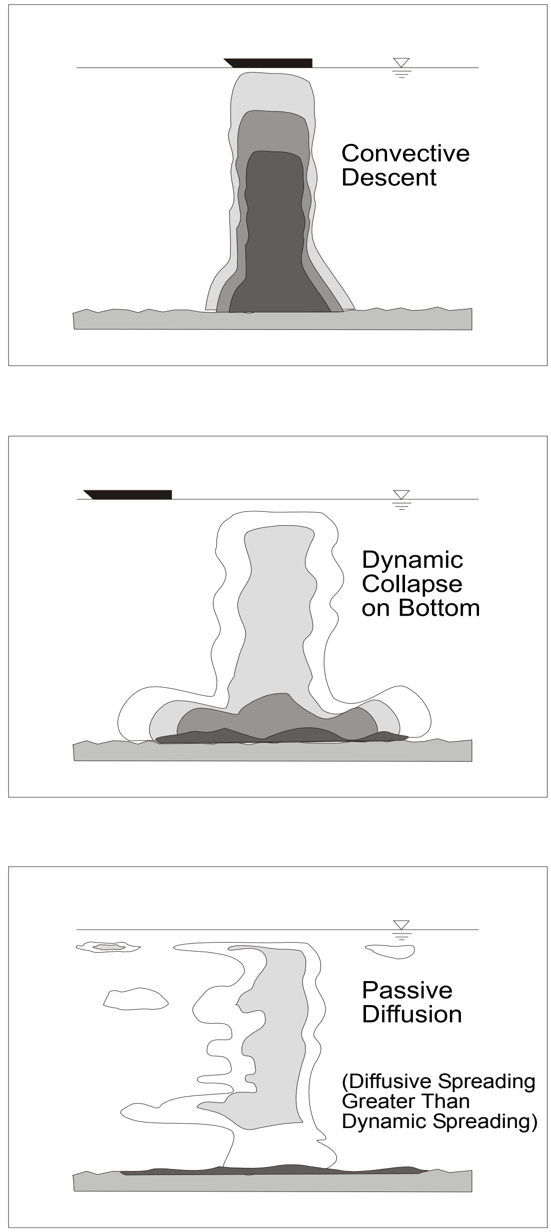

Figure 11. Illustration of Idealized Dredged Material Plume Behavior.

During release of volume of dredged material from a barge into the water column, the behavior of the plume is separated in three phases: convective descent, during which the plume settles under the influence of gravity; dynamic collapse, occurring when the descending plume impacts the bottom or reaches a neutrally buoyant position in the water column and diffuses due to its own momentum; and passive diffusion, beginning when transport and diffusion of the plume are caused more by the ambient oceanographic conditions (currents and turbulence) than by the dynamics of the plume body (Scorer, 1957; Woodward, 1959; Csanady, 1973; Brandsma and Divoky, 1976; Tsai and Proni, 1985; Ecker and Downing, 1987; Kraus, 1991). This analysis is somewhat idealized, but it contains all the important hydrodynamic elements of the physical process. See Figure 11.

During the convective descent phase, the dredged-material plume maintains its identity as a single plume by the formation of a vortex ring structure. This analysis (Brandsma and Divoky, 1976) was based upon the work of Scorer (1957) and Woodward (1959) whose work treated a buoyant plume composed entirely of fluid. The study showed that once released, the plume will descend due to its initial momentum and its negative buoyancy. During its descent, it experiences drag from the ambient fluid that it is displacing. The plume grows as the receiving water is entrained into it and the concentration of the plume is greatly reduced due to the entrainment and turbulence. The convective descent phase will typically last only a few seconds in shallow water.

If the plume immediately impacts the bottom, the dynamic collapse phase consists of the impact and collapse of the cloud as momentum spreads it horizontally. In shallow water, dredged materials have sufficient momentum to travel hundreds of meters laterally after impact with the bottom. If, while mixing with the receiving water, the plume's density approaches the local density, the plume may reach the depth of neutral buoyancy before hitting the bottom. This is more likely to occur under conditions of stratified water column. In this case, the dynamic collapse phase is somewhat different. The plume's downward vertical momentum will tend to make it overshoot the neutral buoyant depth. The plume will land tend to return it to the depth of neutral buoyancy. The result will be decaying vertical oscillations about the depth of neutral buoyancy. These oscillations increase the turbulence and increase the speed with which the plume tends to collapse vertically and spread out horizontally as it seeks hydrostatic equilibrium. Studies have shown that dredged material plumes released in shallow water (less than 25 m) usually experienced dynamic collapse by impacting the bottom as their initial momentum is too great to be overcome the plume buoyancy.

The final phase is the period of passive diffusion which occurs when transport and diffusion of the plume are caused more by the ambient oceanographic conditions (currents and turbulence) than by the momentum of the plume itself. Passive diffusion is the long-term dispersion and transport of the plume in which the cloud is passively carried by the local currents while undergoing gaussian diffusion. It operates on time scales of hours to days.

5.2. Model Input Requirements

Input data required by the models have been grouped into three categories: (1) description of the disposal operation, (2) description of the ambient oceanographic conditions at the release site, and (3) description of the dredged-material. In addition, the model uses default coefficients that parameterize poorly quantified physical processes including entrainment, settling, and dissipation, which may be modified if desired. The model input requirements include:

- Disposal Operation Description
    - -Volume of dredged-material in barge
    - -Vessel course & speed

-Barge length & width
-Post disposal draft of barge

- Disposal Site Description
  -Water depth
  -Water column density profile
  -Water Column Velocity Profile
- Dredged-Material Description
  -Bulk density
  -Bulk contaminant concentration
  -Moisture content
  -Number of solid fractions
  -Solid-fraction volumetric concentration
  -Solid-fraction specific gravity
  -Solid-fraction deposited void ratio
  -Solid-fraction settling velocity
  -Solid-fraction cohesiveness

It should be noted that the authors of this model have indicated that limitation to the model include the model sensitivity to assumed model coefficients including the turbulent entrainment coefficient, the drag coefficient, and the vertical diffusion. The model also assumes that the dredged material plume behaves as a dense liquid which will only be true if the dredged material is composed of primarily fine-grained solids.

5.3. Application of STFATE to the Alternative Sites

The STFATE model simulations were performed for each of the four alternative disposal sites on grids encompassing the disposal site and surrounding area (Table 13). The water depths were set to a uniform depth of the approximate mean site depth. To model the most conservative ("worst") case, a stratified density profile representing typical summer conditions was determined from historical data (ENSR, 2001) and used for all model runs (surface layer 27 ppt, 12°C and bottom layer and 31 ppt, 8°C). It was assumed that water from the dredging site would be fresher (less saline) than water at the disposal site. The disposal operation parameters, including volume of dredged material and barge dimensions, were based on information from typical dredge barges previously used by the Corps. Estimates of the current velocities were determined from the analysis of current meter data described previously. Time variant currents are not modeled by STFATE.

Table 13. STFATE Model Grid Parameters.

	Bridgeport	CLIS	Milford	WLIS
Num Z Grid Points	45	45	45	45
Num X Grid Points	44	44	44	44
Z Grid Spacing	333	333	250	250
X Grid Spacing	150	150	180	180

Sediment samples collected for the recent proposed harbor dredging projects in New Haven, Norwalk, and Guilford were analyzed for grain size and contaminant toxicity parameters (Battelle, 2000a; Battelle 2000b; Battelle 2000c). These data were used in STFATE modeling in view of the fact that they represent typical dredged sediments that might be disposed in the alternative sites in the future. The average geotechnical composition of the sampled sediments was selected for use in the model and consisted of a mix of 10% fine sand, 76% silt, and 14% clay. Field experience shows that in clamshell dredging operations with cohesive sediment a significant portion of the dredged material remains as clumps within the barge and during disposal. For that reason, mixes of 40% and 60% clumps were used for all STFATE model runs (see Table 14).

In the New Haven, Norwalk, and Guilford dredged material evaluations, biological testing was used to determine the sensitivity of indicator organisms to elutriated contaminants. This was done by determining the dilutions required of sediment samples to reach levels fatal to 50 % of the indicator organisms, the so called LC50. Of the nearly 40 elutriate analyses done in the three studies, the four samples requiring the greatest dilution for 50% mortality were diluted to between 22% and 49%, with an average of 34%. The "Green Book", Evaluation of Dredged Material Proposed for Ocean Disposal — Testing Manual, sets criteria for dilution to 1/100th of the LC50 concentration. A concentration higher than 1/100th of the LC50 cannot be exceeded after the period of initial mixing (4 hours after dumping) anywhere in the designated disposal site or at anytime outside the disposal site. The STFATE model was used to evaluate water quality by tracking predicted plume dilution in the water column and comparing it to water quality criteria of 1/100th of the LC50, (0.34%).

Table 14. Dredged Material Properties Used in STFATE Model Simulations.

	Model Run	Velocity	Run Duration	Barge Volume (cyd)	Clumps (% vol)	Free Water (% vol)	Moisture Content (% wt)	Vol Water (% of tot)	Vol Clumps (% of tot)	Vol Sand (% of tot)	Vol Silt (% of tot)	Vol Clay (% of tot)
WLIS												
	10D	0.9 (0.52,-0.74)	7200	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	14D	0.6 (0.34,-0.49)	10800	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	18D	0.9 (0.52,-0.74)	7200	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	22D	0.6 (0.34,-0.49)	10800	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	12D	0.9 (0.52,-0.74)	7200	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	16D	0.6 (0.34,-0.49)	10800	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	20D	0.9 (0.52,-0.74)	7200	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	24D	0.6 (0.34,-0.49)	10800	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
Bridgeport												
	10A	0.9 (0.35,-0.83)	7200	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	14A	0.6 (0.23,-0.55)	10800	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	18A	0.9 (0.35,-0.83)	7200	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	22A	0.6 (0.23,-0.55)	10800	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	12A	0.9 (0.35,-0.83)	7200	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	16A	0.6 (0.23,-0.55)	10800	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	20A	0.9 (0.35,-0.83)	7200	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	24A	0.6 (0.23,-0.55)	10800	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
Milford												
	10C	1.1 (0.55,-0.95)	6300	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	14C	0.7 (0.35,-0.61)	7500	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	18C	1.1 (0.55,-0.95)	4800	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	22C	0.7 (0.35,-0.61)	7500	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	12C	1.1 (0.55,-0.95)	4800	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	16C	0.7 (0.35,-0.61)	7500	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	20C	1.1 (0.55,-0.95)	4800	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	24C	0.7 (0.35,-0.61)	7500	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%

Table 15. Dredged Material Properties Used in STFATE Model Simulations.

	Model Run	Velocity	Run Duration	Barge Volume (cyd)	Clumps (% vol)	Free Water (% vol)	Moisture Content (% wt)	Vol Water (% of tot)	Vol Clumps (% of tot)	Vol Sand (% of tot)	Vol Silt (% of tot)	Vol Clay (% of tot)
CLIS												
	10B	1.1 (0.46,-1.00)	6000	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	14B	0.7 (0.30,-0.63)	8400	5000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	18B	1.1 (0.46,-1.00)	6000	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	22B	0.7 (0.30,-0.63)	8400	3000	40%	10%	100%	70.62%	13.06%	1.63%	12.40%	2.29%
	12B	1.1 (0.46,-1.00)	6000	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	16B	0.7 (0.30,-0.63)	8400	5000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	20B	1.1 (0.46,-1.00)	6000	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%
	24B	0.7 (0.30,-0.63)	8400	3000	60%	25%	100%	71.09%	23.13%	0.58%	4.39%	0.81%

Table 16. STFATE Model Disposal Operation Parameters.

	Bridgeport	CLIS	Milford	WLIS
Disposal Operation Type	Split Hull Barge	Split Hull Barge	Split Hull Barge	Split Hull Barge
Disposal Location	Geographic center of site	Geographic center of site	Geographic center of site	Geographic center of site
Length of Disposal Bin	160	160	160	160
Width of Disposal Bin	42	42	42	42
Pre-Disposal Draft	17	17	17	17
Post Disposal Draft	4	4	4	4
Time to Empty	20	20	20	20

5.4. Results

5.4.1. Western Long Island Sound

For WLIS, the STFATE model calculations were performed on a 7,500 feet by 7,500 feet (2,300 meter by 2,300 meter) grid encompassing the disposal site and surrounding area with grid resolution of 150 feet N by 250 feet E. The water depth was set to a uniform depth of 98 feet (30 meters). Long-term current meter measurements made near WLIS (Fredriksson and Dragos, 1996) and short-term measurements made inside the boundaries of WLIS (ENSR, 2001 and Morton et.al., 1982) were described earlier. Depth-averaged currents for the period of the simulation corresponding to release during peak spring flood tide, superimposed on a 75% frequency of occurrence of wind-driven and/or density-driven currents were determined to be 0.9 ft/s (0.3 m/s), directed toward the west-southwest. These conditions were selected to represent highest expected currents over the duration of any disposal event, which is typically only 2 to 3 hours. Also simulated were less extreme conditions, *i.e.,* currents corresponding to release during peak flood tide (average for times other than spring conditions) and average wind-driven and/or density-driven currents superimposed (0.6 ft/s [0.2 m/s] directed toward the west-southwest).

STFATE predicted the spread of the material in the water column during settlement, the footprint of the material on the bottom, and the distribution in space and time of the residual plume of suspended solids and contaminants above background. See Figure 12 through Figure 27. For WLIS, as with all four alternative sites, simulations showed the vast majority of the released dredged material settled to the bottom in close proximity to the point of release. The high current conditions chosen for the simulation were the most significant factor in determining the residual plume conditions. This might be expected given that a current of 0.9 ft/s (0.3 m/s) would cross half the width of WLIS in less than one hour. For all simulations, the center of the site was chosen as the release point. The results of the STFATE model predictions for dilution relative to the toxicity criteria (1/100th of the LC50) are presented in Table 17. The toxicity criteria exceedences occurred when the plume passed out of the site boundaries, approximately 90 min after release, although the dilution reached no exceedance levels within another 20 min beyond the site boundary. The dilutions were all well within the limits after the four hour initial mixing period. Had the spring tide current (worst case) not carried the plume over the short travel distance from the site center to the site boundary, the dilution criteria would not have been exceeded. Barge size was another significant factor, but the percent volume of clumps and percent volume of free water used in the simulations were not significant in the ranges simulated. The results suggest that dilution of contaminants below the proscribed 1/100th LC_{50} level for worst case projects could be achieved simply by adjusting the management approach either by 1) limiting barge size, 2) limiting operations to times other than during spring tide, 3) positioning the release point according to the ambient currents, or 4) expanding the site boundaries.

Table 17. STFATE Model Parameters and Dilution Results for the Western Long Island Sound Disposal Site.

Barge Volume (yd3)	Current Speed (ft/s) and Direction	Clumps (% vol)	Free Water (% vol)	Elutriate Criteria Model Exceedence (Cause)
5,000	0.9 wsw	40%	10%	Exceedence Outside Boundary
5,000	0.9 wsw	60%	25%	Exceedence Outside Boundary
5,000	0.6 wsw	40%	10%	No Exceedence
5,000	0.6 wsw	60%	25%	No Exceedence
3,000	0.9 wsw	40%	10%	No Exceedence
3,000	0.9 wsw	60%	25%	No Exceedence
3,000	0.6 wsw	40%	10%	No Exceedence
3,000	0.6 wsw	60%	25%	No Exceedence