9 Dredged Material Dispersion Analysis for Emmord's Hole Near PA 187

The CESWG has proposed diverting some quantity of channel-maintenance dredged material from existing placement areas (PA) 186 to 189 to a site in Upper Laguna Madre on the west of the GIWW known as Emmord's Hole. The numerical hydrodynamic and sediment transport model was modified and used to simulate the dispersion of material from the proposed site. About 50 percent of disposed material was resuspended and dispersed from the site over a one-year simulation. The model was used to gauge impacts of such dispersion on suspended-sediment concentrations and light penetration in the surrounding lagoon area, which is largely covered by submersed vegetation. Dispersion was greatest during the first month following disposal and resulted in a suspended-sediment plume of 13 mg/l over ambient no-disposal concentration and in a displacement of the isopleth describing 20 percent irradiance reaching the bottom of more than 10 km to the north of the site. However, subsequent months had plumes no greater than 7 mg/l and displacements of the 20 percent bottom-irradiance isopleth of no more than about 150 m beyond the natural, no-disposal condition.

Site Information

Emmord's Hole is located in Upper Laguna Madre between latitudes 27° 26' and 27° 33' N and longitudes 97° 19' and 97° 21' W near a previously authorized PA designated 187. Emmord's Hole is a depression reaching 2 m below mean lower low water (mllw), which is about 1 m deeper than the surrounding lagoon bottom. Depths in the area, based on the 1995 bank-to-bank survey described in Chapter 7, are shown in Figure 94. The area is reported to be bare of submersed vegetation, although it has previously been both vegetated (1988) and bare (1967 and 1975-76) (Quammen and Onuf, 1993). Bed sediments are mainly sand in this area, with mean grain size of about 0.156 mm, (n = 5, White et al. 1989). A bed sample collected in October 2001 by PBS&J (a contractor of CESWG) was found to be 91 percent sand sized (0.05 to 2.0 mm), and 4.7 percent fines smaller than 0.05 mm.

Water samples were collected three times at four locations in the study area by PBS&J. These four stations were designated PB-181, PB-184, PB-187, and

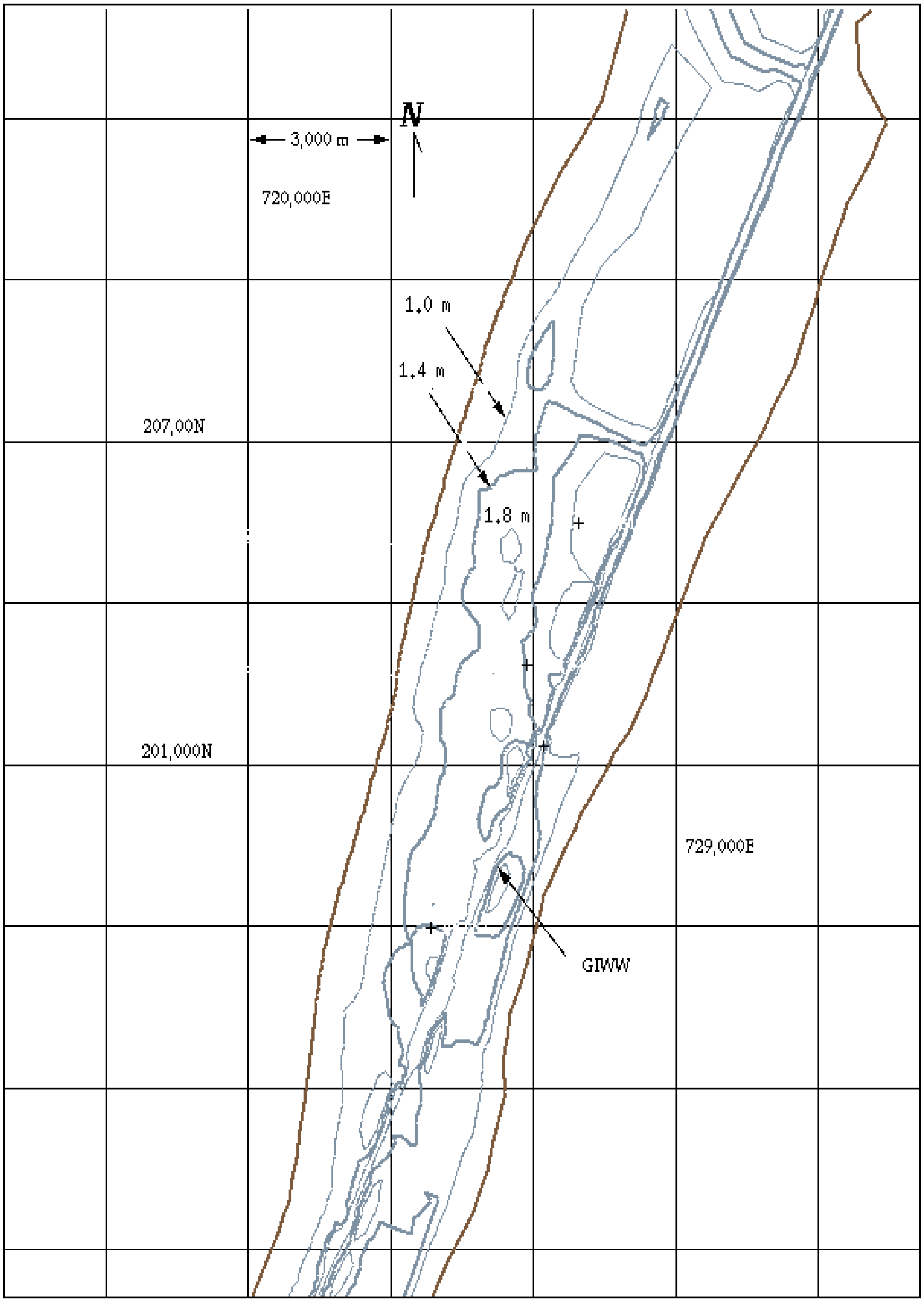

Figure 94. Depth contours (1, 1.4, and 1.8 m) near Emmord's Hole (coordinates are state plane NAD27, in meters)

PB-445; locations are shown in Figure 95. Results of suspended-sediment sample analyses are given in Table 49.

Two Texas Natural Resource Conservation Commission (TNRCC) monitoring stations are located near the study area. Statistical distributions of total suspended material (TSM) values sampled at these TNRCC stations are shown in Figure 96. TNRCC station 13445 is located on the GIWW adjacent to the study area. The station PB-445 was located near to TNRCC station 13445. TNRCC station 13444, referred to here as TNR-444, is located opposite Baffin Bay on the GIWW. See Figure 75.

TSM distributions at TNRCC monitoring sites are log-normal and have very similar standard deviations of the TSM log-values (about 0.785), as seen in Figure 96. Since the TNRCC station 13445 and PB-445 are at the same location and if the distribution-spreading parameters are the same for all stations, distributions can be estimated based on the PB-445 sample probabilities within the 13445 data. Results are shown in Figure 96.

Table 49
Field TSM Results, mg/l

	Sampling Date			
Station	10/04/01	10/09/01	10/18/01	Geometric Mean
PB-181	3.0	2.4	6.5	3.6
PB-184	3.0	4.0	13.0	5.4
PB-187	15.0	20.0	18.0	17.5
PB-445	8.5	9.5	8.0	8.6

Model Modification and Adjustment

The numerical model mesh of Laguna Madre required modification to the Emmord's Hole study area. Mesh resolution was increased and an area of the lagoon bed was specified as bare based on reports from the field. Approximately 3,000 numerical model nodes were added to the original model mesh to improve model resolution in the area. The area specified as bare was that deeper than 1.4 m mllw, closely corresponding to that identified by PBS&J as bare in the field. Boundaries of the seagrass areas and a plot of the model mesh in the area are shown in Figure 95.

The previous model was validated to suspended sediment data from Lower Laguna Madre from 1994 and 1995, as described in Chapter 7. The model included both Upper and Lower Laguna Madre and the connecting Land Cut. The model was driven by water level elevations at its three ocean connections (Brazos Santigo, Manfield Inlet, and Corpus Christi Bay), freshwater inflow at Arroyo Colorado, and a uniform wind field. Evaporation was included. Erosion

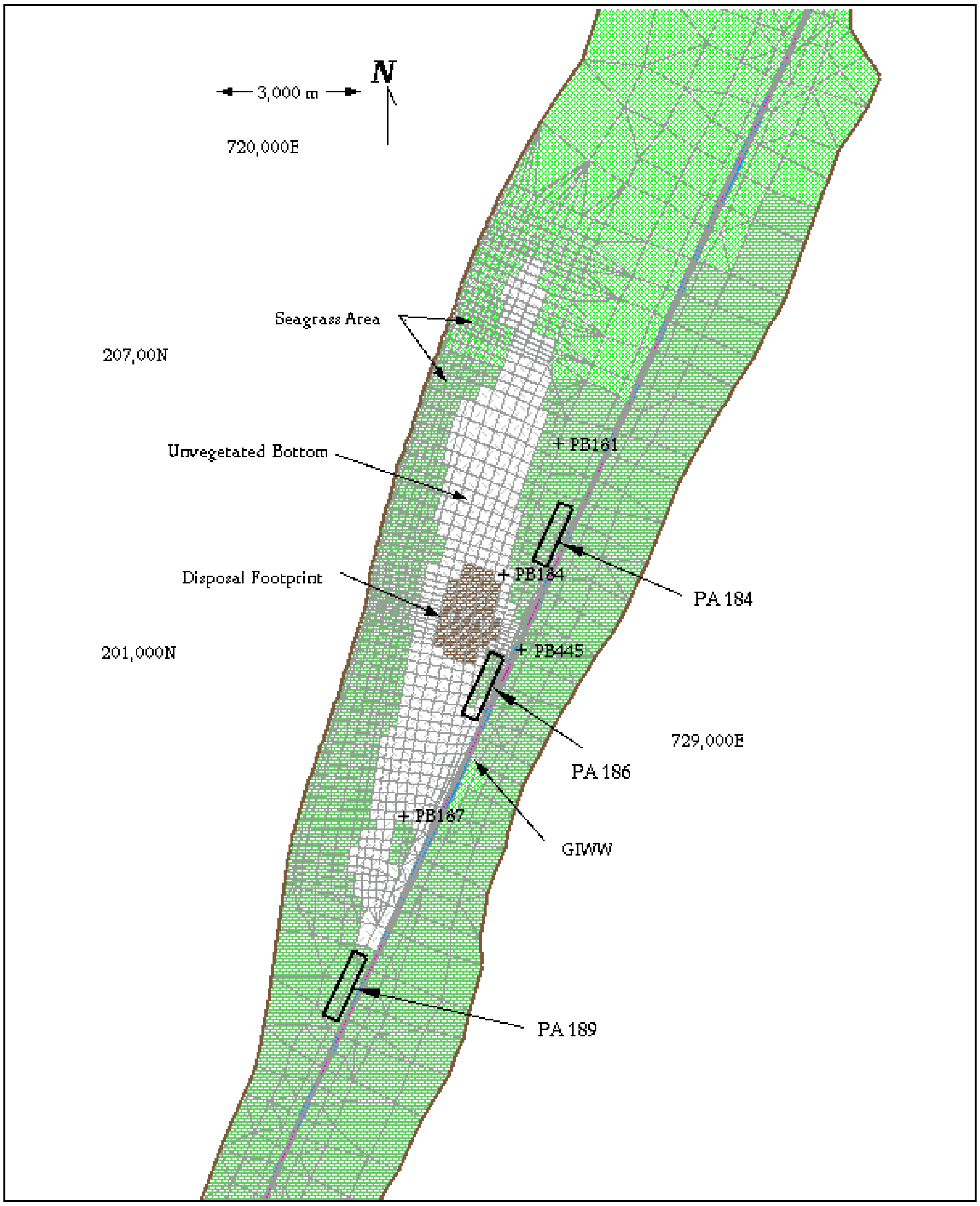

Figure 95. Bottom vegetation, disposal footprint, and station locations near Emmord's Hole (coordinates are state plane NAD27, in meters)

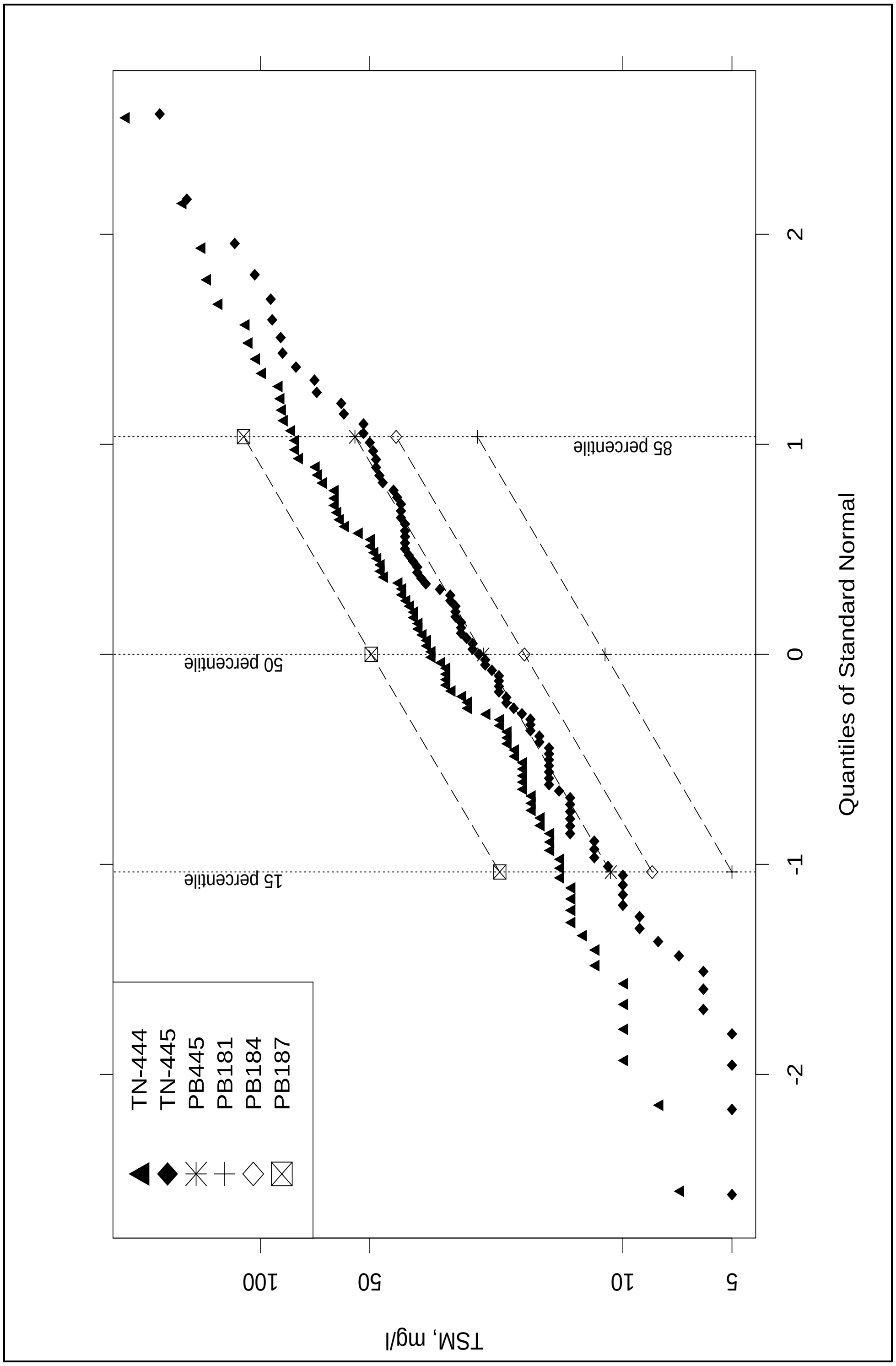

Figure 96. TSM distributions for TNRCC stations and PB samples plotted in relation to their deviation from the median

and settling tests performed on channel and lagoon sediments provided information on sediment transport characteristics.

Since the model mesh was appreciably expanded, the original numerical code could not be reused and the model for this study was slightly different from earlier models. The model was re-adjusted since the wind-wave shear stresses were slightly different from before. Model adjustment was checked against field information on TSM data from previous studies (Brown and Kraus 1997; Militello et al. 1997), and the samples were collected for this study. These included data collected by the TNRCC (TNR prefix and with 13,000 dropped from station numbers), and the Conrad Blucher Institute (CBI prefix). A description of these stations and data sources are presented in Table 50.

Table 50
Suspended-Sediment Monitoring Stations in Laguna Madre

Station	Latitude, N	Node	Material Type	Bottom Condition
TNR-443	27° 36.0'	604	17	Near GIWW
TNR-445	27° 28.75'	3785	16/5	"
TNR-444	27° 16.6'	7453	7/5	"
TNR-449	26° 47.0'	9927	17/5	"
TNR-448	26° 34.0'	12291	7	"
TNR-447	26° 22.0'	16567	42	"
TNR-446	26° 05.0'	21185	38/5	"
CBI-ULM2	27° 17.14'	6068	16	*Halodule*
CBI-ULM3	27° 11.55'	8313	5/8	bare
CBI-FIX[1-3]	26° 10.85'	19737	37	bare
CBI-LLM2a	26° 08.1'	20601	41	*Thalassia*
PB-181	27° 32.52'	2401	17	*Halodule*
PB-184	27° 30.32'	3215	10	bare
PB-187	27° 27.66'	5430	10	bare

Results of the model comparison to field TSM are presented in Table 51. Model TSM's are lower than the corresponding field values at the Lower Laguna Madre FIX stations. This difference is the result of having no dredged material disposal in the model near this location, as was present during the field data collection. The only disposal simulated in this study was that at Emmord's Hole.

Areas within Emmord's Hole that encompass certain depth contours are presented in Table 52. These estimates are for the northern portion of Emmord's

Hole above latitude 27° 28' N (state plane 199,500N m), where the feature is separated from the GIWW by lesser depths and, therefore, deemed to be suitable for initial disposal. Currently the remainder of the area is directly connected or slopes toward the GIWW, and runback could be a problem.

Table 51
Field-to-Model Suspended-Sediment Distribution Comparisons

	Field TSM, mg/l			Model TSM, mg/l		
Station	15 %	50 %	85 %	15 %	50 %	85 %
TNR-443	8	26	56	4	10	18
TNR-445	11	25	51	8	18	39
TNR-444	15	34	81	13	27	67
TNR-449	12	24	60	7	17	41
TNR-448	16	27	54	14	30	67
TNR-447	15	30	60	3	14	65
TNR-446	13	30	61	47	65	109
CBI-ULM2	5	32	95	4	10	25
CBI-ULM3	3	22	61	10	22	50
CB-FIX[1-3]	65	150	253	47	97	185
CBI-LLM2	11	15	28	14	25	46
PB-181 ▽	5	11	25	8	18	41
PB-184 ▽	8	19	42	15	36	80
PB-187 ▽	22	50	112	12	32	72

▽ Field distributions were estimated.

Table 52
Areas and Volumes in Northern Emmord's Hole

Depth Contour, m mllw	Area, 10^6 m^2	Volume to mllw, 10^6 m^3
1.25	23.3	35.1
1.5	8.3	13.4
1.75	1.7	3.1

Disposal Scenario

The average dredged-material volumes per dredging event were 83, 98, 128.7, and 112.5 × 10^3 m^3 (109.2, 128.9, 169.3, and 148 kcyds) for PAs 186 to 189, respectively, for the history of these sites - excluding 1989. The total disposal has been 422 × 10^3 m^3 (555.4 kcyds) per dredging cycle. The total disposal for 1989 was a very high 1.7 × 10^6 m^3 (2,200 kcyds). The average disposal cycle time for PAs 187 to 189 has been about 3 years, while for PA 186 the average cycle has been about 4.5 years.

The average sand content for material disposed (weighted by the average PA disposal volume) is about 20 percent. (Sand content for material going to PA 189 was not available.) Morton et al. (1999) estimated the dispersion of material from PA 187 to be 48 percent. This site receives material with a sand content of 24 percent. Sand content is critical to the total dispersion from Laguna Madre sites. The north side of PA 187 is exposed to a long fetch length, while the fetch to the southeast of the PA is limited. Based on available information, a grain-class composition for the model was estimated as shown in Figure 97 and compared to that found for PA 233 in Lower Laguna Madre.

The model scenario consisted of a 422,000-m^3 disposal assumed to contain 600 dry-kg/m^3 of sediment. The material was disposed in an area below 1.6 m mllw depth which had an area of 2.1 × 10^6 m^2. The disposal scenario footprint is shown in Figure 95. Seventy percent of the material was inserted into the model bed over a 24-hour period, and the remaining 30 percent was injected into the water column over a 5-day period at the beginning of October.

The model was operated with a one-hour time step for 12 months after a one-month spin-up period. The boundary conditions used to drive the model were from September 1994 through August 1995. The September boundary conditions from 1994 were added onto the August 1995 boundary conditions so that a year was simulated after the disposal.

Model Results

The model was operated with identical conditions for disposal and no-disposal scenarios. Model TSM results were averaged by month, starting with the portion of October remaining after the five-day disposal, for both disposal and no-disposal scenarios. The effects of the disposal and subsequent sediment dispersion for the stations given in Table 51 are presented in Table 53 for no-disposal (background) and disposal. Near the disposal at the PB stations and TNR-445, median TSM increased by several mg/l as a result of the disposal. The 85^{th} percentile values increased more, about 18 mg/l in the bare areas of Emmord's Hole. However, the most important conditions affecting light conditions for submersed aquatic vegetation are those occurring below the 85^{th} percentile. Seagrasses are sensitive to changes in "normal" conditions, as reflected by median values, rather than to relatively rare events. The disposal affected suspended-sediment conditions most during times of high energy, when suspended-sediment concentrations are high anyway.

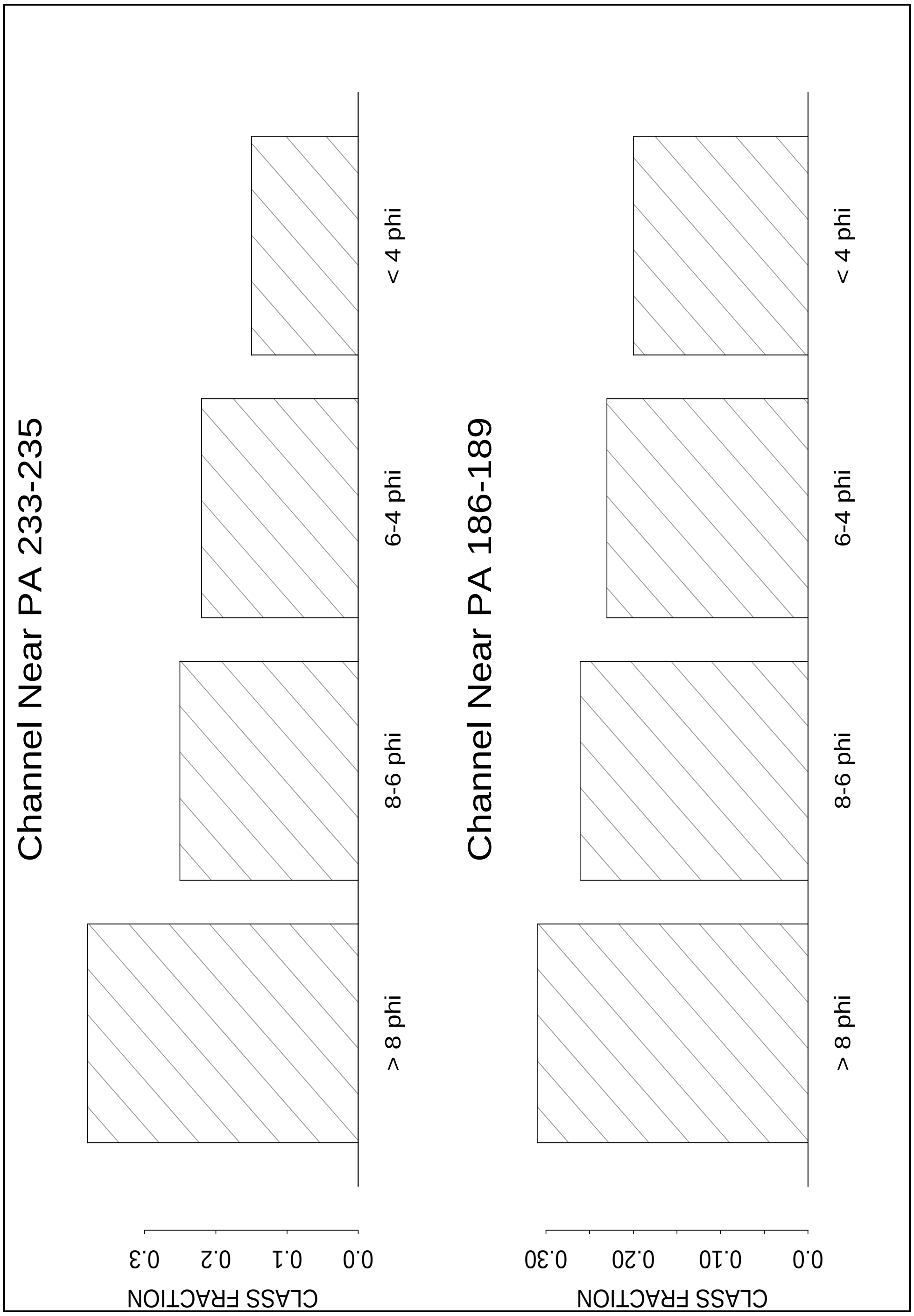

Figure 97. Model grain class composition for dredged material for Upper and Lower Laguna Madre

Table 53
Effects of Disposal on TSM Distributions at the Monitoring Stations

	Background TSM, mg/l			TSM with Disposal, mg/l		
Station	15 %	50 %	85 %	15 %	50 %	85 %
TNR-443	4	9	18	4	10	18
TNR-445	8	15	33	8	18	39
TNR-444	12	26	67	13	27	67
TNR-449	8	17	41	7	17	41
TNR-448	14	30	67	14	30	67
TNR-447	3	14	65	3	14	65
TNR-446	47	65	108	47	65	109
CBI-ULM2	4	9	22	4	10	25
CBI-ULM3	10	22	50	10	22	50
CB-FIX[1-3]	47	67	185	47	97	185
CBI-LLM2a	14	25	46	14	25	46
PB-181	8	16	35	8	18	41
PB-184	13	29	62	15	36	80
PB-187	10	25	54	12	32	72

Model results and comparisons are presented as plots in Appendix D. Monthly average TSM distributions for the disposal scenario are presented in Plates D1 to D12 as contours of TSM concentration (dry-kg/m^3). Monthly suspended-sediment concentration differences between average disposal and no-disposal scenarios are presented in Plates D13 to D24.

Over a period of many months, seagrass requires about 20 percent of the solar radiation penetrating the water surface to produce plant matter in excess of that lost through respiration and to maintain biomass. Calculations of isopleths of 20 percent irradiance reaching the bottom were based on monthly average TSM values based on the relationships presented in Chapter 7 (Equation 69). Results are presented in Plates D25 to D36. The bare area of Emmord's Hole can be seen in those figures to have consistently less than the 20 percent irradiance needed to support seagrass. The exception was September (Plate D36) in which Emmord's Hole did exceed 20 percent irradiance for both disposal and no-disposal scenarios.

The mass of sediment dispersed from the site was estimated from model results to be 50 percent (or about 126.6×10^6 dry-kg) after one year. This dispersion rate is higher than the 48-percent estimated from field information for PA 187 because the dredging cycle is about three years and, therefore, sediment dispersion continues for three years in the prototype instead of the one year allowed in the model simulation.

A portion of the disposed sediment dispersed from the site redeposited in the model a short distance after transport by currents. Results indicate that the thickness of this deposit is expected to be greatest immediately outside the bare area of Emmord's Hole. Here the deposit thicknesses were between 2 and 3 cm. At distances greater than about 250 m from the edge of the bare area, deposit thicknesses caused by dispersed dredged material diminished to less than 1 cm.

Discussion

Following material placement, sediment dispersion during the remainder of October increased suspended-sediment concentrations, disposal versus no-disposal, by 13 mg/l or more over an area 18 km long with a maximum width about 4 km (Plate D13). This impact occurred during the first three weeks after the disposal. The disposal displaced the 20 percent irradiance isopleth some 12 km to the north of the proposed site and west of the GIWW (Plate D25) into areas of submersed vegetation. There was also a displacement of the isopleth for a maximum of about 1 km to the east and across the GIWW. Such impacts are sensitive to wind conditions during the month of disposal.

During dredging in Upper and Lower Laguna Madre in 2000, repeated sampling along the GIWW indicated median suspended sediment increases of 30 mg/l within 300 m north and south of the dredges (see Chapter 3). In the model, TSM increased by 26 mg/l in an area about 700 m long and centered over the disposal footprint. Thus there is some similarity between observed dredging impacts on TSM and those predicted by the model. Subsequent months, November through September, were predicted by the model to have average monthly impacts on TSM of no more than 7 mg/l increase outside of Emmord's Hole. During these months, the 20 percent irradiance isopleth displacements between disposal and no-disposal were typically 150 m, representing an increase of roughly 5 percent (or of roughly 4×10^6 m^2) in the area with less than 20 percent irradiance reaching the bottom.

The 50 percent sediment dispersion from the site, calculated by the model, over a one-year period is actually greater than the average 48 percent dispersion of material estimated by Morton et al. (1999) for the PA 187 site because the latter reflects the longer time period between disposal operations in the prototype. The model calculation was done over 12 months, which is appreciably shorter than the dredging cycle time of about three years. The prototype conditions allow sediment dispersion over the entire dredging cycle time. Therefore, the model estimate of 50 percent should be increased to perhaps 66 percent when comparisons to other field estimates to (crudely) include dispersion over an entire dredging cycle are made. Unfortunately only a rough estimate is possible because the sediment fractions are not equally eroded and dispersed. The sand fraction is expected to be the greatest fraction of the lag deposit remaining at the disposal site.

An estimate of the useful life span of the site can be based on the available site volume and the volume of material retained by the site each year. The total disposed over the 45-yr period, 1950 to 1995, was 5.2×10^6 m^3 (6.9×10^6 cyds), not including the hurricane-related dredging of 1989 (1.7×10^6 m^3 total). The average dredging cycle was 3.6 yr. The density of the lag deposit figures into the calculation and can be estimated by assuming a grain distribution and settled density for the sediment fractions of the lag deposit. If 30, 21, 14, and 1 grain-class percentages of the total original sediment shown in Figure 97 are eroded from the four size fractions, respectively, the lag deposit would consist of 6, 15, 24, and 56 percents of the four classes. Then if the settled densities are assumed to be 100, 400, 960, and 1,400 kg/m^3, respectively, for the four classes, the original material would have a solids content of 627 kg/m^3 compared to 1,073 kg/m^3 for the lag deposit. For comparison, the surface density for PA 233 in Lower Laguna Madre was measured to be 1,688 to 1,814 kg/m^3, but dispersion is greater at this site, and the lag deposit consisted of a greater percentage of sand (79 to 87 percent).

Based on the information in the last paragraph, a conservative estimate of the useful life span for the site (183 years) is outlined in Table 54. Note that the estimate of sediment dispersion from the model used in Table 54 does not include the effects of hurricanes or other extreme events.

Table 54
Useful Life Span Estimate for Proposed Northern Emmord's Hole PA

Available Volume	
Volume at 1.5 m depth contour to mllw (Table 52)	13.4×10^6 m^3
Volume at 1.5 m depth to elevation -1.0 mllw	5.1×10^6 m^3
Sediment Volume	
Retained sediment volume from original	34 percent
In-place solids content of dredged material	627 kg/m^3
Estimated solids content of lag deposit	1,073 kg/m^3
Volume of sediment retained = 420,000 m^3 / 3-yr × 0.34 × 627 kg/m^3 / 1,073 kg/m^3	27,815 m^3/yr
Volume of sediment retained in 50 yr	1.39×10^6 m^3
Average thickness of deposit after 50 yr	0.17 m
Useful Life Span	
Available Volume / Sediment Volume = 5.1×10^6 m^3 / 27,815 m^3/yr	183 yr