US Army Corps of Engineers
Engineer Research and Development Center

Wind-Wave Resuspension and Circulation of Sediment and Dredged Material in Laguna Madre, Texas

Allen M. Teeter, Gary L. Brown, Michael P. Alexander, Christopher J. Callegan, M. Soraya Sarruff, and Darla C. McVan

January 2003

REVIEW DRAFT

Summary

Dispersed dredged material from Gulf Intracoastal Waterway (GIWW) placement areas in Laguna Madre have allegedly impacted nearby seagrass ecosystems, the most extensive and important in Texas. An investigation was conducted to determine the extent of the alleged impact on these areas. As part of this larger investigation, this study used sediment information and a numerical model to predict the effects of dredged material placement, resuspension, and dispersion on water column suspended sediment levels, especially in environmentally sensitive seagrass beds. The model study objective was to predict long-term (annual) dispersion of dredged material placed in designated Placement Areas (PA) and its effect on water column concentrations and light conditions in Laguna Madre.

The Laguna Madre which consists of two shallow tidal bays transected and connected by the GIWW, extends 183 km from Corpus Christi Bay to Port Isabel, Texas, near the Mexican border. The average depth is about 1 m. The total surface area is about 1,500 km^2 of which 70 percent is covered by seagrass. Tidal currents and circulation are weak. Wind-waves and wind stress play important roles in sediment resuspension and in material transport.

Since its completion in 1949, dredging of shoaled sediments has been a part of routine GIWW maintenance. The GIWW is 4.3 m deep and 38.1 m wide (14 ft deep by 125 ft wide). Dredging is typically performed on as little as 20- to 38- month cycles to as much as 5- to 46-year cycles, depending on the channel reach; the average total channel sedimentation rate is about 1.6×10^6 m^3 (2.1×10^6 yds^3) per year, which is more than the natural sediment inputs to the system. GIWW construction formed mounds of lagoon sub-bottom sediments along the waterway which have been subject to erosion. In addition, much of the maintenance material disposed along the GIWW eventually is resuspended and dispersed. Channel maintenance materials are mainly fine-grained silts and clays less than 62 μm.

The basis of much environmental concern is that an appreciable area of Lower Laguna Madre apparently became bare sometime between a seagrass survey in 1965 and a subsequent survey in 1974. The deepest area of Lower Laguna Madre apparently was converted from vegetated to bare bottom, while some Upper Laguna Madre areas was converted from bare to vegetated bottom. Speculation was that increased turbidity and decreased light penetrations resulting from dredged material disposal and subsequent dispersion were the cause of the seagrass decline. A seagrass survey in 1988 showed no appreciable increase in bare-bottom areas.

Observations have shown that wave action is primary to the resuspension of sediments; therefore, the first step in wave modeling was to assess previous wave-prediction techniques by comparing the results predicted by use of these techniques with new field data. Waves observed in Laguna Madre did not follow previous wind-wave relationships, possibly because of high wave-dissipation due to friction. Bottom friction, white-capping, and seagrass friction are involved in wave dissipation and are especially important in Laguna Madre. Wave and wind measurements were analyzed and results used to develop a new wind-wave shear stress algorithm for the model system. The new algorithm is based on a partitioning of atmospheric shear stress. Expressions for atmospheric drag coefficient and depth-limited wave height and period were also developed.

Measurements made of suspended sediment concentrations, suspended floc-size distributions, and bed-material properties show suspended sediment concentrations vary both spatially and temporally and overall from about 5 to 500 mg/l. Bed sediments are sands over most of Laguna Madre with some limited areas of fine-grained sediments. Measurement information from this study, from associated studies, and from previous studies was used to specify initial, boundary, sediment, and seagrass conditions in the model and to validate model performance.

Field measurements and laboratory experiments were conducted to develop information on settling, erosion, and depositional properties for use in the sediment model. In this study, sediment bed erodibility was the key factor under investigation. Erosion parameters were determined by erosion experiments and characterization tests on material from the system. Erosion experiments were performed on undisturbed box cores obtained from the lagoon. Channel sediments were also used in the laboratory to create simulated dredged-material slurries. Slurry samples were allowed to settle and consolidate before erosion testing was begun.

Erodibility of dredged material depends upon the dredging and disposal procedures as well as upon sediment properties. Field sampling was performed around a working dredge to obtain characteristics of the fluid-

mud-gravity underflow and the water-column plume formed by the disposal. The underflow extended about 500 m from the pipeline disposal point. Median fluid mud thicknesses were 0.45 m of which the top 60 percent was interpreted as underflow, and the remainder was deposit. A plume of 200 to 500 mg/l above ambient concentrations occurred above, but not much outside of, the underflow footprint.

The effect of suspended sediment concentration on floc settling rate due to flocculation was included in the model. Information on this process was obtained from the field and laboratory settling experiments. Field experiments were carried out to measure floc size on undisturbed suspensions; a limited number of underwater light and turbidity measurements were made in the field; laboratory settling experiments were performed, and several dozen water samples were collected, and their organic and calcium carbonate contents were determined.

Because it is very difficult to separate effects of dredged material resuspension by use of field data, the approach of this study was to apply a physics-based sediment model, with and without dredged material disposal, to gauge the water-column TSM effects from disposal area resuspension and thereby to eliminate the variability in other conditions. One purpose of model simulations was to provide suspended sediment time-series, at certain points within the system, to a Seagrass Productivity Modeling (SPM) team for seagrass growth assessment. Another purpose was to provide spatial distributions of water column impacts on suspension concentrations and on availability of light to seagrasses.

Two-dimensional, depth-averaged, numerical hydrodynamic and sediment transport models were developed and applied. The modeling effort was divided into estuarine circulation, wind-wave, and sediment components. Modeling was performed in two dimensions (2-D), depth-averaged, using the U.S. Army Corps' Surface Modeling System (SMS ©) and the TABS-MDS model. TABS-MDS is an enhanced version of the earlier RMA10-WES and RMA10 models that did not have sediment transport capability. The TABS-MDS was given new capabilities for this study.

The TABS-MDS model performs implicit finite-element solutions of the depth-averaged Navier-Stokes equations for turbulent flow. Model equations based on conservation of mass and momentum (shallow water wave equations) include non-linear advective and friction effects. The latest bathymetry was compiled and used to develop the model mesh. Assignment of model roughnesses was based on the sediment type, bed roughness features, depth, and the species of submersed aquatic vegetation. The effect of aquatic vegetation on hydraulic roughness was obtained from literature. Precipitation and evaporation were included.

Sediment grain-size distributions were discretized into one clay, two silt and one sand fractions for TABS-MDS model simulations. The TABS-MDS sediment model simulates erosion and deposition processes and includes bed processes such as consolidation and erodibility relationships for grain size composition and bed density. For a given erosion rate (mass per unit area), the model uses the dry density of the bed layers to compute the change in bed elevation. The model uses a layered bed structure to characterize the density and erodibility both horizontally and vertically in the bed.

During model adjustment, sediment parameters were adjusted in small steps about their estimated values and the response of the model observed. In this way, the combination of parameters that were physically reasonable and that minimize the differences between model and prototype data were determined. Model adjustment simulations lasted long enough to wash out the effects of initial conditions and to reach equilibrium concentrations with respect to water-mass residence times.

After the model adjustment, the ability of the model to predict suspended-sediment concentrations was quantified by comparing its data to field data. Suspended-sediment concentrations, channel deposition, and overall placement area (PA) erosion rates were used in the comparisons. The initial model scenarios included annual simulations with and without dredged material disposal. Six PA were simulated. Results were used to gauge water column impacts of the dredged material as it dispersed in the year following disposal. Results from 26 locations, mostly in Lower Laguna Madre, were also used in the SPM seagrass growth model.

Sediment model comparison of disposal and no-disposal conditions showed that disposal at, and subsequent dispersion from, six existing most heavily used PAs had a relatively small effect on adjacent seagrass areas, other than during the disposal period. Areas which had the greatest TSM impacts tended to be those specified as bare in the model and, therefore, those areas that already had high TSM levels. This explains why there were only small differences in the 20 percent bottom irradiance contours (subsequent to model disposals and first month dispersion). Disposal versus no-disposal channel shoaling differences were also relatively small, only about a 6 to 15 percent decrease attributable to removing dredged material from the system. About 14 percent of dispersed dredged material redeposited in the GIWW channel.

Several plans for alternate PA locations were tested with the model. In Lower Laguna Madre, PA 233 and 234 (located about 12 km north of Port Isabel) have received the highest dredged material volumes in Laguna Madre, and the adjacent channel area has long been identified as one of

the major deposition and channel maintenance problems along the Texas section of the GIWW. Model tests were performed and these PA's were relocated to the west into deeper water. Channel shoaling was reduced, and more material was retained within the proposed sites. A confined site configuration was also tested for the PA's.

Slightly to the north, PA 232, which has shoaled up over the years, was moved from the west to the east side of the GIWW in the model. Model results indicated that in the new location channel shoaling was slightly decreased. Subsequent investigation indicated that seagrass was growing at the proposed relocation site.

In Upper Laguna Madre, PA 186 to 189 were combined into a site on the west side of the GIWW at a relatively deep area known as Emmord's Hole. The intent was to concentrate immediate water column impacts into an area that has no vegetation at the present time. During the month of disposal, the model indicated that an area about 700 m long would have TSM increased by 26 mg/l. During the subsequent 11 months, TSM increased by no more than 7 mg/l outside of Emmord's Hole.

Contents

Summary ii

Preface xx

1---Introduction 1
Background 1
Seagrass and sediment interactions 1
Site description 4
Environmental concerns 9
Purpose 10
Scope 11
Estuarine circulation modeling 12
Wind-wave modeling 12
Sediment transport modeling 12
Report Organization 13

2---Wind-Waves and Atmospheric Shear Stress 14
Background 14
Atmospheric shear stress 14
Shear stress budget 16
Depth-limited waves for unvegetated bottoms 17
Wave friction formulations 18
Measurements and Data Processing 19
Waves and currents 19
Wind conditions 20
Observational results 24
Wave conditions 24
Current conditions 24
Results and Discussion 24
Atmospheric friction factors 24
Shear stress budget 35
Depth-limited waves with high bed roughness effects 37
Wave friction factors 47

3---Suspension and Underwater Light Conditions 48
Background 48
WES TSM and underwater light measurements 48
Texas Natural Resources Conservation Commission monitoring 50
Conrad Blucher Institute TSM monitoring 50

Seagrass Productivity Model Team measurements 51
Satellite images 51
WES Methods 52
Underwater light 52
Suspended material 53
Data and sample analysis 53
PAR 53
OBS 53
TSM 53
Turbidity 54
CaCO3 and LOI. 54
Floc size. 54
Results 54
PAR profiles 54
December 1996 54
June 1997 56
November 1997 58
TSM and turbidity 61
Sediment and floc characteristics 71
SPM measurements of TSM 73
Satellite images 77
Discussion and Conclusions 77

4---Sediment Measurements and Experiments 83
Settling Experiments 83
Background 83
Methods 84
Results 86
Bed Sediments 94
Methods 94
Results 94
Erosion Experiments 99
Background 99
Materials and methods 100
Results 102
Discussion 102

5---Initial Sediment Dispersion Near a Dredged Material Discharge 109
Introduction 109
Pipeline Discharge Underflows 110
Field Observations 111
Field methods 111
Laboratory methods 113
Field and laboratory results 115
February 10. 115
February 16. 119
Underflow Spreading Processes 131
Entrainment into the Water Column 131
Discussion 137

6---Model Description 139
General Model Features 139
Bed material types 140
Bed sheltering by submersed vegetation 140
Model limitations 141
Hydrodynamic Model 142
Frictional effects of submersed vegetation 143
Current friction. 144
Wave friction. 144
Sediment Transport Model 144
Cohesive sediment characteristics 146
Grain-class formulation 147
Size-spectra response to deposition 147
Concentration effects on settling velocity 148
Deposition rate 151
Erosion rate 153
Bed-layer model 154
Coefficient adjustment method 157
Model tests 157
Numerical grain-class deposition experiments. 157
Numerical steady-state suspension experiments 158

7---Model Validation and Base Simulations 163
Model Mesh 163
Hydrodynamic Model Validation 167
Validation data set 167
Model-prototype comparisons 171
Sediment Transport Model 181
Validation data sets 183
CBI TSM measurements. 183
TNRCC measurements. 184
Model-Prototype Comparisons 184
Suspended material. 184
Dispersion of sediment from PAs. 188
Channel shoaling. 193
Base Simulations 196
Scenario description 196
Results 197
Water column impacts 198
Light availability effects 198

8---Sediment Model Testing of Proposed Relocation of
PAs 232, 233, and 234 196
Introduction 196
Methods 196
Results 200
Discussion 201

9---Dredged Material Dispersion Analysis for Emmord's Hole Near PA 187 203
Site Information 203

Model Modification and Adjustment 205
Disposal Scenario 210
Model Results 210
Discussion 213

10—Conclusions 215

References 218

Appendices

A—TABS-MDS Hydrodynamic Description A1

B—Base-Run Results and Comparisons . . . . . Plates B1 - B103

C—Relocation Run Results . . . . . Plates C1 - C40

D—Emmord's Hole Results and Comparisons . . . . . Plates D1 - D36

List of Figures

Figure 1. The coupling of shear stresses under the influence of seagrass roughness, wave steepness, and resuspension 3

Figure 2. The Laguna Madre study area, wave station locations, and depth contours (coordinates are state plane, NAD27 Texas South, in meters) 5

Figure 3. Dredging history for PA 233 7

Figure 4. Dredging history for PA 234 8

Figure 5. Example measurement spectra (a) for current component and pressure signals, and (b) with regression line fit to velocity component to determine peak height 21

Figure 6. The statistical distributions of raw and 3-hr low pass smoothed wave heights 22

Figure 7. Comparison of measured maximum near-bed wave currents with those calculated from wave characteristics and linear wave theory 23

Figure 8. The statistical distributions of raw wind speeds from three stations and 3-hr low pass smoothed wind speed 25

Figure 9. Histogram of wind direction for the study period 26

Figure 10. Histograms of significant wave heights for the six measurement stations 27

Figure 11. Histograms of peak wave periods for the six measurement stations 28

Figure 12. Comparison of atmospheric friction factors calculated based on Wu (Wu 1980), A & K (Atakturk and Katsaros, 1999), and Equations 4, 23, and 24 33

Figure 13. Comparisons of atmospheric friction factor calculated Equations 23 (symbols) and 24 (lines) for four measurement stations . . . 34

Figure 14. Ratios τ_{aw}/τ_a calculated according to Charnock's parameter and Equation 9, Equation 26, and wave characteristics and atmospheric shear stresses 36

Figure 15. Dimensionless wave parameters for station U1w (diamonds are optimum winds and dots are all other winds) with model fits: (a) wave energy versus depth, and (b) wave frequency versus depth 38

Figure 16. Dimensionless wave energy E^* versus depth h^* for four Laguna Madre measurement stations with previous model fits 39

Figure 17. Dimensionless wave frequency f^* versus depth h^* for four Laguna Madre measurement stations with previous model fits 40

Figure 18. Dimensionless wave energy versus fetch length χ^* at stations L1w and L2w for four ranges of h^* 41

Figure 19. Dimensionless wave energy E' versus depth h^* for four Laguna Madre measurement stations 43

Figure 20. Dimensionless wave frequency f' versus depth h^* for four Laguna Madre measurement stations 44

Figure 21. Significant wave heights computed with Equation 29 versus observed values for four Laguna Madre stations 45

Figure 22. Peak wave periods computed with Equation 30 versus observed values for four Laguna Madre stations 46

Figure 23. Measurement ranges for the November 1997 tidal pass survey 49

Figure 24. Tidal survey TSM and discharge time-series data for Brazos Santiago Pass (with trend lines), June 1997 62

Figure 25. Tidal survey TSM and discharge time-series data for Old Port Isabel Causeway (with trend lines), June 1997 63

Figure 26. Tidal survey TSM and discharge time-series data for Port Mansfield Pass (with trend lines), June 1997 64

Figure 27. Tidal survey LOI and CaCO3 data for Brazos Santiago Pass, June 1997 65

Figure 28. Tidal survey LOI and CaCO3 data for Port Mansfield Pass, June 1997 66

Figure 29. Scatter plots of turbidity, LOI, and CaCO3 against each other for the June 1997 Brazos Santiago Pass tidal survey 67

Figure 30. Scatter plots of turbidity, LOI, and CaCO3 against each other for the June 1997 Port Mansfield Pass tidal survey 68

Figure 31. Tidal survey TSM versus turbidity for Brazos Santiago Pass, Old Port Isabel Causeway, and Port Mansfield Pass (Ranges 1, 5, and 7) with trend line, June 1997 69

Figure 32. Relationship between TSM and turbidity for samples collected by WES within Laguna Madre (with trend line), June 1997 . . . 70

Figure 33. Scatter plots of TSM, CaCO3, LOI, and floc size (µm) against each other. Data from Lower Laguna Madre taken November 1997 72

Figure 34. LANDSAT 5, band 3 image from Port Isabel to Arroyo Colorado taken 20 August 1994 with 0.7- and 1.4-m depth contours and station locations superimposed (coordinates are UTM zone 14, NAD83, in meters) 78

Figure 35. LANDSAT 5, band 3 image from Port Isabel to Arroyo Colorado taken 24 November 1994 with 0.7- and 1.4-m depth contours and station locations superimposed (coordinates are UTM zone 14, NAD83, in meters) 79

Figure 36. Depth-mean K_{dm} versus TSM for the three WES surveys 81

Figure 37. Point K_m versus TSM for the three WES surveys 82

Figure 38. Experimental results for the effect of shear on settling velocity and a fit of Equation 34 to the data 87

Figure 39. Model clay settling velocity results for varying shear and concentration and a fit of Equation 35 to the data 88

Figure 40. Natural sediment settling velocity results for varying shear and concentration and a fit of Equation 35 to the data 89

Figure 41. Cumulative settling velocity and dispersed particle-size distributions for the special particle-size settling test 91

Figure 42. The 25, 50, and 75 percentile (less than) settling velocities for quiescent column tests 92

Figure 43. Time-series of discrete dispersed-particle-size distributions during the special particle-size settling test 93

Figure 44. Example suspension time-series for the first test series 104

Figure 45. Example suspension time-series for the second test series . . . 105

Figure 46. Linear-regression fits through 1-, 7-, 14-, and 21-day standing time taking all slurry tests together 106

Figure 47. Cumulative probability distributions for various standing times plotted on standard deviation coordinates 107

Figure 48. Cumulative probability distributions for various *BWD*'s plotted on standard deviation coordinates 108

Figure 49. Vicinity sketch of Lower Laguna Madre north of Port Manfield, Texas, with depth contours and discharge locations (coordinates are state plane NAD27, Texas South, in meters) 112

Figure 50. Fluid-mud sampler on deck in the open position 114

Figure 51. Hindered settling test results (right) with the (dashed) fit to the data described in the text, and low-concentration settling results (left) from Teeter et al. (2001a) 116

Figure 52. Times/depths (CST/m) for stations taken 10 February 2000 . . 117

Figure 53. Depth-averaged TSM (mg/l) collected 10 February 2000 . . . 118

Figure 54. Overflight photo of the dredging and disposal operation taken 1019 CST 10 February 2000 (coordinates are state plane NAD27, Texas South, in meters) 120

Figure 55. Times/depths (CST/m) for stations taken 16 February 2000 . . 121

Figure 56. Photo of a pipeline discharge into about 0.5 m water depth and the resulting turbulent surface flow 122

Figure 57. Vertical fluid mud profiles taken 16 February 2000 123

Figure 58. Interpreted and interpolated underflow profiles normalized by underflow thicknesses and mean concentrations 125

Figure 59. Fluid-mud thicknesses collected 16 February 2000 126

Figure 60. Interpolated underflow mean concentrations, thicknesses, deposit thickness, and water-column depth over the underflow for mud profile stations 16 February 2000 127

Figure 61. Depth-averaged TSM (mg/l) collected 16 February 2000 . . . 128

Figure 62. Definitions for some variables 130

Figure 63. Viscosity at 50 sec^{-1} shear rate and yield stress for fluid mud from Gulfport Harbor, Mississippi 132

Figure 64. Yield stress for Laguna Madre GIWW sediments and other muds 133

Figure 65. The relation of friction factors f (left) and Manning's n (right) to current speed u for the data of Gambi et al. (1990) 145

Figure 66. Floc (right) and grain (left) spectra based on tidal measurements of Kranck and Milligan (1992) for varying suspended sediment concentrations 149

Figure 67. Definition of upper and lower limiting concentrations for enhanced settling, and example grain class exponents 150

Figure 68. Settling of a 100-kg/m^3 bed layer deposited instantaneously just after hour 0.0 showing layer boundaries (also lines of constant concentration) and resulting bed profile 156

Figure 69. Numerical experiment results for m = 1, 0, -1 for deposition under a shear stress of 0.16 Pa 159

Figure 70. Relative suspension concentration during kaolinite deposition experiments (Mehta and Partheniades 1975). Initial shear stress was 1.05 Pa for all tests 160

Figure 71. (a) Observed C_f/C_o corresponding to Figure 70, (b) example model result with one grain class, (c) example model result for four grain classes 161

Figure 72. Model relative TSM concentration curves for ns = 1 for (a) 0.1 hour, and (b) 1 hour of deposition 162

Figure 73. Model mesh nodes and depths. TNRCC stations TNR-446 and TNR-447 are indicated as circles south-to-north along the GIWW 164

Figure 74. Model mesh nodes and depths. TNRCC stations TNR-448 and TNR-449 are indicated as circles south-to-north along the GIWW 165

Figure 75. Model mesh nodes and depths. TNRCC stations TNR-444, -445, and -443 are indicated as circles south-to-north along the GIWW 166

Figure 76. Lower Laguna Madre model bed material types. Bare areas are solid colors and seagrass areas are textured green colors . . 168

Figure 77. Upper Laguna Madre model bed material types. Bare areas are solid colors and seagrass areas are textured green colors . . 169

Figure 78a. Model and prototype 1997 water-surface elevation comparisons 171

Figure 78b. Model and prototype 1997 water-surface elevation comparisons 172

Figure 79. Model and prototype tidal discharges at Brazos Santiago . . . 173

Figure 80. Model and prototype tidal discharges at South Bay Pass 174

Figure 81. Model and prototype tidal discharges at Port Isabel Causeway 175

Figure 82. Model and prototype tidal discharges at Port Isabel 176

Figure 83. Model and prototype tidal discharges at Port Mansfield Inlet 177

Figure 84. Model versus prototype current magnitudes 178

Figure 85. Model and prototype currents West of the GIWW 180

Figure 86. Example TSM data from the beginning of LLM1 to 3 and combined time-series 183

Figure 87. Cumulative standard-normal distributions for LLM1 to 3 and combined data sets (see text for further explanation) . . . 185

Figure 88. Lower Laguna Madre TNRCC station TSM time-series 187

Figure 89. Cumulative standard-normal distributions for Lower Laguna Madre TNRCC stations 188

Figure 90. Example model and prototype TSM time-series at LLM1 starting 1 September 1994. Disposal occurred during hours 720 to 840 189

Figure 91. Channel shoaling distribution for validation model run 191

Figure 92. Existing PA 232 to 234 sites with 5,000-m grid lines and 1,000-m grid points overlain. Site PA 232 was displaced to the west in the model because of very shallow water existing at the designated site 197

Figure 93. Proposed relocated PA 232 to 234 sites 199

Figure 94. Depth contours (1, 1.4, and 1.8 m) near Emmord's Hole (coordinates are state plane NAD27, in meters) 204

Figure 95. Bottom vegetation, disposal footprint, and station locations near Emmord's Hole (coordinates are state plane NAD27, in meters) 206

Figure 96. TSM distributions for TNRCC stations and PB samples plotted in relation to their deviation from the median 207

Figure 97. Model grain class composition for dredged material for Upper and Lower Laguna Madre 211

List of Tables

Table 1. Limiting TSM for Plant Light 2

Table 2. Comparison of PA 233 and 234 Dredging Volumes (m^3) for Three Periods 6

Table 3. Wave Station Locations and Select Fetch Length 19

Table 4. Summary of Wave Gauge Observations 29

Table 5. Summary of Current Observations 30

Table 6. Coefficients for Equation 21 for Wind Direction Bands 31

Table 7. Wave Friction Heights and Shear Stresses for Lower Laguna Madre Stations 47

Table 8. Laguna Madre Reach Descriptions 50

Table 9. Location of TNRCC Monitoring Stations in Laguna Madre . . . 51

Table 10. LANDSAT 5 Band Wavelength and Color 52

Table 11. Station Locations December 1996 55

Table 12. Depth Average Light and TSM for December 1996 55

Table 13. Light and TSM Profiles for December 1996 55

Table 14. Station Locations June 1997 56

Table 15. Depth Average Light and TSM for June 1997 56

Table 16. Light and TSM Profiles for June 1997 57

Table 17. Station Location and Times for 11 and 12 November 1997 . . . 58

Table 18. Station Locations, Depths and Times for 13 November 1997 58

Table 19. Depth Average Light and TSM for November 1997 59

Table 20. Light and TSM Profiles for November 1997 59

Table 21. Floc Size and TSS at 0.76 m Depth on 13 November 1997 . . . 73

Table 22. Seagrass Productivity Model GIWW Station Locations 73

Table 23. Summary of Seagrass Productivity Model TSM Measurements (mg/l) 75

Table 24. Comparison of TSM (mg/l) Between Nearby Stations 75

Table 25. Field Settling Tests June 1997 86

Table 26. Settling Velocity Distributions, mm/sec, for Quiescent Column Tests 90

Table 27. Settling and Dispersed Particle Size Distributions 90

Table 28. Bed Sediment Station Locations 95

Table 29. Summary of Bed-Sediment Density and Grain-Size Measurements 96

Table 30. Summary of Resistivity Measurements on Bed Sediment 98

Table 31. Erosion Test Sediment Characteristics 102

Table 32. Summary of Fluid-Mud Sediment Characteristics from Near Pipeline Discharge 129

Table 33. Entrainment Conditions at Underflow Profile Stations 136

Table 34. Estimated Bed Sheltering Factors for Seagrass Species 141

Table 35. Field and Model Tidal Water Level Variability for January 1998 170

Table 36. Dredged Material Disposal Characteristics 181

Table 37. Grain-Class Distribution for Model Placed Dredged Material 181

Table 38. Statistical Analyses of LLM1 to 3 and Combined Data Sets 184

Table 39. Model Validation TSM Comparisons 186

Table 40. Model Sediment Dispersion from Disposal PA 190

Table 41. Example With- and Without-Disposal Model Channel Shoaling Volumes 192

Table 42. Model Base-Simulation TSM Comparisons 193

Table 43. Base-Run Model Sediment Dispersion from Disposal PAs 194

Table 44. Example Irradiance Percentages and $ln(Q/Q_o)$ Reaching the Bed 195

Table 45. Existing PA Areas and Disposal Rates in the Model 198

Table 46. Relocated PA Areas in the Model 201

Table 47. Channel Shoaling as a Percent of the Base 201

Table 48. Sediment Dispersion as a Percent of the Placed Material . . . 202

Table 49. Field TSM Results, mg/l 205

Table 50. Suspended-Sediment Monitoring Stations in Laguna Madre 208

Table 51. Field-to-Model Suspended-Sediment Distribution Comparisons 209

Table 52. Areas and Volumes in Northern Emmord's Hole 209

Table 53. Effects of Disposal on TSM Distributions at the Monitoring Stations 212

Table 54. Useful Life Span Estimate for Proposed Northern Emmord's Hole PA 214

Preface

The study described herein was conducted from April 1997 to March 2002 for the U.S. Army Engineer District, Galveston (CESWG), by personnel of the U.S. Army Engineer Research and Development Center (ERDC), Waterways Experiment Station (WES), Coastal and Hydraulics Laboratory (CHL). General supervision was provided by Dr. James R. Houston, former Director CHL; Mr. Thomas W. Richardson, Director, CHL; Dr. William H. McAnally, Jr., former Chief, Waterways and Estuaries Division; and Dr. Rob McAdory, Chief, Estuarine Engineering Branch (EEB), CHL.

Dr. Allen M. Teeter and Messrs. Gary L. Brown, Michael P. Alexander, Christopher J. Callegan, and Mses. M. Soraya Sarruff and Darla C. McVan, all of EEB, conducted the model study. Messrs. Howard Benson, Sam Varnel, and Thad Pratt, all of EEB, and Mr. Dave Thomas, of PBS&J a contractor to CESWG, participated in the field data collection. Ms. Claire Livingston, a contractor to EEB, and Mr. Doug Brister, EEB, performed the laboratory analyses and experiments.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander.

This report should be cited as follows:

Teeter, A. M., Brown, G. L., Alexander, M. P., Callegan, C. J., Sarruff, M. S. , and McVan, D. C. (2002). “Wind-wave resuspension and circulation of sediment and dredged material in Laguna Madre, Texas,” ERDC/CHL TR-02-XX, U. S. Army Engineer Research and Development Center, Vicksburg, MS.