Overview of Corps of Engineers Nearshore/Aquatic Placement Tools and Models

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Jarrell Smith

GOAL

- Develop a suite of models and tools to represent sediment and constituent transport due to dredging
- Range from screening level to highly complex, 3-D models
- Includes research to understand and better predict (model) sediment processes

Sediment and Dredging Processes

- Most dredged material is mixture of sand, silt and clay
- Behavior of these mixtures not as well understood as pure sand
- Dredging impact on sediment processes not well understood
- Ongoing DOER funded research in dredging and mixed sediment processes is supporting modeling
  - Mixed sediment erosion and transport
  - Dredging loss terms
  - Monitoring dredging and placement operations
  - Long-term dispersion and consolidation of dredged material

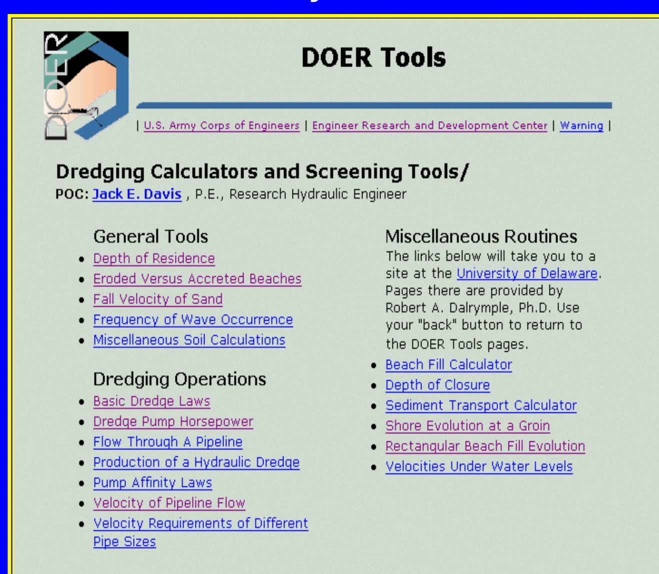
Three Tiers of Models

- Web-based screening level tools/models
- Process-specific, near-field models
  - STFATE
  - MDFATE
  - LTFATE
  - GTRAN
- Large domain, far-field models
  - SSFATE/PTM

Dredging Tools via Web

- Interactive tools related to dredging operations and sediment movement.
- www.wes.army.mil/el/dots/doer/tools.html

http://el.erdc.usace.army.mil/dots/doer/tools.html



DOER Tools

| U.S. Army Corps of Engineers | Engineer Research and Development Center | Warning |

Dredging Calculators and Screening Tools/

POC: Jack E. Davis , P.E., Research Hydraulic Engineer

General Tools

- Depth of Residence
- Eroded Versus Accreted Beaches
- Fall Velocity of Sand
- Frequency of Wave Occurrence
- Miscellaneous Soil Calculations

Dredging Operations

- Basic Dredge Laws
- Dredge Pump Horsepower
- Flow Through A Pipeline
- Production of a Hydraulic Dredge
- Pump Affinity Laws
- Velocity of Pipeline Flow
- Velocity Requirements of Different Pipe Sizes

Miscellaneous Routines

The links below will take you to a site at the University of Delaware. Pages there are provided by Robert A. Dalrymple, Ph.D. Use your "back" button to return to the DOER Tools pages.

- Beach Fill Calculator
- Depth of Closure
- Sediment Transport Calculator
- Shore Evolution at a Groin
- Rectangular Beach Fill Evolution
- Velocities Under Water Levels

DOER Tools

Estimating the Terminal Fall Velocity of Sand

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- This method is a quick screening tool and is **not** for detailed design. The results are considered a **rough estimate** and a more thorough evaluation should be considered for a detailed design.
- This method should **not** be used with mass discharge. It should be used only for low concentrations.

Parameter Limitations		
Parameter	**Range**	
Specific gravity of solid	0 to 3.0	
Sand size, D_{50}	0.074 to 10 mm	
Depth of disposing vessel	0 to 30 ft or 0 to 9 m	Input
Depth of water	3 to 500 ft or 1 to 150 m	
Current	0 to 6.5 ft/sec[1] or 1 to 200 cm/sec[1]	

[1]**NOTE:** If the maximum value of current is selected, the sediment will not remain on the bed (deposit out) and will transport either as suspension or bed load.

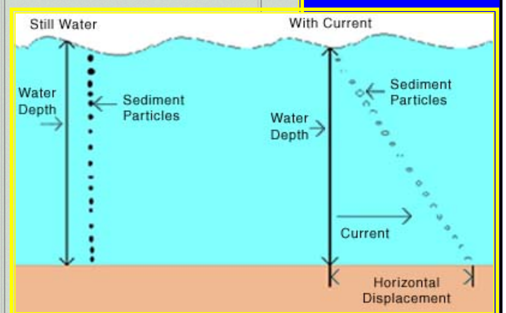
Fall Velocity of Beach Sand

Specific gravity of solid 1.65	Current velocity 20 (•) cm/sec ( ) ft/sec
Water (•) Salt (33 ppt) ( ) Fresh	Water depth 20 (•) m ( ) ft
Median grain size **(mm)** .3	Draft of disposing vessel 4 (•) m ( ) ft
Water Temperature °C 20	

Calculate or Clear Form

Fall Velocity Calculations

INPUT		OUTPUT	
Specific Gravity Solid	1.65	**Fall Velocity**	1.91 cm/sec (0.063 ft/sec)
Specific Gravity Fluid	1.025	**Descent Time**	835 sec (13 min 55 sec)
Median Grain Size	0.300 mm	**Horizontal Displacement**	167 m (548. ft)
Water Temperature	20. °C		
Water Depth	20 m (66. ft)		
Fluid Kinetic Viscosity	0.0105 cm^2/sec		
Current Velocity	20.0 cm/sec (0.66 ft/sec)		
Draft Disposing Vehicle	4.0 m (13.1 ft)		



Near-Field Models

- http://el.erdc.usace.army.mil/dots/models.html
- STFATE
- MDFATE/MPFATE
- LTFATE
- GTRAN

- Generally, designed to model a specific dredging process

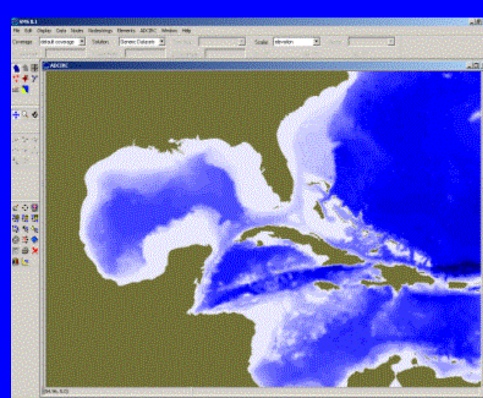
Near-Field Model Interface

- Models depend on both field data and large domain hydrodynamic data
- SMS is the large-domain modeling interface for ERDC
- Includes multiple hydrodynamic, wave, and atmospheric models
- Incorporate near- and far-field dredging models into SMS while maintaining stand-alone versions.

What is the SMS?

Surface-water Modeling System --- interface for:

- Grid generation and editing
- Model control file generation
- Input forcing functions (*Tide, wind, waves, river flows)*
- Model simulation
- Coordinate conversion
- Incorporate data fields
- Model simulation
- Model output visualization
- Report-quality graphics



STFATE

Short-Term Fate of Dredged Material

- Background
- Model Description
- Required Input
- Examples

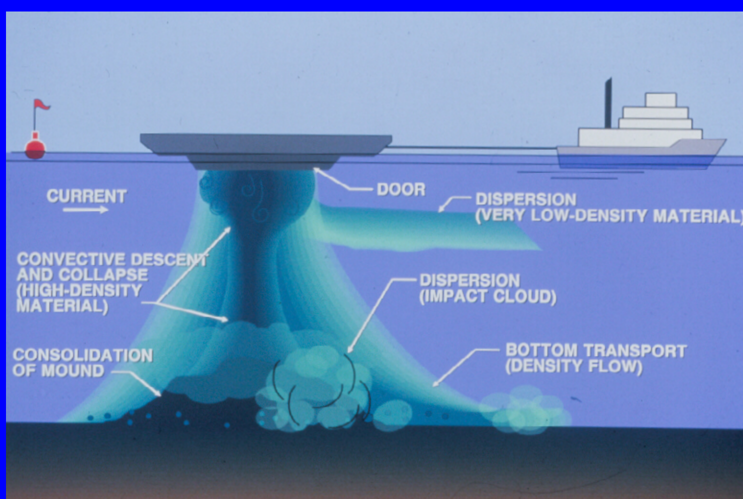
STFATE Applications

- Provide initial deposition pattern from placement
- Provide water column concentrations for environmental purposes
- Guide field data collection
- Disposal site selection
- Manage disposal sites

Processes Represented

- Convective Descent - controlled by gravity and momentum
- Dynamic Collapse - bottom encounter or neutrally buoyant, horizontal spreading dominates
- Passive Transport Dispersion – currents & turbulence dominate

Phases of Disposal Operation



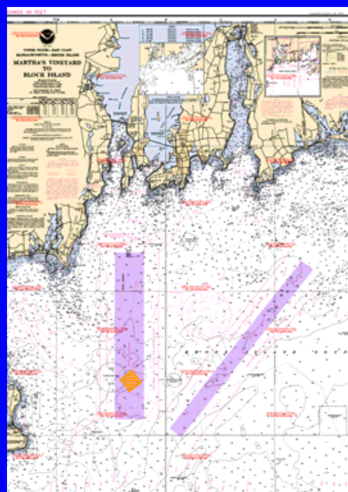
Environmental Applications

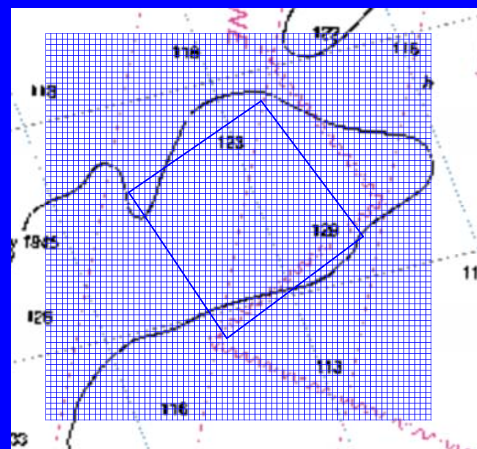
- Section 103 of the Marine Protection Research and Sanctuary Act (Ocean Dumping)
- Section 404 (B)(1) of the Clean Water Act (Inland Dumping)
- Plume Generation and Transport Evaluations

Input Requirements

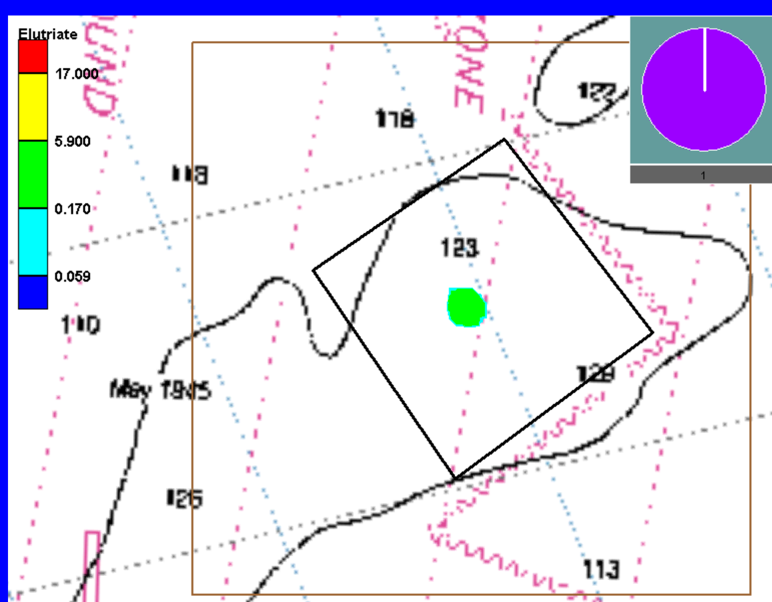
- Disposal site description
- Currents & density profile at disposal site
- Input/output/execution Controls
- Dredged material description
- Disposal operation
- Model coefficients

Disposal Site Description

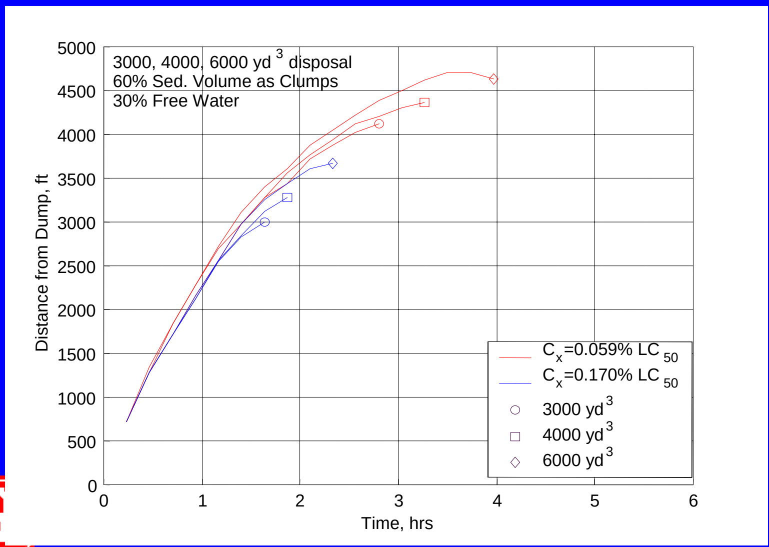




Model Simulation



Site 69b, Elutriate



STFATE Software

http://el.erdc.usace.army.mil/dots/models.html

- Software - older DOS Version
- New SMS version now available
- User’s guide - from Inland Testing Manual, also online
- POC - Dr. Paul Schroeder (601) 634-3709
- Paul.R.Schroeder@erdc.usace.army.mil

MDFATE/ MPFATE

Multiple Disposal Fate of Dredged Material
Multiple Placement Fate of Dredged Material

- Background
- Model Description
- Basic Model Input/Output
- Example Applications

MDFATE Background

- Placement of dredged material at Open water Dredged Material Placement Sites (ODMPS)
- Concerns
  - Obtaining/maintaining regulatory approval
  - Minimize navigation hazards
  - Maximize site volumetric capacity
  - Capping of sediment deposits

MDFATE Background

- Developed for quantitative assessment of bathymetric changes resulting from multiple open water placements
- Includes consolidation, erosion, and avalanching
- New MPFATE also includes resulting accumulation of suspended material
- Utilizes modified versions of STFATE and LTFATE

ODMPS Management Tool

- Ensure environmental compliance & maximize site efficiency
  – No navigation hazards
  – No adverse impacts to resources
  – Maximize site volumetric capacity
  – Maximize operational efficiency
- Couple monitoring and modeling for more efficient management

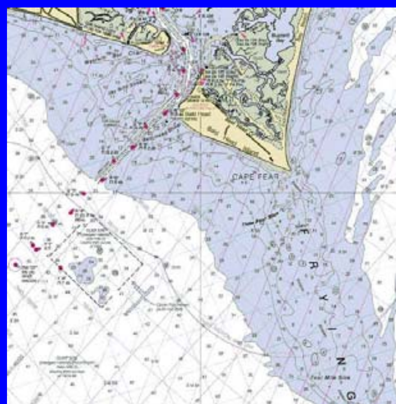
MDFATE Description

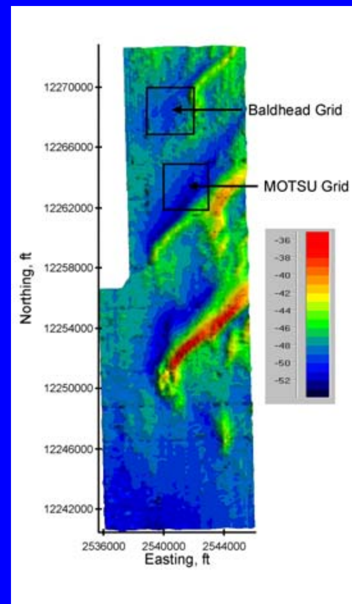
- Provide final deposition pattern
  - conventional placement
  - capping or spreading placement
- Assess options for site selection
- Manage placement sites
  - Impact of changes in placement operations
- Placement operations tool

MDFATE Description

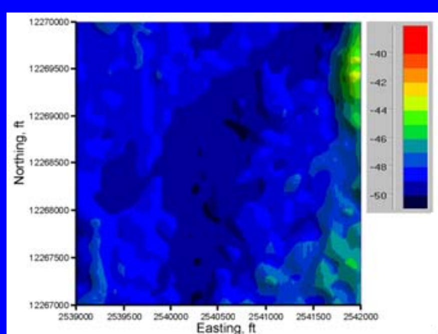
- **STFATE processes –** Only MPFATE includes water column calculation for mixing zone, tracer concentration etc.
- **Avalanching -** due to mound slope instability
- **Consolidation –** for cohesive sediments
- **Long-term sediment migration/dispersion - ** due to waves & currents (non cohesive)

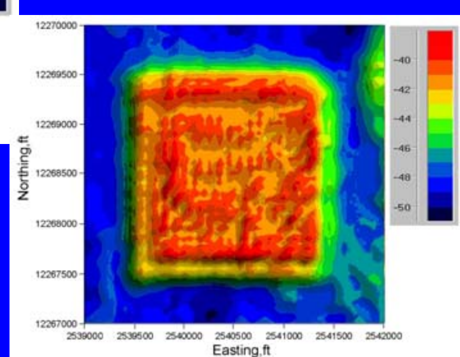
Dredged Material Fate Modeling of Wilmington Harbor ODMDS





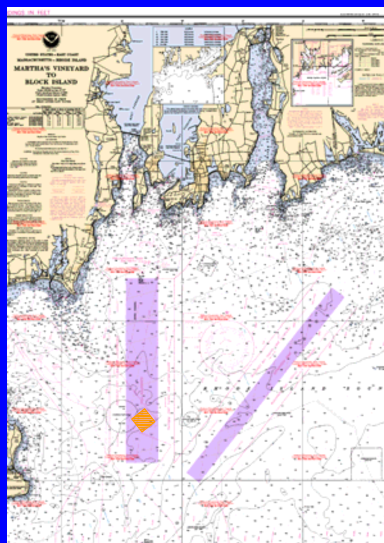
Wilmington proposed ODMDS bathymetry and Baldhead Shoal and MOTSU MDFATE grids (depth in ft).

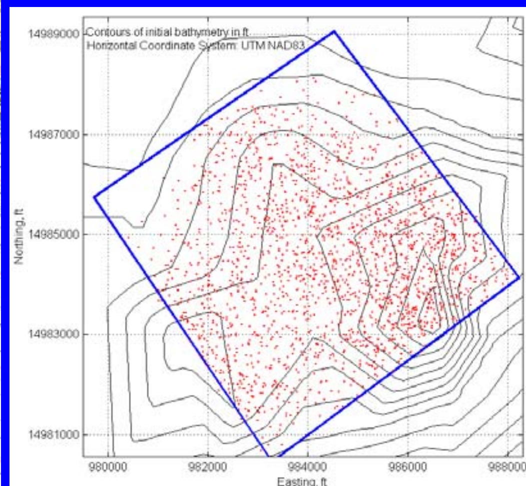




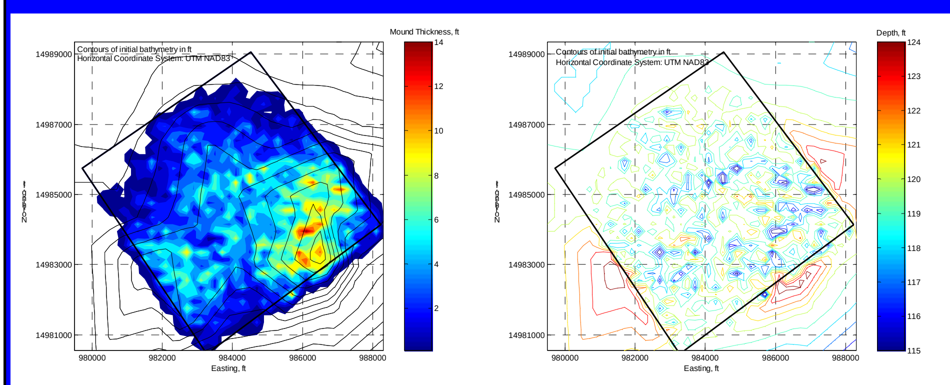
Pre- and Post-placement bathymetry for the Baldhead Shoal Channel dredged material mound (depth in ft).

MPFATE Disposal

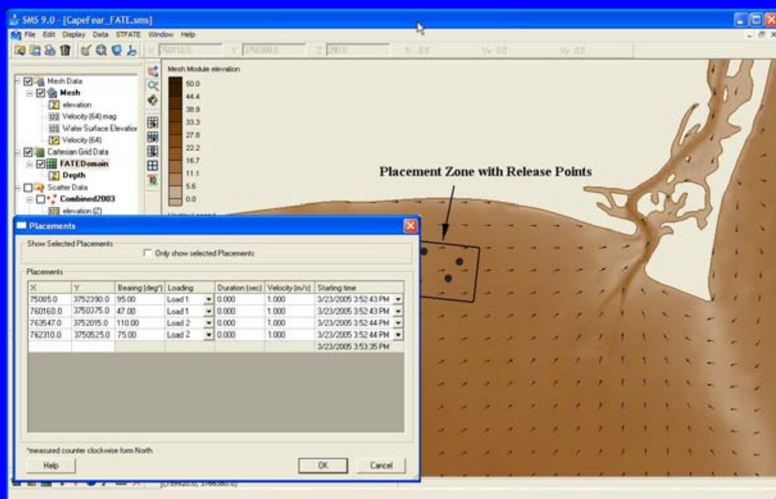




Final Configuration



SMS Interface for MPFATE



MDFATE/MPFATE Software

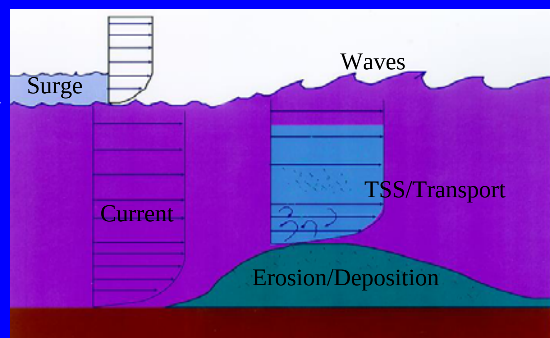
http://el.erdc.usace.army.mil/dots/models.html

- MDFATE software - older DOS Version
- User’s guide – available online
- MPFATE available upon request
- SMS-MPFATE available 09/05
- POC - Mr. Jarrell Smith (601) 634-4310
- Jarrell.Smith@erdc.usace.army.mil

LTFATE

Long Term Fate of Dredged Material

- Background
- Model Description
- Basic Model Input/Output
- Example Applications



LTFATE Model Description

- 2-D finite difference hydrodynamics and sediment transport
- Localized model with flexible boundary conditions developed from data or other models
- Designed for multiple storm simulations
- Includes complex cohesive sediment processes
- Three-dimensional layered sediment bed model
- Bathymetry changes updated frequently
- Temporal variation of seconds, spatial variation ~10m

LTFATE Model Input

- Mound and local bathymetry (surveys, MDFATE)
- Hydrodynamic boundary conditions (time series of current velocity and direction
- Wave boundary conditions
- Sediment Properties
  - Grain size distribution
  - Cohesive erosion parameters
  - Settling velocity

LTFATE Model Output

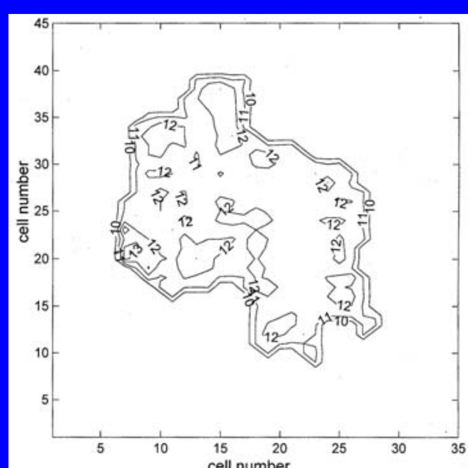
- Mound migration/spreading
- Loss of material from local area (dispersion)
- Final mound bathymetry
- Final mound sediment composition
- Erosion depths
- Time-varying concentrations
- Sediment bed shear stress time history

LTFATE Model Application: LALB Harbor

- Mound bathymetry from MDFATE model
- Areas outside pit assumed to be 9 m depth
- Queen’s Gate erosion algorithms and bulk density profiles incorporated into the model
- CH3D circulation model used to develop current and elevation boundary conditions
- Wave hindcast and shoaling used to develop local storm wave conditions

Initial Energy Island Bathymetry

- Idealized mound bathymetry (can be created within LTFATE)
- Import mound bathymetry from MDFATE model
- Develop mound bathymetry from data



Storm Conditions (20 year hindcast)

TABLE 1: Storm Conditions of selected test storms

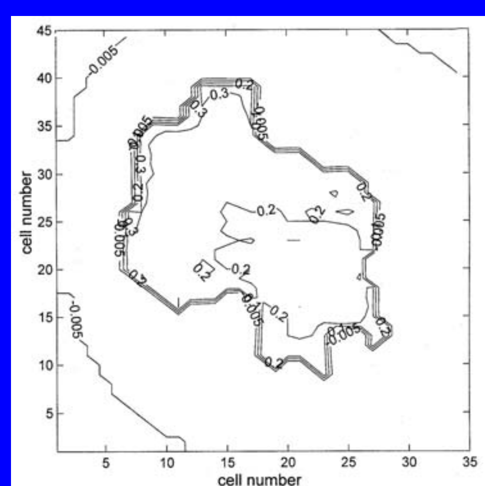
Storm Date	Maximum Wave Height at Harbor Entrance (m)	Maximum Wave Height at CAD cell (m)	Maximum Wave Period (s)	Maximum Velocity at CAD cell (cm/s)
01/17/88	4.4	2.0	16.5	5.9
01/26/83	2.6	1.0	18.0	8.6
02/14/86	4.1	1.8	16.5	6.9
02/28/83	5.4	2.5	17.5	22.4

TABLE 2: Storm induced erosion from CAD cell

Storm Date	Maximum erosion (m)	Average Erosion (m)
01/17/88	0.12	0.06
01/26/83	0.05	0.02
02/14/86	0.12	0.06
02/28/83	0.30	0.12

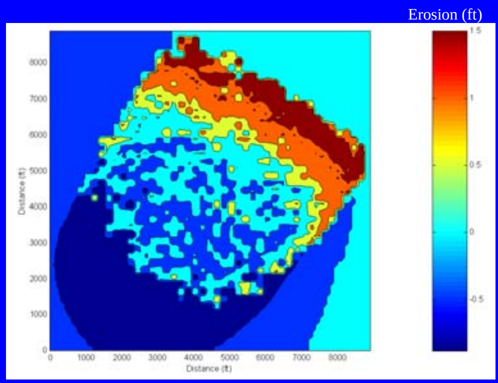
LTFATE Model Results

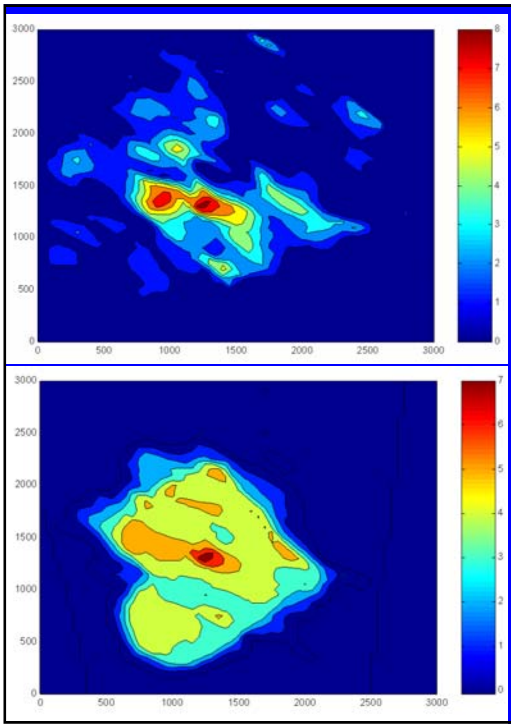
- Estimate of mound migration
- Estimate of volume removed from mound
- Estimate volume re-deposited locally
- Estimate volume dispersed
- Multiple variation of possible storm conditions
- Multiple variations of sediment properties and mound configurations



LTFATE Model Results

- Estimate of mound migration
- Estimate of volume removed from mound
- Estimate volume re-deposited locally
- Estimate volume dispersed
- Multiple variations of possible storm conditions
- Multiple variations of sediment properties



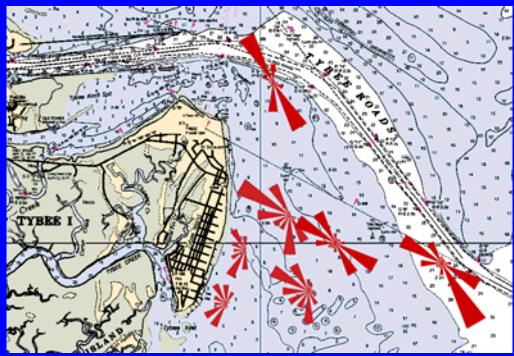


- Comparison of actual and estimated erosion at MOTSU mound, Wilmington ODMDS during Hurricane Fran

GTRAN

Gridded TRANsport Model

- Background
- Model Description
- Basic Model Input/Output
- Example Application



GTRAN Model Description

- Calculates transport direction and magnitude at multiple points on a domain
- Does not calculate fate of material
- Designed to operate on large domain model output
- Includes complex cohesive sediment processes and sand transport processes
- Designed for nearshore application outside of wave breaking zone (includes wave asymmetry)
- Temporal variation: storm - seasonal - years

GTRAN Model Input

- Time series of current (hourly) over an entire domain
- Time series of wave conditions over an entire domain
- Domain Bathymetry
- Sediment Properties
  – Grain size distribution
  – Cohesive erosion parameters

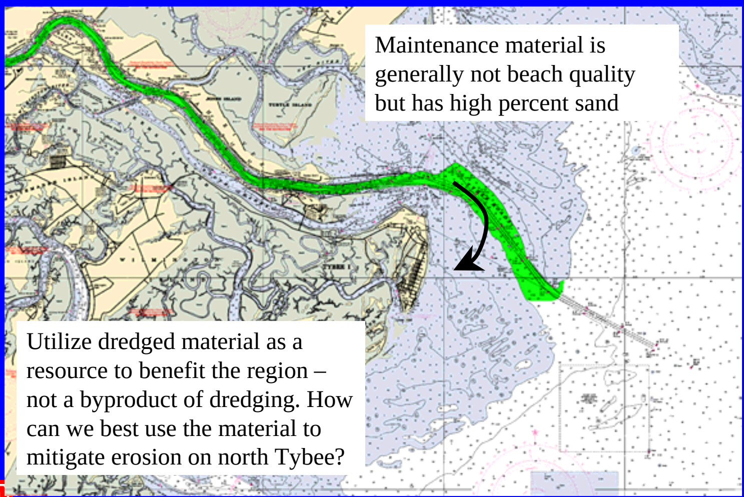
GTRAN Model Output

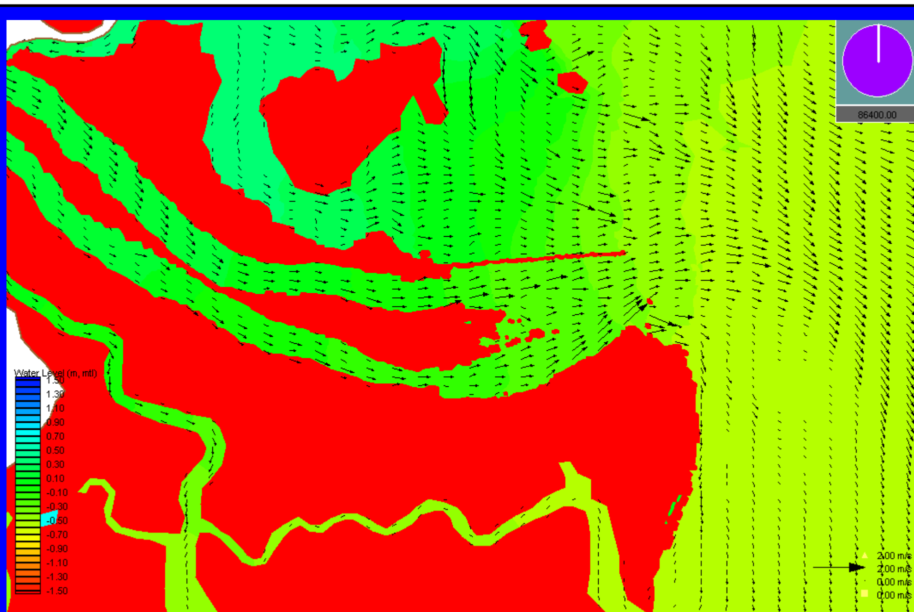
- Transport directions and magnitudes at multiple locations on the domain
- Data interpreted to determine transport pathways and generalized transport directions

GTRAN Model Application: Savannah Harbor Entrance Channel

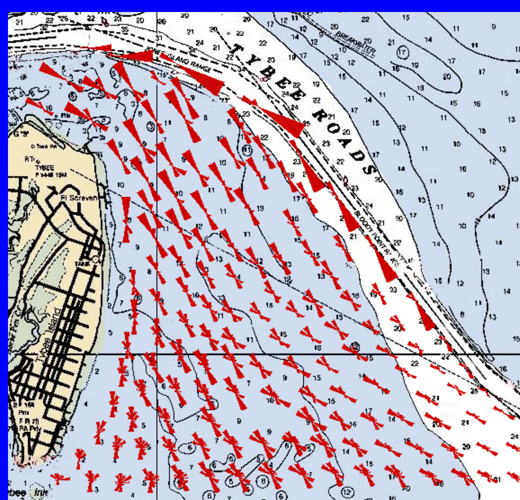
- Multibeam survey of entire ebb shoal region
- District plans to place dredged material in nearshore for littoral zone nourishment and barrier island stabilization
- Both cohesive and sandy dredged material
- Choose placement locations to optimize benefit to the barrier island and minimize material rehandling

GTRAN Model Application: Savannah Harbor Entrance Channel



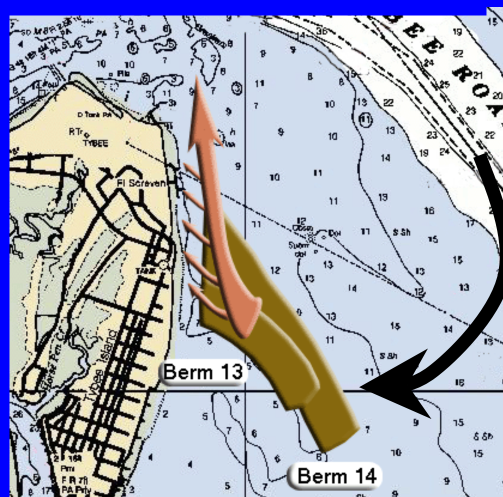


GTRAN Model Application: Savannah Harbor Entrance Channel



GTRAN Model Application: Savannah Harbor Entrance Channel

- Move mixed material from channel to Berm 13/14
  Allow natural winnowing to remove fine content
  Longshore transport patterns will move sediment into sand-starved north Tybee littoral zone



SSFATE and Particle Tracking Model (PTM)

- PTM is a Lagrangian particle tracker used to evaluate particle transport and pathways
- PTM predicts suspended sediment behavior under waves, tides and currents.
- It is applicable to rivers, waterways, coasts and oceans.
- PTM is being developed to operate within the Surface-water Modeling System (SMS) as a joint effort by DOER and CIRP

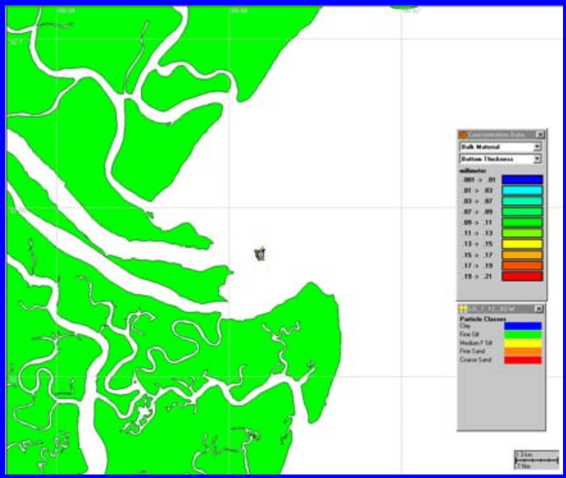
SSFATE/PTM Capabilities

- Isolate and track specific sources of sediment (outfalls, dredging, prop-induced suspension, …)
- Map sediment pathways (e.g. monitor movement of sediment from a specific source such as a dredge)
- Predict of sediment accretion and erosion zones
- Forecasting the potential negative impact of turbidity and deposition on WQ, beaches, SAV, spawning grounds, etc…
- Tracking and predicting contaminant and contaminated-sediment transport

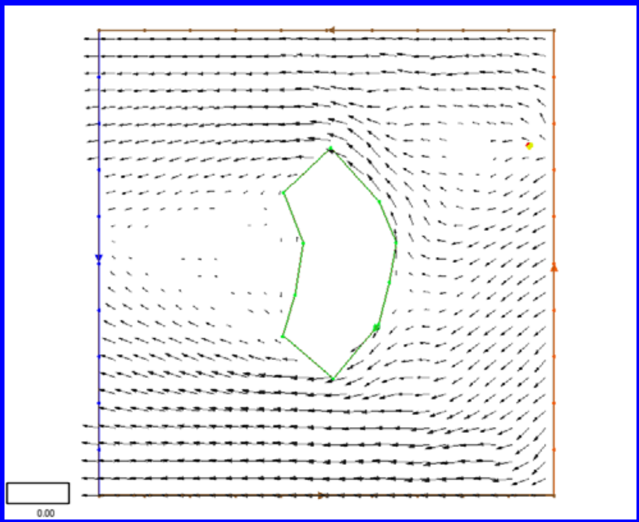
SSFATE/PTM Capabilities

- Unstructured grid to permit modeling of complex regions
- Uses large-domain models for hydrodynamics and waves to drive the sediment particles, including settling and resuspension
- Multiple sediment classes simulated
- Define specific dredging process sediment sources (based on DOER-sponsored field and laboratory research efforts)
- 2-D, Quasi-3D, and 3D modes

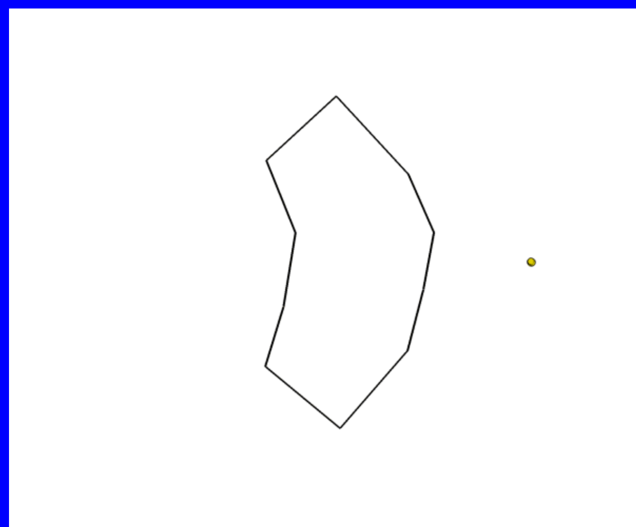
SSFATE Dredging Scenario



PTM Dredging Scenario



PTM Dredging Scenario



Summary

- Continued advancement of three tiers of dredging tools for screening level through advanced applications
- Development of new interfaces and systems for easy interaction between dredging models and large domain hydrodynamic models
- Continued research to understand dredging and sediment processes to support modeling