

Applying Particle Tracking Model in the Coastal Modeling System

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PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes procedures to set up a particle tracking simulation through coupling the Coastal Modeling System (CMS) and Particle Tracking Model (PTM) in the Surface-water Modeling System (SMS). The step-by-step CMS-PTM setup is illustrated by a coastal application at Noyo, CA.

INTRODUCTION: The CMS is an integrated wave, current, sediment transport, and morphology change model for coastal and inlet applications (Buttolph et al. 2006; Lin et al. 2008) that was developed by the Coastal Inlets Research Program (CIRP). The Particle Tracking Model (PTM) was developed jointly by CIRP and the Dredging Operations and Engineering Research (DOER) program as a tool to compute the fate and pathways of sediments and other waterborne particulates in coastal engineering and dredging operations (MacDonald et al. 2006; Demirbilek et al. 2008). CMS-PTM is implemented in the SMS (Aquaveo 2010), which is a graphical user interface utility for PCs developed by the U.S. Army Corps of Engineers (USACE).

NOYO NEARSHORE SEDIMENT PLACEMENT PILOT STUDY: Noyo Harbor and Noyo River are located on the northern California coast. Every year about 30,000-40,000 cy of beachquality sediment is dredged from the Noyo River Federal Navigation Channel. The USACE San Francisco District (SPN) and the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center, are presently collaborating with the Noyo Harbor District and stakeholders in a pilot study to investigate a potential candidate site for nearshore placement of dredged sediment. Upland disposal sites used in the past will soon be exceeded. The pilot study proposes a dispersive nearshore site 3 to 8 miles north of Noyo Bay along the northern California coast (Figure 1).

To evaluate the potential impacts of nearshore placement, a Short-Term Fate of Dredged Material Model (STFATE) and CMS were applied for the study. SPN has applied STFATE to calculate near-field sediment transport and suspended sediment concentration during the placement of the dredged material. The USACE CIRP applied the CMS and CMS-PTM to simulate sediment transport for combined waves and currents under various ambient conditions and project alternatives. The model results will provide the technical information necessary to evaluate a demonstration site that is economically feasible for the optimum sediment placement location.

CMS-PTM: The CMS calculates water levels, currents and waves through the coupling of a hydrodynamic model, CMS-Flow and a wave spectral model, CMS-Wave. CMS-Flow also simulates sediment and salinity transport, and morphology change.

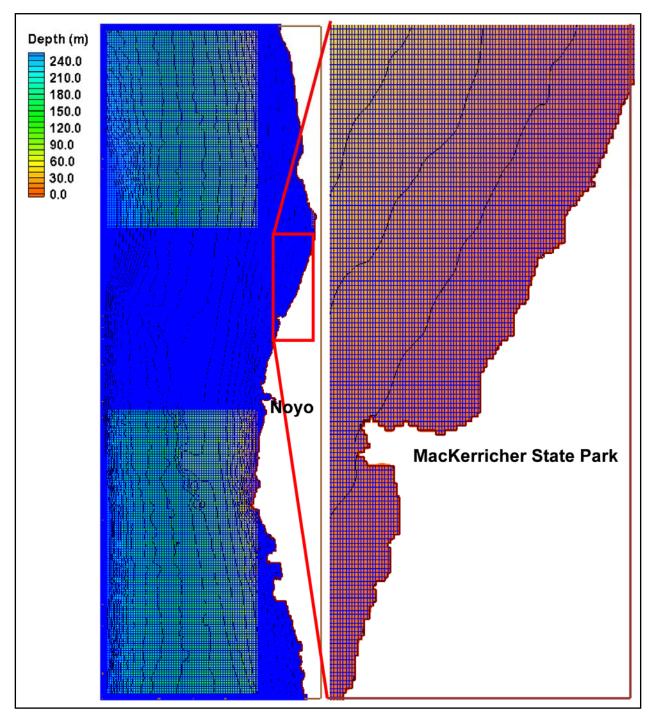


Figure 1. CMS domain, grid, and bathymetry.

CMS-Flow is driven by time-dependent water surface elevation at the offshore open boundaries, and wind forcing over the surface boundary. Directional wave data for input to CMS-Wave are available from the National Data Buoy Center (NDBC, *http://www.ndbc.noaa.gov*) and Coastal Data Information Program (CDIP, *http://cdip.ucsd.edu*). The wave conditions are specified at the seaward boundaries.

CMS-Flow requires three input files and CMS-Wave requires six input files through the SMS. Each of the CMS-Flow and CMS-Wave simulations will generate its own output file (Figure 2).

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My Recent	<pre> flow-exist-Alt2.cmcards flow-exist-Alt2_grid.h5 flow-exist-Alt2_mp.h5 </pre>	CMS-Flow Input	
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Desktop	wave-exist-Alt2.eng wave-exist-Alt2.sim wave-exist-Alt2.std wave-exist-Alt2.struct	CMS-Wave Input	
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Figure 2. CMS files.

The CMS-Flow input and output files are required, while the CMS-Wave output files are optional for setting up a CMS-PTM simulation. After loading the required hydrodynamic and/or wave files, users can follow the steps below to set up the CMS-PTM simulation for the Noyo application.

- **1. Native Sediment Dataset:** CMS-PTM requires spatially varying native bed sediment data specified as datasets, including the grain size information of d35, d50, and d90 for each cell, in the CMS-Flow grid.
 - i) Select and open the CMS-Flow control file, *"flow-exist-Alt2.cmcards"* (Figure 2).
 - ii) Choose *Data* | *Data Calculator* in the CMS-Flow menu.
 - iii) Name the first dataset, d35, in the *Output data set name* and specify a constant value, 0.1 mm in the *Calculator*.
 - iv) Click *Compute* to generate the dataset.
 - v) Repeat steps iii) and iv) to generate the datasets for d50 and d90 (Figure 3), (for the Noyo simulation, d50=0.2 mm and d90=0.4 mm).

Ataset Toolbox Tools - Math - Compare data sets - Data Calculator - Temporal - Sample time steps - Compute derivative - Conversion - Scalar to Vector - Vector to Scalar - Modification - Map activity - Filter	Data Calculator Data Sets Alt3 (CMS-Flow) 123 a. D50 123 b. Hard Bottom 123 c. ManningsN 2 d. Depth 3 imulation 123 e. Bathymetry 123 f. Capacity 123 g. Concentration 123 h. Current_Magnitude 123 j. Water_Elevation	Time Steps
	Add to Expression Data Set Info	Calculator () min * In x^y max - log sqrt ave + 1/x abs trunc
Update Available Tools Help	Output data set name: d35	Compute

Figure 3. Generate the datasets, d35, d50, and d90.

- vi) Click Done to exit the Data Calculator.
- vii) Highlight the datasets, d35, d50, and d90, right-click, and select Export Datasets (Figure 4).
- viii) Select *XMDF file* in the *File Type*, check *All time-steps* in the *Time-steps*, and click the *Filename* to save the file "NativeSediments.h5" in the present working folder.
- 2. Land-water Interface Boundary Strings: CMS-PTM requires specifications of both open and closed boundaries. Open boundaries are specified in CMS-Flow, so closed boundaries need to be added for CMS-PTM (future versions of SMS will automatically generate the closed boundaries). The steps to perform this task are described as follows:
 - i) Choose *Cellstring* | *Generate Along Boundary* (this step will generate redundant boundary strings overlapped with existing strings along open boundaries) (Figure 5).
 - ii) Choose the *Select Cellstring* tool and select the *Land boundary* along the open boundary.
 - iii) Right-click and choose *Delete* (Figure 5).

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Figure 4. Generate the native sediment file.

- iv) Repeat steps ii) and iii) to delete other *Land boundary* cellstrings overlapped with existing open boundaries if more than one open boundaries exist in CMS-Flow.
- v) Save the project.
- **3. Sediment Sources:** Particles can be released from different source options. In CMS-PTM, sediment sources can be specified as points, lines, or areas. For the Noyo application, an area source was designated to represent the nearshore placement of dredged materials from a barge. The steps for creating the source file in SMS are:
 - i) Switch to the *Map Module* by clicking the icon \checkmark .
 - ii) Right-click the *default coverage* and choose *Type* | *Models* | *PTM* after generating the rectangular area for the sediment release (Figure 6).
 - iii) Choose the *Select Feature Polygon* icon 🔊 and click on the area source.
 - iv) Right-click the polygon, select *Attributes*, and the *Feature Object Attributes* will pop up.
 - v) Select the *Horizontal Polygon Source* in the *Type* (Figure 7).
 - vi) Specify *Date/Time* for the particle release, *Parcel Mass (kg)*, released mass *Rate (kg/m^2/s)*, and *Median Grain Size (mm)* of released particles (Figure 7).
 - vii) Save the area source specification as a map file.

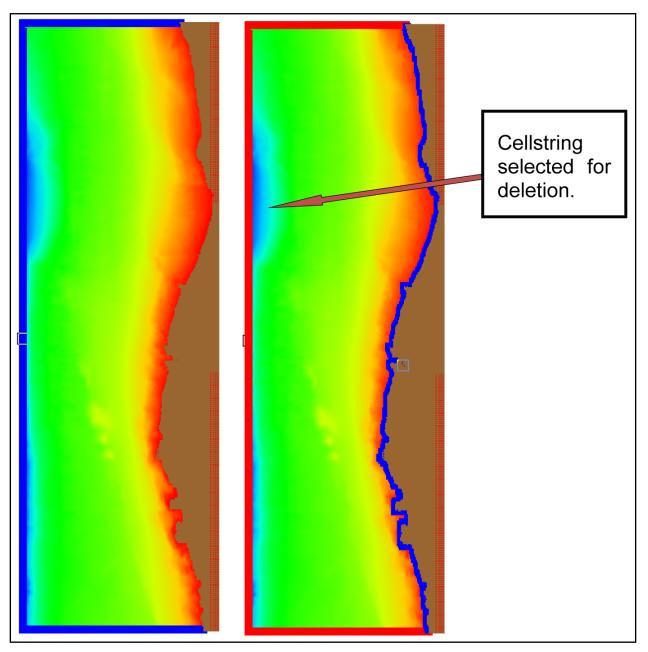


Figure 5. Generate the boundary cellstrings.

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Figure 6. Link source file to CMS-PTM.

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ame: Default Polygon Name	•				🗌 🗆 Show Co	ordinates ir	n Spreadsheet		
Date/Time	Parcel Mass	Vert. Radius	Rate	Median Grain Size	Standard Deviation	Density	Fall Velocity	Critical Shear Initiation	Critical Shear Deposition
	(kg)	(m)	(kg/m²/s)	(mm)	(Phi-units)	(kg/m²)	(m/sec)	(N/m²)	(N/m²)
8/2/2008 8:00:00 AM 🛛 💌	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 8:10:00 AM 🛛 🔽	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 8:10:01 AM 🛛 🔽	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 3:59:59 PM 🛛 🔽	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
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Figure 7. Define particle release scenario from the area source.

- **4. CMS-PTM Setup:** After the hydrodynamic data, native sediment data, source file, and boundary cellstrings are generated, users can follow the steps below to specify the CMS-PTM parameters and set up the CMS-PTM simulation.
 - i) Switch to *Particle Module* by clicking the icon **S**.

- ii) Choose *PTM* | *New Simulation*.
- iii) Choose *PTM* | *Model Control*.
- Simulation time (Figure 8).
 - i) Specify the starting time of the completed CMS-Flow simulation in the *Hydrodynamics*.
 - ii) Specify the starting and ending times of a CMS-PTM run in the *Simulation*.
 - iii) Specify the time-step for the CMS-PTM simulation and the output time interval in the *Particle Output*.
 - iv) Specify how often to update the sediment parameters and the hydrodynamic variables.

The starting time of CMS-Wave and the time-step for the wave forcing update need to be specified if waves are included in the simulation and selected in the *Files* page.

PTM Model Control for Simula	ation: PartSet	\mathbf{X}
Time Files Computations Output		
	PTM Model Timing	
Simulation Run Hydrodynamics Sources Waves		22 Fri 1 Mon
Aug 2008	Date/Time	
Simulation Start: 8/ 2/2008 12:00:00 AM Stop: 8/31/2008 12:00:00 AM	Particle Output Every: 36 time steps (01:00:00.00 hh:mm:ss)	Shears, Bedforms, and Mobility Update Every: 36 time steps (01:00:00.00 hh:mm:ss)
Ouration: 2505600.000 seconds Time Step: 100.000 seconds	Mapping Output Every: 1000 time steps (27:46:40.00 hh:mm:ss)	Flow and Elevation Update Every: 36 time steps (01:00:00.00 hh:mm:ss)
Waves Start: 8/ 2/2008 8:00:00 AM ▼ Time Step: 10800.0 seconds	Hydrodynamics Start: 8/ 2/2008 12:00:00 AM 💌	Start: 8/ 2/2008 12:00:00 AM I Stop: 1/ 2/1950 12:00:00 AM I Last timestep trap
Help		OKCancel

Figure 8. CMS-PTM model control pages (*Time*).

- Links to hydrodynamic and sediment data (Figure 9).
 - i) Click *Select paths* under the *XMDF Path* and set *Alt2/Datasets/Depth* for the *Depth Path*.
 - ii) Select the CMS solution file, *flow-exist-alt2_sol.h5*, in the working folder for the *Hydrodynamics*.

Description	Options		Filename	XMDF Path			
Grid	CMS-Flow (XMDF)	-	PartAlt2_grid.h5	Select p	aths		
Hydrodynamics	CMS-Flow		Select file	N/A			
Boundary conditions	Existing file		Part_Alt2_mp.h5	N/A			
Sediment source	Existing file	-	Select file	N/A	Select XMD	F D-4h	
Neighbor	Create when model is run	-	Select filename	N/A	Select XMD	r Paun	
Native sediments grain size	XMDF data set		Select file	N/A	Description	Options	XMDF Path
Тгар	Not included in simulation	-	N/A	N/A	Grid Path	Required	Alt2
Waves and breaking	Not included in simulation	-	N/A	N/A	Depth Path	Required	Alt2/Datas
	Not included in sinteletion			108			
Create input file(s) from data				1025			
Create input file(s) from data		Filenar		1028			
Create input file(s) from data						10	Canc

Figure 9. CMS-PTM model control pages (Files).

- iii) Set *Simulation/Current_Velocity* for the *Velocity*, and *Simulation/Water_Elevation* for the *Water surface elevation*.
- iv) Select *default coverage* in the *Sediment source* and name the *part.source* in *Select file-name*.
- v) Select *create when model is run* in the *Neighbor* and name the *part.neighbors* in *Select filename*.
- vi) Include *Waves and breaking* by selecting *CMS-Wave* and click *options* to obtain wave input for CMS-PTM (Figure 10).
- vii) Click the icon it to browse the working folder and to link the wave simulation file, *wave-exist-Alt2.sim*, under the *Parent Grid Geometry* | *CMS simulation file*.
- viii) Click the icon Load (*.wav) to link the wave input file, *wave-exist-Alt2.wav*, under the *Parent Grid Solution Data*.
- *ix)* Specify the *Number of Spectra in file*.
- *x)* Click *OK* to complete the specifications of the page.

Because the wave simulation is included in CMS-PTM, it is necessary to return to the previous (*Time*) page to specify the *Start* time and the *Time-step* under the *Waves* (Figure 8).

Waves	
- Parent Grid Geometry CMS simulation file: 🔲 C:\Noyo\wave-exist-Alt2.sim	Nested Grid Geometry Use Nested Grids CMS simulation file: (none selected)
Parent Grid Solution Data	Note: The nested and parent grids must have the same number of frames and the same times associated with each frame Nested Grid Solution Data Delete
Number of Spectra in file: 248	↓ Load (*.wav) Number of Spectra in file must be the same as the Parent Grid Delete
Load (*.brk)	Load (#.brk)

Figure 10. Specifications of wave input.

• Computation parameters and output

Most of the options in the *Computations* page are default for this Noyo application, except that the 3D mode is selected (Figure 11). In the *Output* page (Figure 12), *Print default keywords* is selected in the *File Output*, and *Source* and *State* are selected in the *Particle Output*.

5. CMS-PTM Results: As described in the previous sections for the Noyo application, CMS-PTM was designed to investigate the fate and transport of dredged materials under the combined influence of waves and currents from proposed placement sites.

The placement site, a rectangular area of $86,600 \text{ yd}^2$, is located about 4 miles north of Noyo Harbor near MacKerricher State Park. The CMS-PTM simulation is for August 1–30, 2008. In this application, clay materials were released at a level of 1 m above the ocean bottom at a rate of twice daily for 12 days. Each release lasted 10 minutes to mimic the barge placement operation. Figures 13 and 14 show the snapshot of calculated clay particle distributions at the end of the release (day 12) and the end of simulation (day 30), respectively. The simulation shows that clay particles either follow the waves propagating towards shore or move southward, driven by the northerly wind in this summer period. A good portion of the fine sediments can move past Noyo Bay to the model's south boundary and some out of the model domain through the simulation. At the end of the simulation, about 65 percent of the released clay particles are considered "dead,"

which means that they are either permanently buried at the sea bed or have moved out of the model domain.

PTM Model Control for	Simulation: PartSet	
Time Files Computations Outp	ut]	
Computation Methods	Computational Parameters	
Advection: 3D 💌	Bed porosity: 0.4	Temperature: 15.0 °C
Centroid: Rouse	Bed density: 2650.0 kg/m ³	Salinity: 34.0 ppt
Distribution: By grain size 💌 Eulerian: PTM 💌	Minimum depth: 0.01 m	
Velocity: 2D (Logarithm	Diffusion Parameters Horizontal	Vertical
Numerical scheme: 2	Min. diffusion coefficient: 0.0 m²/s	0.0 m²/s
	Turbulent diffusion scalar: 0.25	0.00859
	Wave diffusion scalar: 5.0	
Model Calculation Options		
Currents	✓ Hiding and exposure	Residency (polygon trap required)
	Particle-bed interaction	Wave mass transport
Neutrally buoyant particles	✓ Turbulent shear	
Gedforms	Source and trap Z-value relative to datum	
Help		OK Cancel

Figure 11. Specifications of CMS-PTM parameters.

Figure 12. Selections of CMS-PTM output.

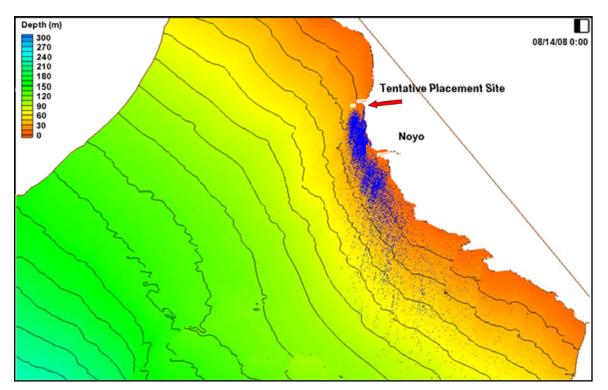


Figure 13. An oblique view of calculated clay particle distribution at the end of the release (day 12). The white square indicates the release area.

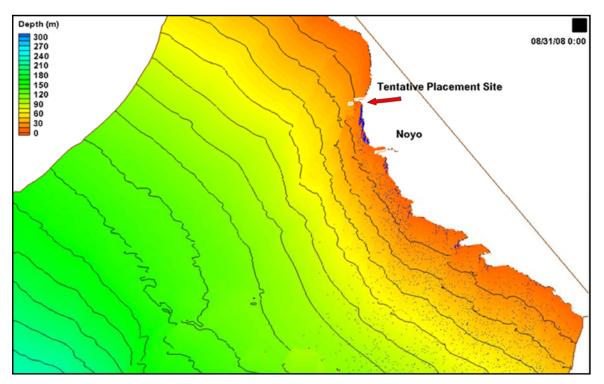


Figure 14. An oblique view of calculated clay particle distribution at the end of the simulation (day 30). The white square indicates the release area.

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