# Coastal Modeling System

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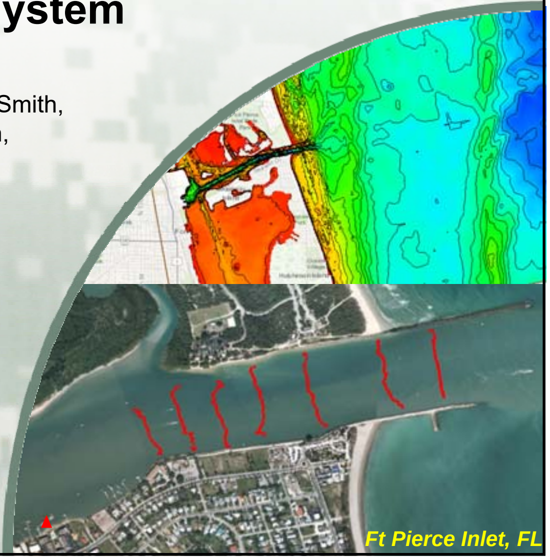

*Ft Pierce Inlet, FL*

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# Coastal Modeling System

- Mission statement
  - Conduct research on nearshore hydrodynamics and sediment transport.
  - Develop numerical modeling tools for district engineers and scientists, apply modeling tools to address engineering issues associated with design, construction, and management of navigation channels, coastal structures, and adjacent beaches, and reduce navigation O&M cost.
- Statements of Need addressed
  - 2017-N-01: Testing and Evaluation of USACE Coastal Numerical Models
  - 2017-N-70: Analysis of Shoreline Response to Nearshore Placement Geometry
  - 2017-N-71: Modeling Effects of Sea Level Change at Tidal Inlets
  - 2016-N-4: Quantifying Wave and Current Driven Sediment Transport at Near-shore Dredge Disposal Sites
  - 2016-N-10: CMS: Continued R&D to Enhance Swash Zone and Surf Zone Sediment Transport Processes
  - 2014-N-7: Quantification of Wave versus Wind-driven Sediment Transport in Beach Morphology Evolution at Shallow Open Coast Inlets
  - 2014-N-14: Coastal Inlet Breach Evolution
  - 2013-N-32: Automated Dredging Analysis Tools for USACE Budgeting and Management
  - 2013-N-37: Dredging Operational Methodologies to Reduce Fines Content at Placement Sites
  - 2013-N-41: Sediment Silt Contents Affect on Turbidity and Associated Environmental Impacts

# FY18 Products

- Journal Papers
  - Coastal Engineering (breach model)
  - JHR (Critical Shear Stress for Erosion)
  - J. Coastal Research (sediment tracer tracking, modeling)
  - Encyclopedia of Coastal Science (Coastal Modeling)
  - J. Marine Science and Engineering (dune erosion) (submitted)
- Technical Reports
  - Long-term Morphological Modeling
  - Sediment Management Studies (Merrimack Inlet)
  - Sediment Tracer Study and CMS Modeling (Coos Bay)
- Contract Report
  - 2-D Coastal Dike and Barrier Breach Model
- CHETNs
  - Linkage between SEDZLJ module and CMS (in review)
  - Modeling sea level change using the CMS (in review)
  - CMS–Wave setup at FRF (in review)
- Conference Papers
  - ICHE2018 (Ft.Pierce)
  - International Conf on Estuaries and Coasts (Tillamook)
  - ICCE2018 (Ogden Dunes, IN)
- Workshops/Webinars/Conferences
  - CMS/PTM/GENCADE Training (Jacksonville District)
  - DOTS (CMS/PTM/GENCADE) Galveston District
  - CWG webinar (CMS/SEDZLJ)
- CMS V5.0 Update
  - Merged code with ASCII input/output
- Release of SMS 12.2/12.3
  - Improved dynamic dialogs

ERDC/CHL TR-18-7
Merrimack Estuary and Newburyport Harbor Sediment Management Studies
ERDC/CHL TR-18-6
Field Measurements, Sediment Tracer Study, and Numerical Modeling at Coos Bay Inlet, Oregon
Coastal and Hydraulics Laboratory

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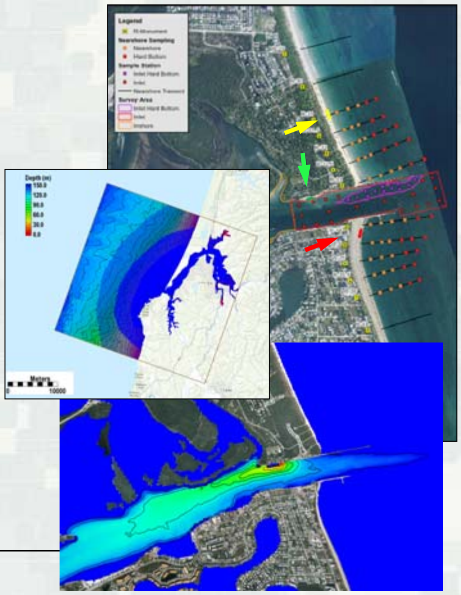
# Sediment Mapping
## (Coos Bay, Oregon and Ft. Pierce, Florida)

- Model development for sediment mapping simulations (Ft Pierce inlet system and adjacent beaches)
- Conduct mid- to long-term simulations to cover the period of sediment tracer deployment and sampling and track sediment with different grain sizes
- Validate sediment mapping implementation in the CMS and predict sediment pathways, and patterns of deposition/erosion demonstrated by tracer release and sampling program
- TR, JP (Coos Bay study)
- Conference Paper (Ft. Pierce study)


Legend
Depth (m)
Meters

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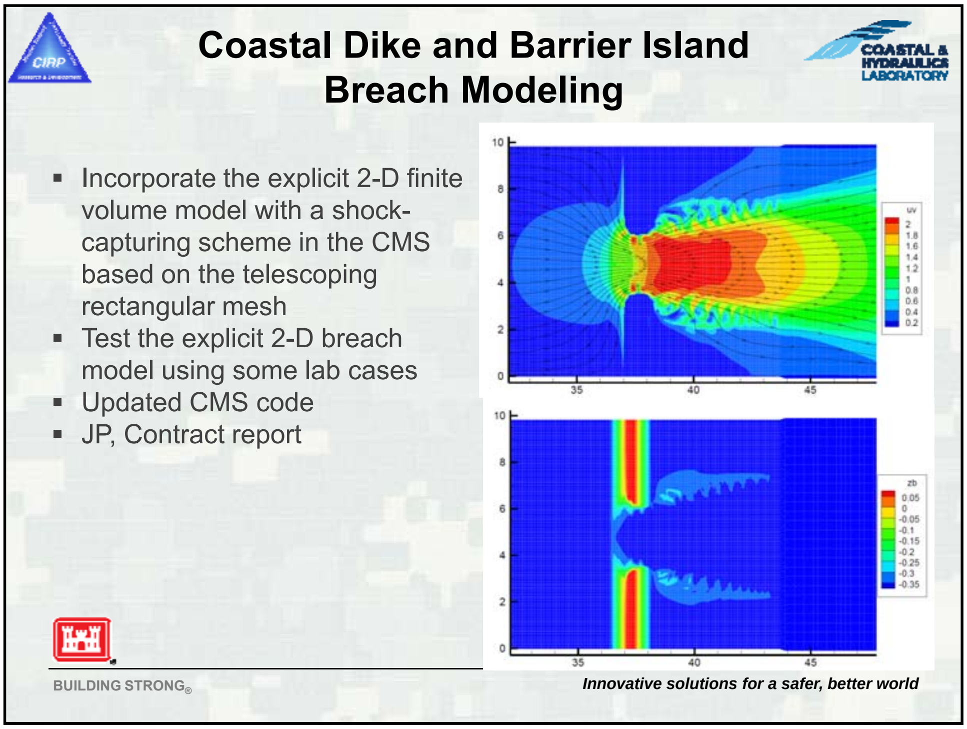
CIRP
10
8
6
4
2
0
35
40
45
uv
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
zb
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35

# Coastal Dike and Barrier Island Breach Modeling

- Incorporate the explicit 2-D finite volume model with a shock-capturing scheme in the CMS based on the telescoping rectangular mesh
- Test the explicit 2-D breach model using some lab cases
- Updated CMS code
- JP, Contract report

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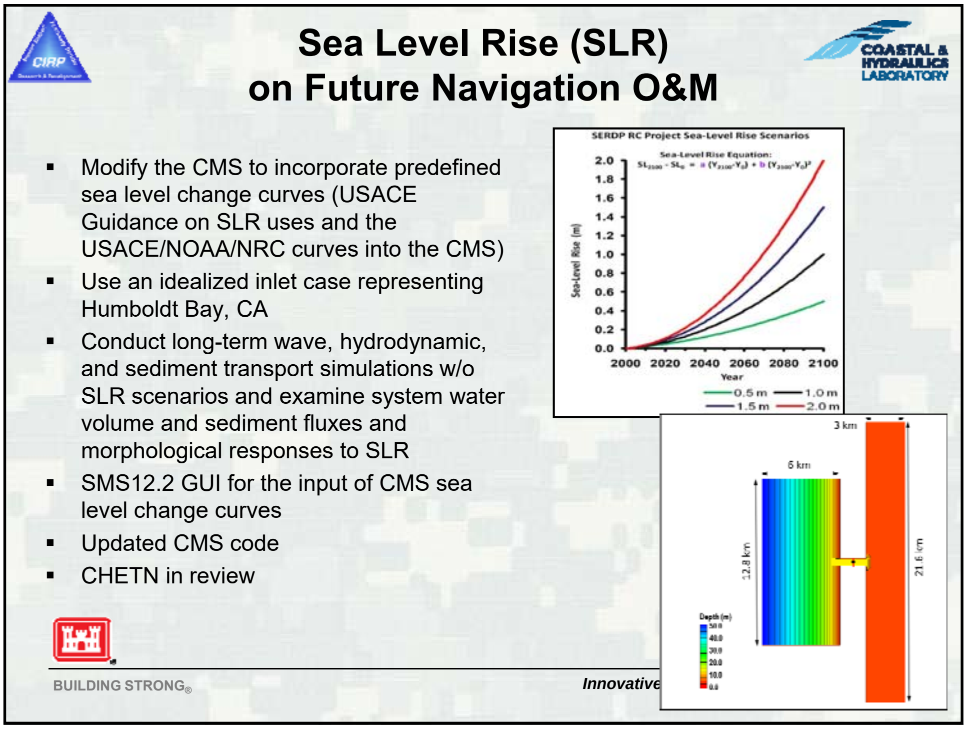
CIRP
SERDP RC Project Sea-Level Rise Scenarios
Sea-Level Rise Equation:
$SL_{2100} - SL_0 = a\,(Y_{2100}-Y_0) + b\,(Y_{2100}-Y_0)^2$
Sea-Level Rise (m)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2000
2020
2040
2060
2080
2100
Year
0.5 m
1.0 m
1.5 m
2.0 m
3 km
6 km
12.8 km
21.6 km
Depth (m)
50.0
40.0
30.0
20.0
10.0
0.0

# Sea Level Rise (SLR) on Future Navigation O&M

- Modify the CMS to incorporate predefined sea level change curves (USACE Guidance on SLR uses and the USACE/NOAA/NRC curves into the CMS)
- Use an idealized inlet case representing Humboldt Bay, CA
- Conduct long-term wave, hydrodynamic, and sediment transport simulations w/o SLR scenarios and examine system water volume and sediment fluxes and morphological responses to SLR
- SMS12.2 GUI for the input of CMS sea level change curves
- Updated CMS code
- CHETN in review

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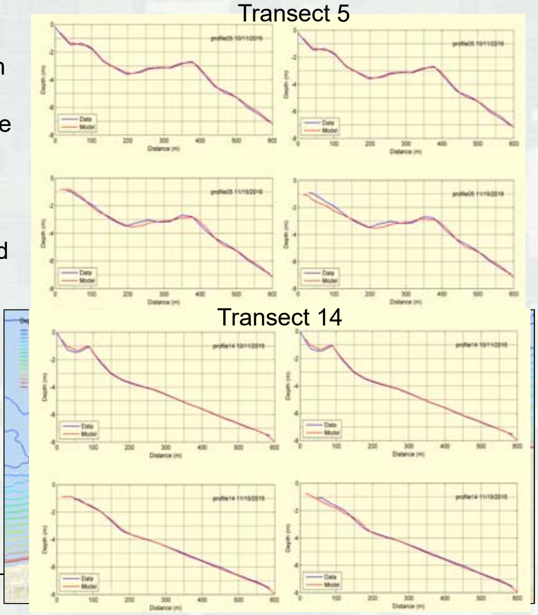
## Modeling Cross-shore Bar Migration

- Test and evaluate two surf/swash zone wave, hydrodynamic, and sediment transport modules in the CMS (Larson 2015; C2SHORE)
- Selected coastal applications for tests (Ogden Dunes, IN)
- Comparisons of beach profile and nearshore morphology changes
- Updated CMS code
- CHETN (draft)


Transect 5

Transect 14

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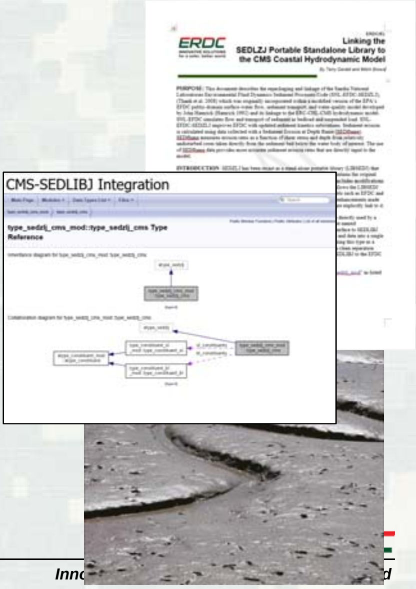
## Mixed Sediment Transport Model (SEDZLJ)

- Incorporate the standalone SEDZLJ library into the merged CMS
- Selected coastal applications for tests (Merrimack Inlet: non-cohesive; Grays Harbor: cohesive)
- Test the mass conservation of transported constituents in the CMS
- Test cohesive and non-cohesive sediment transport
- CHETN in review
- Webinar given to CWG in June 2018
- CMS-SEDZLJ is currently being debugged.


ERDC

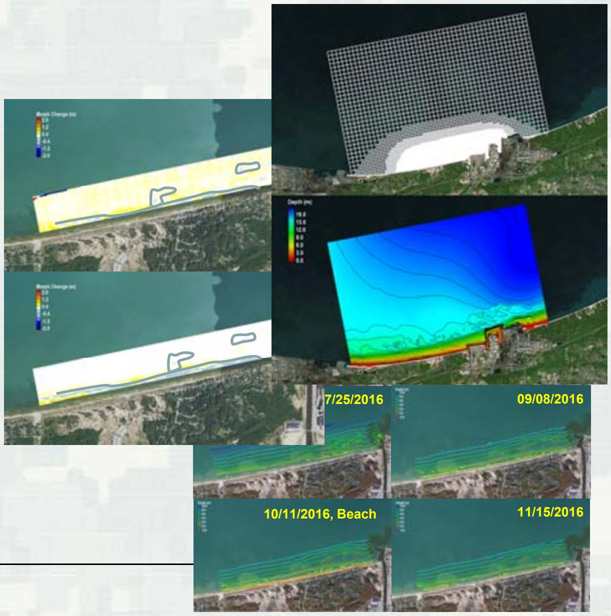
Linking the SEDLZJ Portable Standalone Library to the CMS Coastal Hydrodynamic Model

CMS-SEDLIBJ Integration

type_sedzlj_cms_mod::type_sedzlj_cms Type Reference

## Hydrodynamic, Wave and Sediment Transport Modeling at Ogden Dunes

- Data collection to monitor nearshore placement of dredged material
- CMS modeling of sediment transport and morphology change to make assessments on the effectiveness of placement activities
- TR (draft)


7/25/2016
09/08/2016
10/11/2016, Beach
11/15/2016

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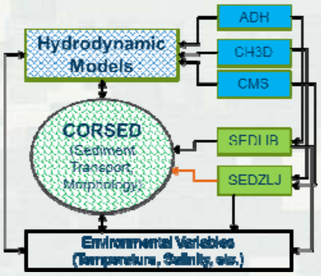
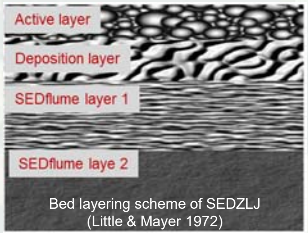
## CORSED (FY18)

- Objective
  - Develop a flexible and adaptable sediment transport library, CORSED, that operates across multiple hydrodynamic frameworks typically used by USACE
  - Fill gaps between models/modules using additional linkers
  - Model Test, V&V Documentation
- Approach
  - Modularize existing sedtran libraries
  - Restructure hydrodynamic models to drive sedtran libraries
  - Perform model validation, version control, and documentation
- Activities and Products (FY18)
  - Analyze codes (GSMB (CHE3D-MB), EFDC, CMS; SEDZLJ, SEDZLJ, CMS-Sed) literature, and test case datasets
  - **Modularization**: SEDZLJ library for GSMB
  - **GSMB-SEDZLJ Hydrodynamic Model Test**: 1) James River - Chesapeake Bay; 2) Horseshoe Bend - Atchafalaya River
  - **GSMB-SEDZLJ Morphodynamic Model Test**: SEDZLJ initialization code has been added to GSMB code and tested.
  - **EFDC-SEDZLJ Test**: Lab Experiment (Little & Mayer 1972)
  - **Linker for Models**: interface module linking GSMB & SEDZLJ


Hydrodynamic Models
ADH
CH3D
CMS
CORSED (Sediment Transport, Morphology)
SEDLIB
SEDZLJ
Environmental Variables (Temperature, Salinity, etc.)

A flowchart of CORSED-driven processes


Active layer
Deposition layer
SEDflume layer 1
SEDflume laye 2

Bed layering scheme of SEDZLJ (Little & Mayer 1972)

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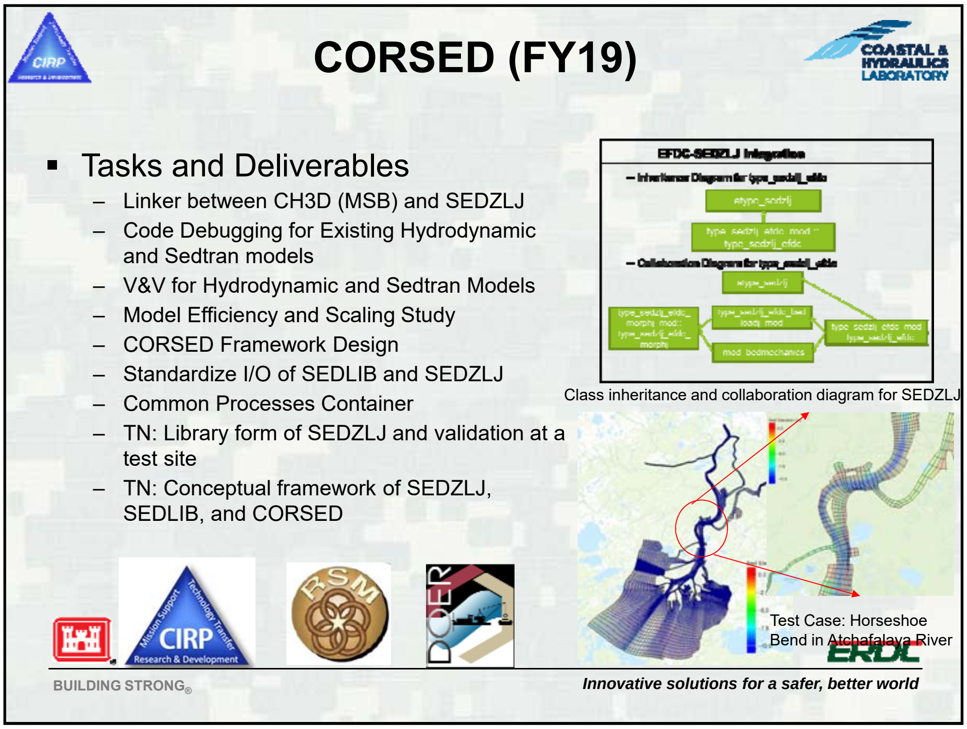

# CORSED (FY19)

- Tasks and Deliverables
  - Linker between CH3D (MSB) and SEDZLJ
  - Code Debugging for Existing Hydrodynamic and Sedtran models
  - V&V for Hydrodynamic and Sedtran Models
  - Model Efficiency and Scaling Study
  - CORSED Framework Design
  - Standardize I/O of SEDLIB and SEDZLJ
  - Common Processes Container
  - TN: Library form of SEDZLJ and validation at a test site
  - TN: Conceptual framework of SEDZLJ, SEDLIB, and CORSED

EFDC-SEDZLJ Integration
– Inheritance Diagram for type_sedzlj_efdc
atype_sedzlj
type_sedzlj_efdc_mod::type_sedzlj_efdc
– Collaboration Diagram for type_sedzlj_efdc
atype_sedzlj
type_sedzlj_efdc_morphj_mod::type_sedzlj_efdc_morphj
type_sedzlj_efdc_bed loadj_mod
mod_bedmechanics
type_sedzlj_efdc_mod type_sedzlj_efdc

Class inheritance and collaboration diagram for SEDZLJ

Test Case: Horseshoe Bend in Atchafalaya River

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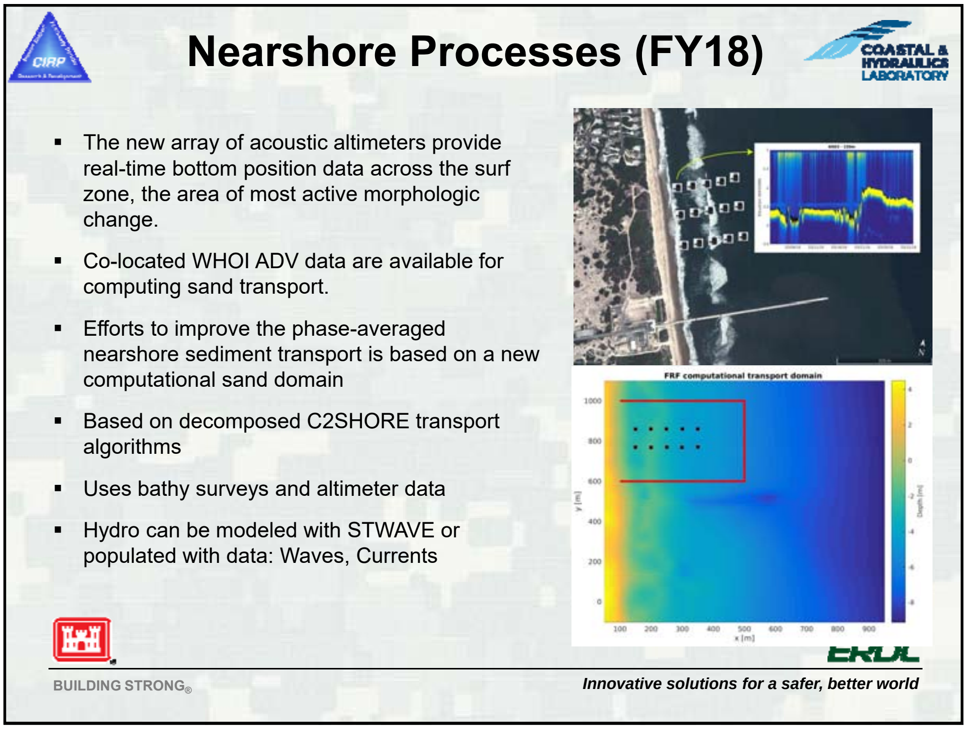

# Nearshore Processes (FY18)

- The new array of acoustic altimeters provide real-time bottom position data across the surf zone, the area of most active morphologic change.
- Co-located WHOI ADV data are available for computing sand transport.
- Efforts to improve the phase-averaged nearshore sediment transport is based on a new computational sand domain
- Based on decomposed C2SHORE transport algorithms
- Uses bathy surveys and altimeter data
- Hydro can be modeled with STWAVE or populated with data: Waves, Currents

FRF computational transport domain
y [m]
x [m]
Depth [m]
1000
800
600
400
200
0
100
200
300
400
500
600
700
800
900

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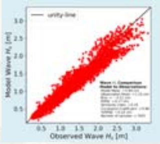
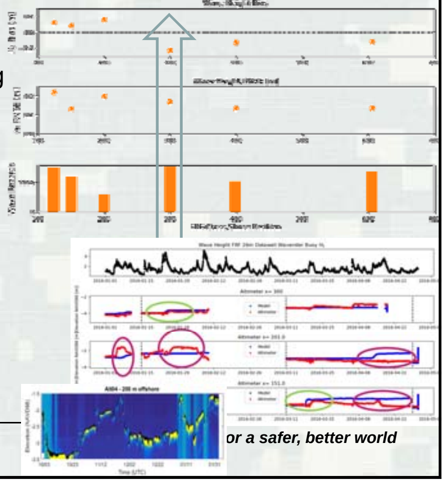
## Nearshore Processes (FY19)

C2SHORE – (FY18) issues related to unexpected delays associated with CMS flow

- Refactor/refine work flow in FY19
  a. focus thus far has been on implementation and operation
  b. Complex work flow (requires extra handling for latent survey data) allowing for efficient studies
- Begin morphology assessment for both CSHORE and C2SHORE
  a. utilize time series comparisons with Altimeter plots
     Look to isolate physical forcing conditions that result in divergence between model predictions and observations
  b. Develop morphology metrics from literature
     Build off "morphoMEDs" tool (from morphos project) (Radermacher, de Schipper, and Reniers, 2018) .



CSHORE Initial Hydrodynamics Comparison



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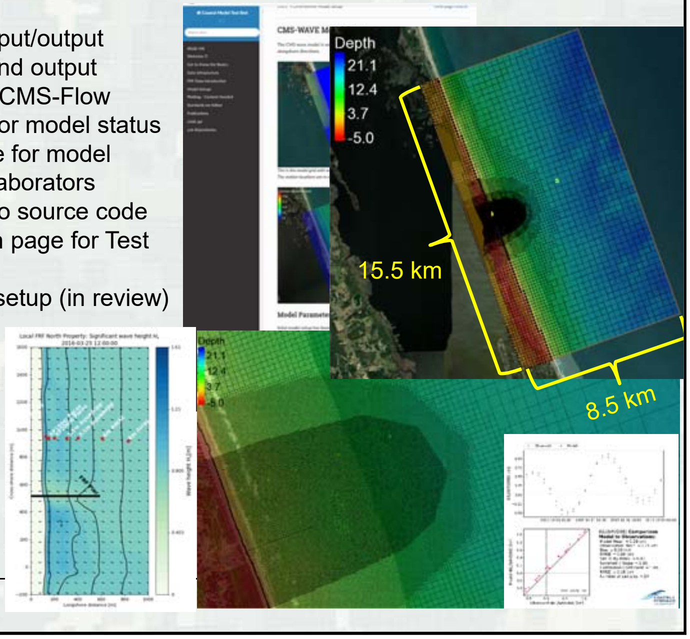
## Coastal Model Test Bed (FY18)

- Automated ASCII input/output generating scripts and output plotting routines for CMS-Flow
- Daily comparisons for model status delivered to Website for model developers and collaborators
- Linux compatibility to source code
- New Documentation page for Test Bed users
- TN on CMS–Wave setup (in review)



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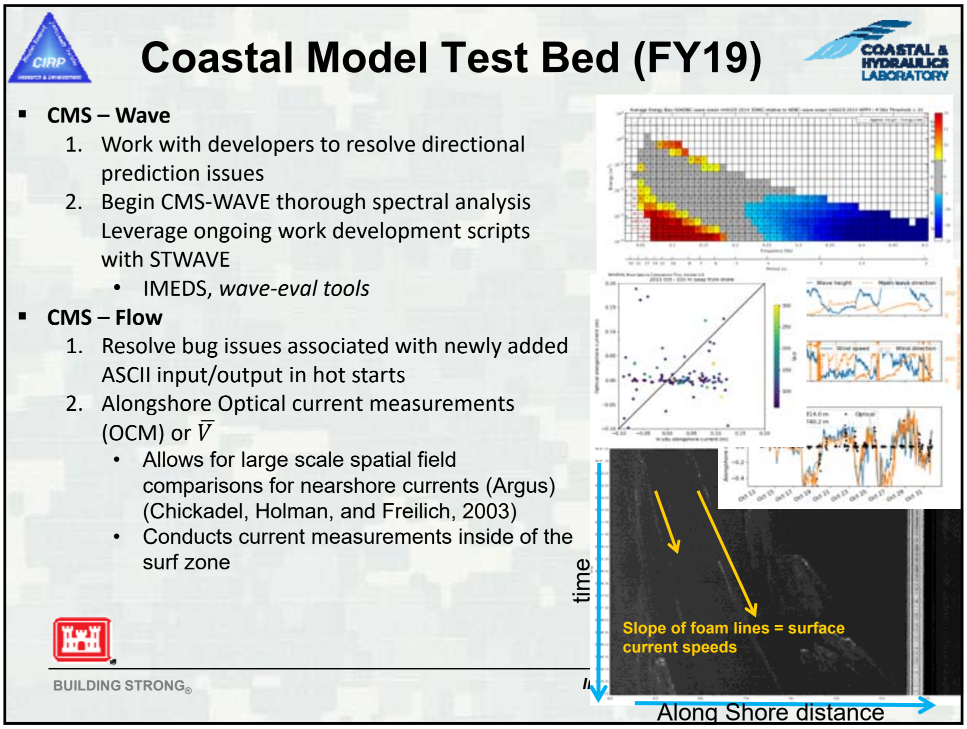

# Coastal Model Test Bed (FY19)

- **CMS – Wave**
  1. Work with developers to resolve directional prediction issues
  2. Begin CMS-WAVE thorough spectral analysis Leverage ongoing work development scripts with STWAVE
     - IMEDS, *wave-eval tools*
- **CMS – Flow**
  1. Resolve bug issues associated with newly added ASCII input/output in hot starts
  2. Alongshore Optical current measurements (OCM) or $\overline{V}$
     - Allows for large scale spatial field comparisons for nearshore currents (Argus) (Chickadel, Holman, and Freilich, 2003)
     - Conducts current measurements inside of the surf zone

time
Slope of foam lines = surface current speeds
Along Shore distance
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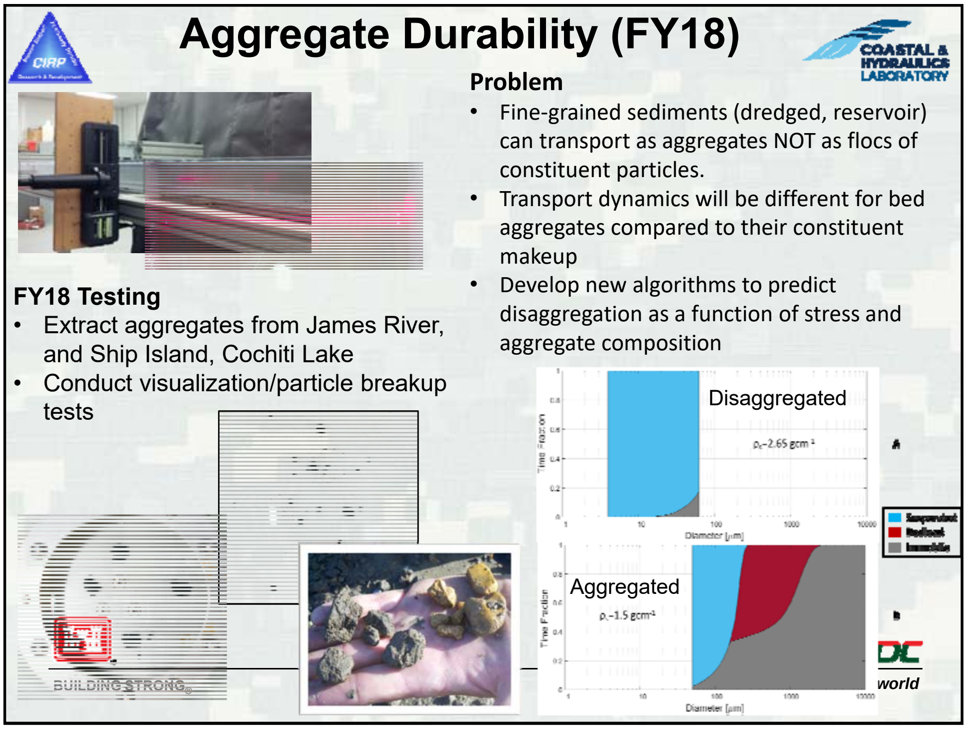

# Aggregate Durability (FY18)

**Problem**

- Fine-grained sediments (dredged, reservoir) can transport as aggregates NOT as flocs of constituent particles.
- Transport dynamics will be different for bed aggregates compared to their constituent makeup
- Develop new algorithms to predict disaggregation as a function of stress and aggregate composition

**FY18 Testing**

- Extract aggregates from James River, and Ship Island, Cochiti Lake
- Conduct visualization/particle breakup tests

Disaggregated
$\rho_s$~2.65 gcm⁻³
Aggregated
$\rho_s$~1.5 gcm⁻³
Time Fraction
Diameter [μm]
1
10
100
1000
10000
0
0.2
0.4
0.6
0.8
1
Suspended
Bedload
Immobile
world
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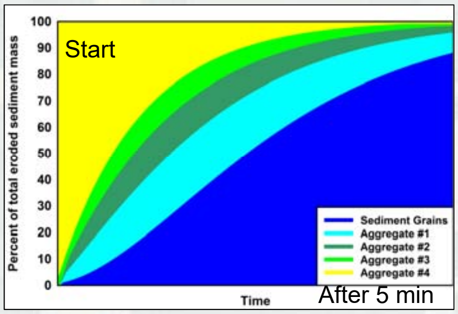
# Aggregate Durability (FY19)

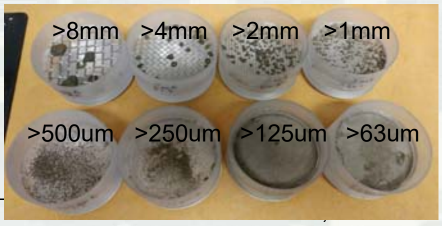
- Laboratory mixed aggregate tests (completed FY18)
- Calibrate/validate abrasion model
- TR – methodology and results
- JP – algorithm development

Model Approach (decision support)

- Static – aggregates don't breakup
- Ignore – no aggregate or easily destroyed
- Dynamic – include abrasion model to account for size class dynamics and evolution of transport modes

Leverage – RSM, NAO
Model development – CORSED, SEDZLJ





Collected aggregates from erosion testing

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# Overview of FY19 R&D and SoNs

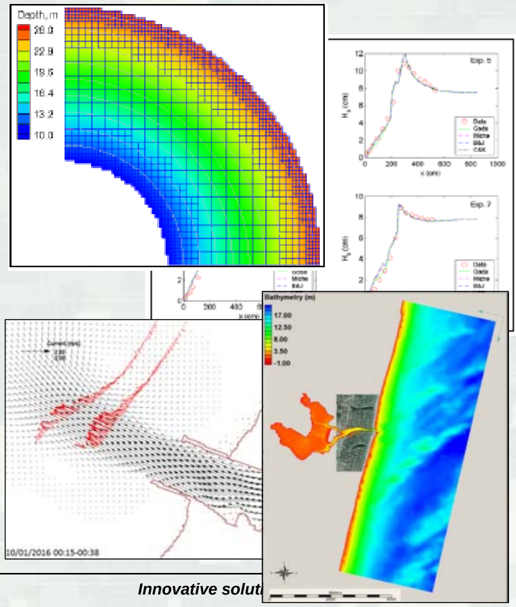
- Verification and Validation of CMS in Field Applications
- Sediment Mapping and SMS GUI Development (Coos Bay)
- Sediment Transport with Sea Level Rise Scenarios in Morphologic Modeling of Tidal Inlets
- Swash Zone Model Evaluation and Development (C2SHORE and CMS)
- 2-D Dam/Levee/Barrier Island Breaching (Coastal Applications)
- Validate CMS/SEDZLJ Module
- CORSED Continued Support
- CMS Technical Transfer, Workshop, Webinar (CIRP, CWG, RSM)
- Nearshore Processes Modeling (F&C, CIRP, CODS)
- Implement and validate CMS via Coastal Model Test Bed
- Develop Algorithms for Disaggregation of Mixed Sediments in Near-bed Transport

**Navigation Statements of Need**

- 2017-N-01: Testing and Evaluation of USACE Coastal Numerical Models
- 2017-N-70: Analysis of Shoreline Response to Nearshore Placement Geometry
- 2017-N-71: Modeling Effects of Sea Level Change at Tidal Inlets
- 2016-N-4: Quantifying Wave and Current Driven Sediment Transport at Near-shore Dredge Disposal Sites
- 2016-N-10: CMS: Continued R&D to Enhance Swash Zone and Surf Zone Sediment Transport Processes

## Verification and Validation of CMS

- Revisit analytical solutions and collect benchmark cases (lab and field) from early V&V reports
- Develop standardized method for quality assurance and quality control of the CMS for tech transfer and user support
- Automate the procedure using Matlab or Python scripting and apply the automated procedure to the V&V benchmarks



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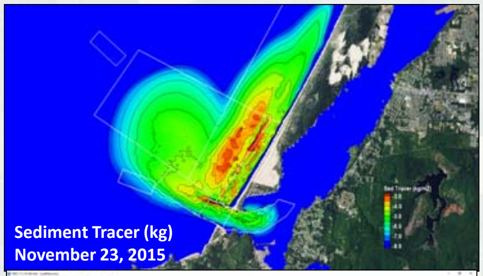
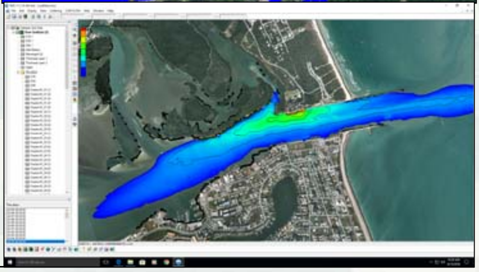
## Sediment Mapping
## SMS GUI Development (Coos Bay)

- Revisit Coos Bay study and set up multiple grain size simulations
- Validate sediment mapping implementation and further sediment tracking capability
- Analyze model output and obtain spatial distributions and pathways of sediment tracer
- Develop SMS GUI for sediment mapping (input/output, bed layers, volume and mass)
- CHETN


**Sediment Tracer (kg)**
**November 23, 2015**



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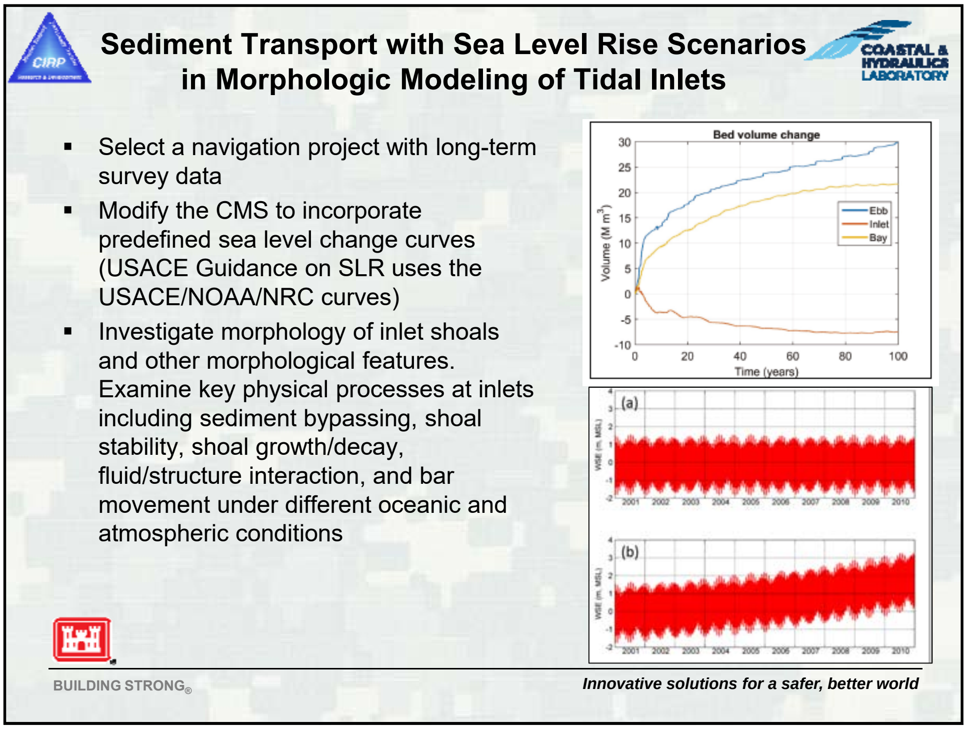

## Sediment Transport with Sea Level Rise Scenarios in Morphologic Modeling of Tidal Inlets

- Select a navigation project with long-term survey data
- Modify the CMS to incorporate predefined sea level change curves (USACE Guidance on SLR uses the USACE/NOAA/NRC curves)
- Investigate morphology of inlet shoals and other morphological features. Examine key physical processes at inlets including sediment bypassing, shoal stability, shoal growth/decay, fluid/structure interaction, and bar movement under different oceanic and atmospheric conditions

Bed volume change
Volume (M m$^3$)
Time (years)
Ebb
Inlet
Bay
30
25
20
15
10
5
0
-5
-10
0
20
40
60
80
100
(a)
(b)
WSE (m, MSL)
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

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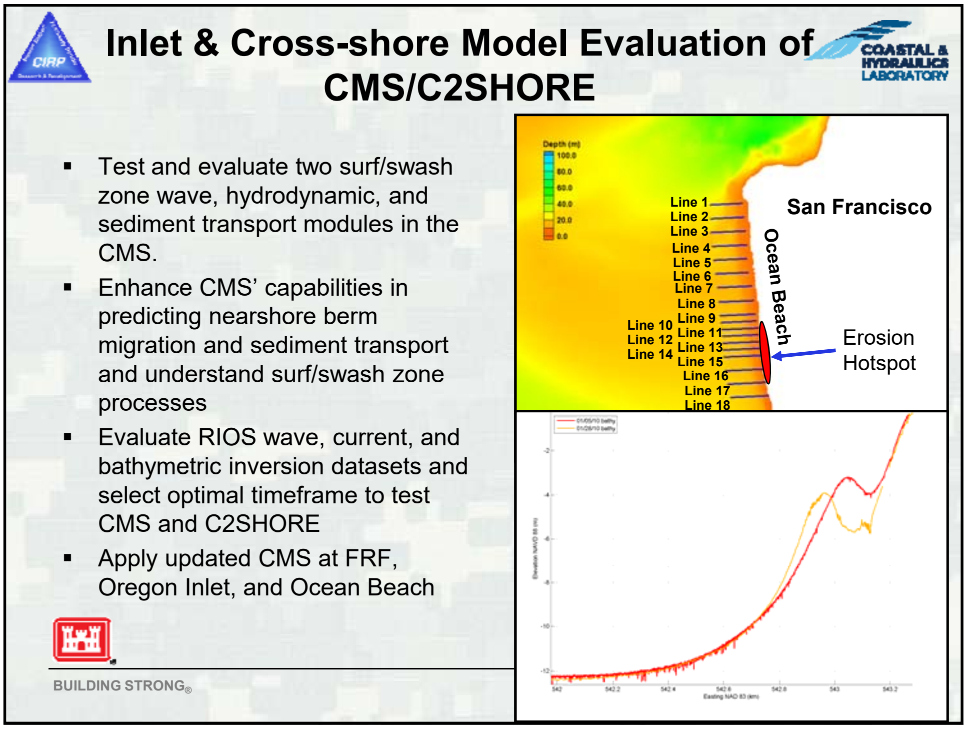

## Inlet & Cross-shore Model Evaluation of CMS/C2SHORE

- Test and evaluate two surf/swash zone wave, hydrodynamic, and sediment transport modules in the CMS.
- Enhance CMS' capabilities in predicting nearshore berm migration and sediment transport and understand surf/swash zone processes
- Evaluate RIOS wave, current, and bathymetric inversion datasets and select optimal timeframe to test CMS and C2SHORE
- Apply updated CMS at FRF, Oregon Inlet, and Ocean Beach

Depth (m)
100.0
80.0
60.0
40.0
20.0
0.0
Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
Line 7
Line 8
Line 9
Line 10
Line 11
Line 12
Line 13
Line 14
Line 15
Line 16
Line 17
Line 18
San Francisco
Ocean Beach
Erosion Hotspot
01/05/10 bathy
01/28/10 bathy
Elevation NAVD 88 (m)
Easting NAD 83 (km)
-2
-4
-6
-8
-10
-12
542
542.2
542.4
542.6
542.8
543
543.2

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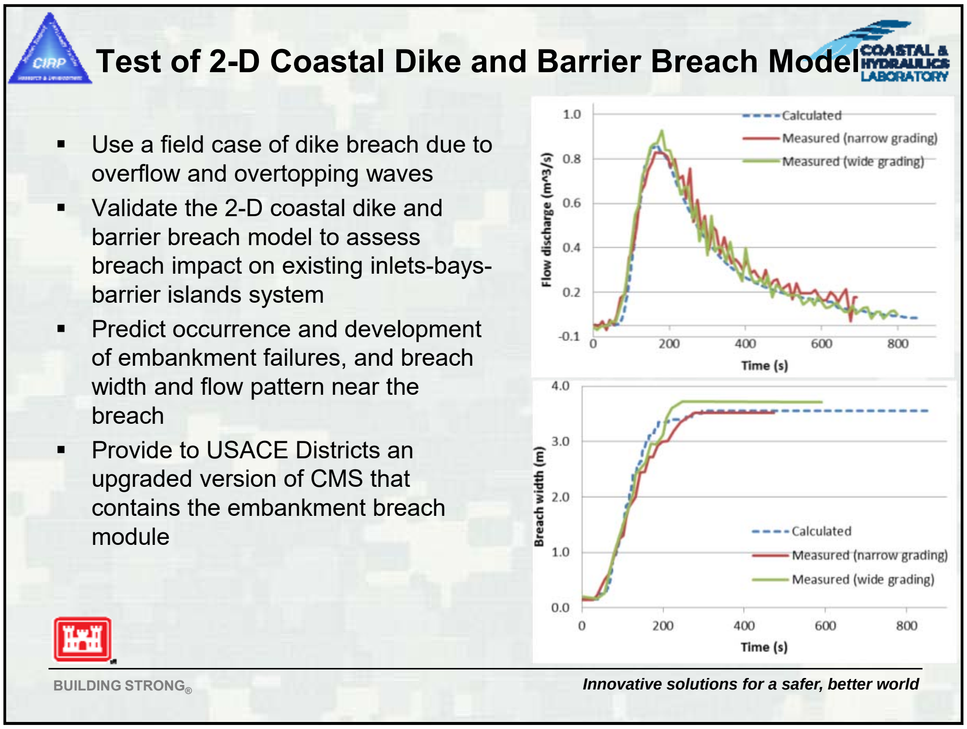

## Test of 2-D Coastal Dike and Barrier Breach Model

- Use a field case of dike breach due to overflow and overtopping waves
- Validate the 2-D coastal dike and barrier breach model to assess breach impact on existing inlets-bays-barrier islands system
- Predict occurrence and development of embankment failures, and breach width and flow pattern near the breach
- Provide to USACE Districts an upgraded version of CMS that contains the embankment breach module

CIRP
COASTAL & HYDRAULICS LABORATORY
Flow discharge (m^3/s)
1.0
0.8
0.6
0.4
0.2
-0.1
0
200
400
600
800
Time (s)
Calculated
Measured (narrow grading)
Measured (wide grading)
Breach width (m)
4.0
3.0
2.0
1.0
0.0
0
200
400
600
800
Time (s)
Calculated
Measured (narrow grading)
Measured (wide grading)

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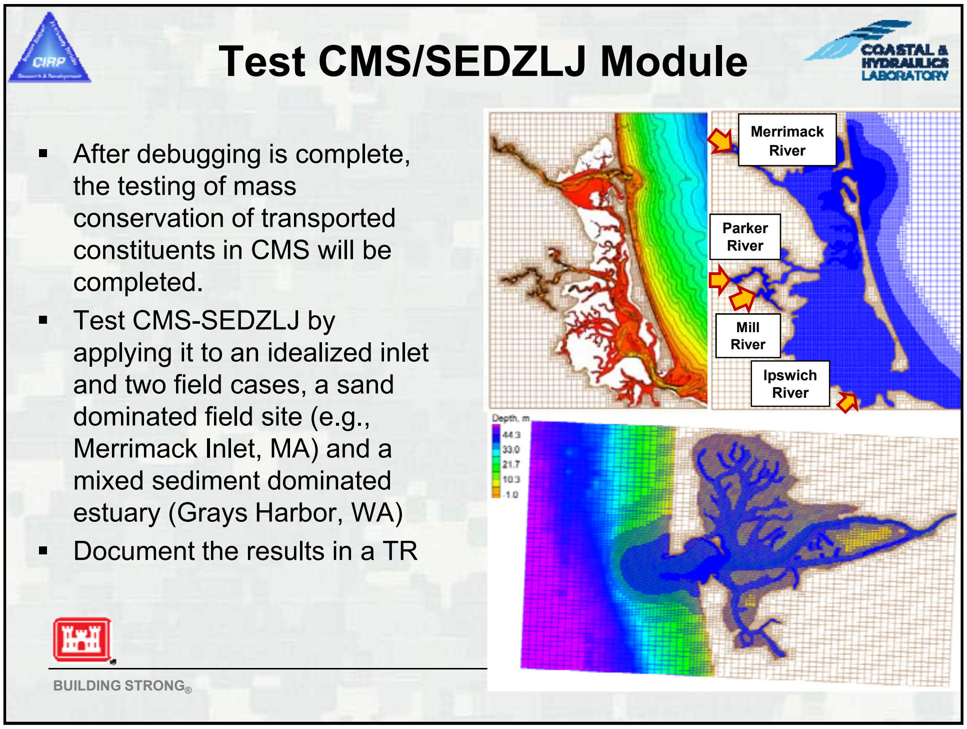


## Test CMS/SEDZLJ Module

- After debugging is complete, the testing of mass conservation of transported constituents in CMS will be completed.
- Test CMS-SEDZLJ by applying it to an idealized inlet and two field cases, a sand dominated field site (e.g., Merrimack Inlet, MA) and a mixed sediment dominated estuary (Grays Harbor, WA)
- Document the results in a TR

CIRP
COASTAL & HYDRAULICS LABORATORY
Merrimack River
Parker River
Mill River
Ipswich River
Depth, m
44.3
33.0
21.7
10.3
-1.0

BUILDING STRONG®

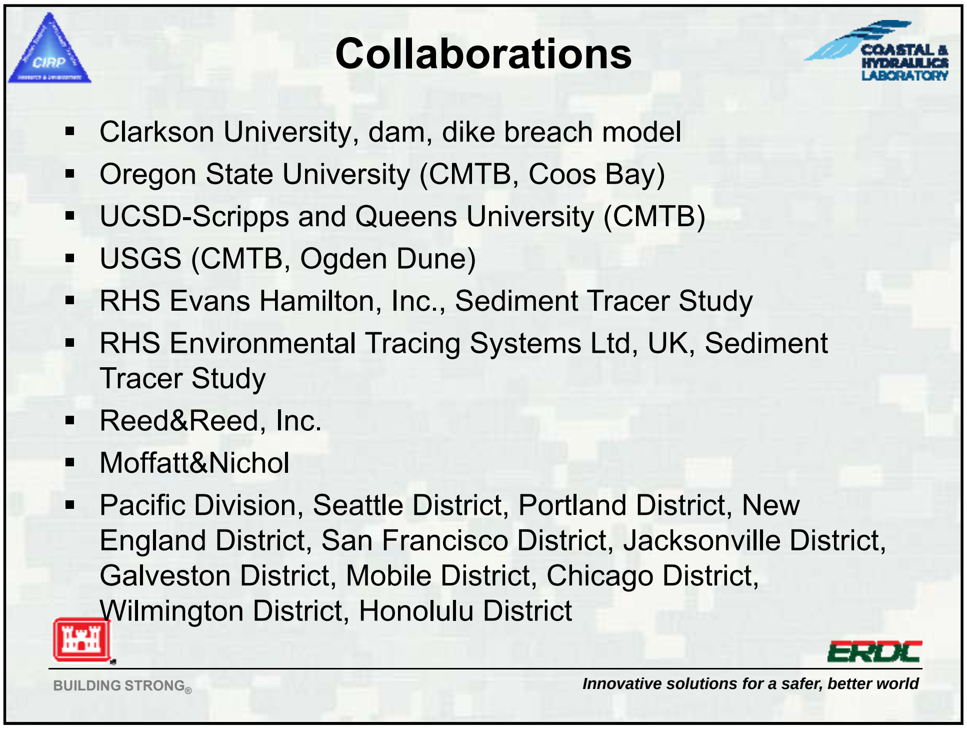
## CMS Technical Transfer

- Conduct on-site CMS/PTM/GENCADE workshops (Detroit, Nov 2018 – Jan 2019; Portland, Jun – Aug 2019)
- Conduct SMS/CMS Webinars (SMS 12.3 and 13.1)
- Develop and maintain wiki website, the CMS User Manual
- Update SMS GUI

## Reimbursables

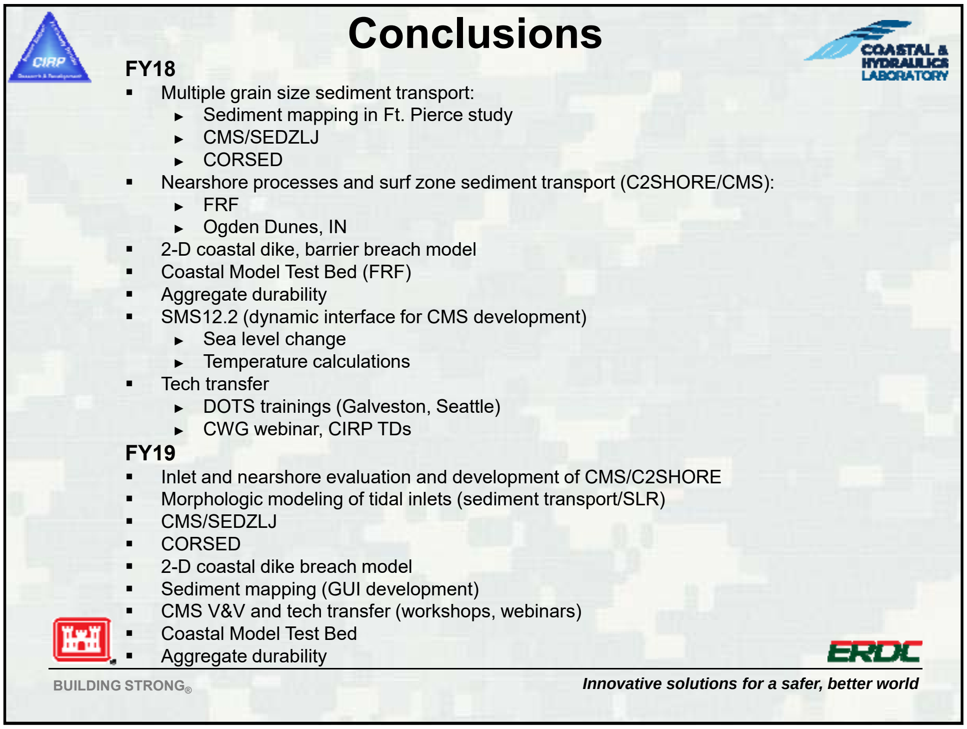
- Ogden Dunes
  - ► Evaluation of nearshore placement in southern Lake Michigan
- Lake Pontchartrain
  - ► Evaluation on a sediment transport modeling study
- James River
  - ► Aggregate durability test

Lake Pontchartrain



# Collaborations

- Clarkson University, dam, dike breach model
- Oregon State University (CMTB, Coos Bay)
- UCSD-Scripps and Queens University (CMTB)
- USGS (CMTB, Ogden Dune)
- RHS Evans Hamilton, Inc., Sediment Tracer Study
- RHS Environmental Tracing Systems Ltd, UK, Sediment Tracer Study
- Reed&Reed, Inc.
- Moffatt&Nichol
- Pacific Division, Seattle District, Portland District, New England District, San Francisco District, Jacksonville District, Galveston District, Mobile District, Chicago District, Wilmington District, Honolulu District



# Conclusions

**FY18**

- Multiple grain size sediment transport:
  - Sediment mapping in Ft. Pierce study
  - CMS/SEDZLJ
  - CORSED
- Nearshore processes and surf zone sediment transport (C2SHORE/CMS):
  - FRF
  - Ogden Dunes, IN
- 2-D coastal dike, barrier breach model
- Coastal Model Test Bed (FRF)
- Aggregate durability
- SMS12.2 (dynamic interface for CMS development)
  - Sea level change
  - Temperature calculations
- Tech transfer
  - DOTS trainings (Galveston, Seattle)
  - CWG webinar, CIRP TDs

**FY19**

- Inlet and nearshore evaluation and development of CMS/C2SHORE
- Morphologic modeling of tidal inlets (sediment transport/SLR)
- CMS/SEDZLJ
- CORSED
- 2-D coastal dike breach model
- Sediment mapping (GUI development)
- CMS V&V and tech transfer (workshops, webinars)
- Coastal Model Test Bed
- Aggregate durability