



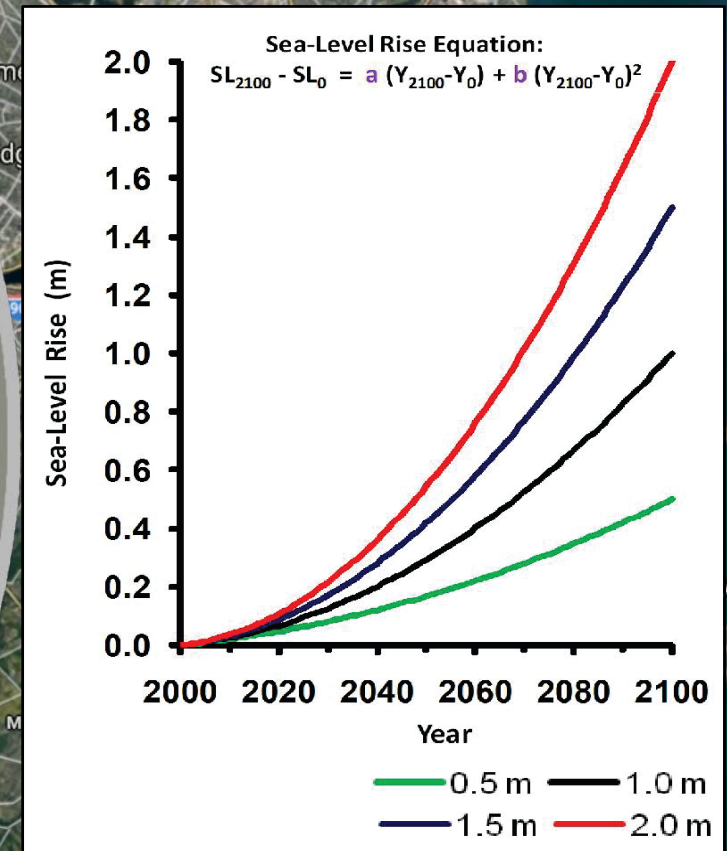
U.S. ARMY



COASTAL MODELING SYSTEM: ADVANCED TOPICS USING CMS 5.1 AND SMS 13.0

DAY 4: CMS SIMULATION WITH SLR

Honghai Li, Mitchell Brown



US Army Corps
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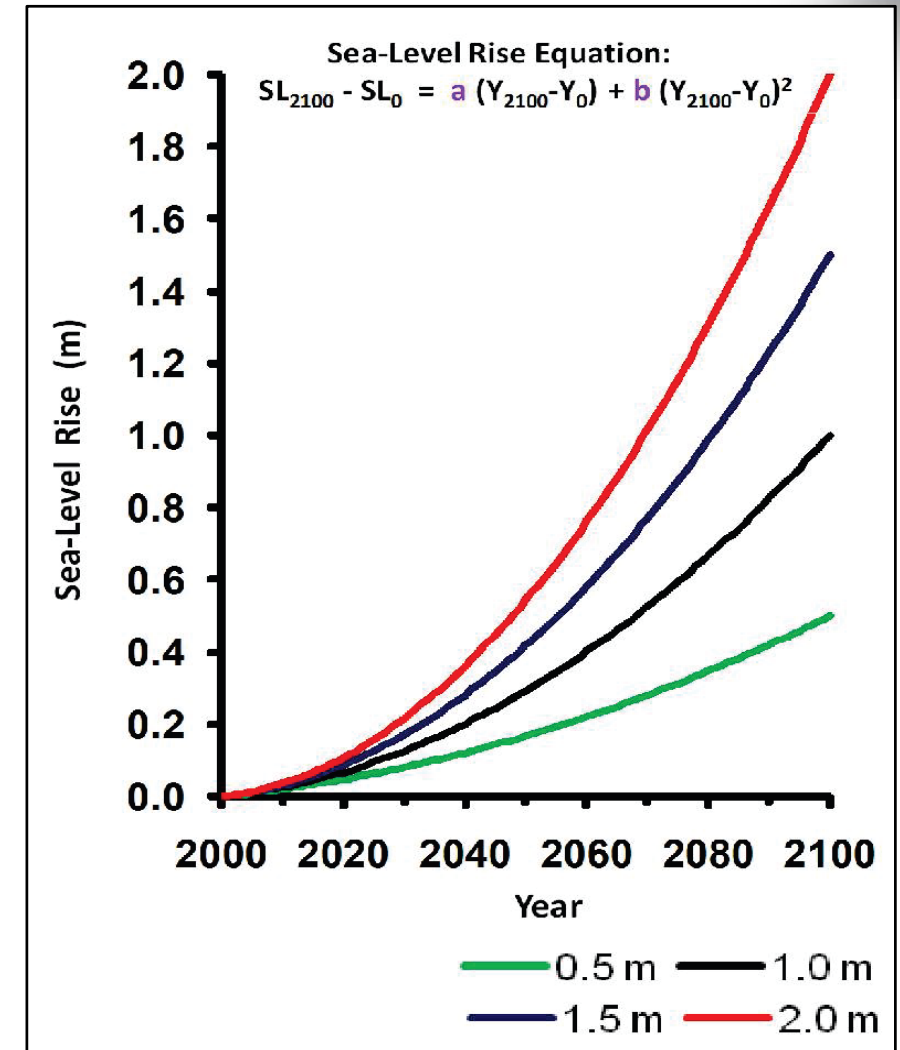
Outline

- **Background**
- **Sea level change in CMS-Flow**
- **Obtain SLC curve**
- **Setup of sea level change in CMS-Flow**
- **Work with SMS to specify SLC at open boundary**
- **Export CMS-Flow files**

Background



- Increasing sea level due to global warming and rise in ocean temperature
- Potential global sea level rise (SLR) can change the depth of navigation channels and introduce sediment into navigation channels through shore erosion
- Coastal model simulations need to incorporate SLR to assess risk and vulnerability of navigation projects and to support operations and maintenance practice





Sea Level Change in CMS-Flow

- CMS-Flow lateral open boundaries allow water exchanges with specifications of water level variations
- Water level boundaries can be obtained from the measurements at coastal tidal gauges or composed from tidal constituents
- The general formula for the boundary WSE is specified by

$$\eta_B = \eta_0 + \eta_E + \Delta\bar{\eta}$$

η_B : boundary WSE

η_0 : initial boundary WSE

η_E : specified external boundary WSE

$\Delta\bar{\eta}$: WSE offset

- The external WSE (η_E) may be specified as a time series, either spatially constant or varying, or may be calculated from tidal/harmonic constituents
- SLC is specified as $\Delta\bar{\eta}$



Setup of Sea Level Change (Obtain SLC Curve)

http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html

Sea-Level Curve Calculator (Version 2019.21)

corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html

67%

Sea-Level Change Curve Calculator

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Sea-Level Change Curve Calculator (Version 2019.21)
This version employs the same computations as previous versions, yielding the same projections along with some additional functionality, the 2014 NOAA rates, and several additional gauges. Previous versions include Version 2015.46 and its manual (pdf, 1.4MB); 2014.88 and its manual (pdf, 4.5 MB); and the original superseded calculator.
EC 1165-2-212 (pdf, 845 KB) and its successor ER 1100-2-8162 (pdf, 317 KB) were developed with the assistance of coastal scientists from the NOAA National Ocean Service and the US Geological Survey. Their participation on the USACE team allows rapid infusion of science into engineering guidance. ETL 1100-2-1 (pdf, 9.87 MB), Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.
EC 1165-2-212 (pdf, 845 KB) and its successor ER 1100-2-8162 (pdf, 317 KB) use the historic rate of sea-level change as the rate for the "USACE Low Curve". ETL 1100-2-1 (pdf, 9.87 MB), Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.
The rate for the "USACE Intermediate Curve" is computed from the modified NRC Curve I considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.
The rate for the "USACE High Curve" is computed from the modified NRC Curve II considering both the most recent IPCC projections and modified NRC projections with the local rate of vertical land movement added.
The three scenarios proposed by the NRC result in global eustatic sea-level rise values, by the year 2100, of 0.5 meters, 1.0 meters, and 1.5 meters. Adjusting the equation to include the historic GMSL change rate of 1.7 mm/year and the start date of 1992 (which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001), instead of 1996 (the start date used by the NRC), results in updated values for the coefficients (b) being equal to 2.71E-5 for modified NRC Curve I, and 1.13E-4 for modified NRC Curve II.
The three local relative sea level change scenarios updated from EC 1165-2-212 (pdf, 845 KB) (and its successor ER 1100-2-8162), Equation 2 are depicted in the Figure to the right of the table. ETL 1100-2-1 (pdf, 9.87 MB), Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation.

EC 1165-2-212, Equation 2: $E(t) = 0.0017t + bt^2$

This on-line Sea Level Change Calculator has several added features which are detailed in the User's Manual. The superseded calculator is available here... You can plot both the USACE and NOAA curves in feet or meters relative to either NAVD88 or LMSL.

Alternate Projections:

- The West Coast National Research Council 2012 West Coast projections are available when a west coast gauge is selected.
- The New York State Department of Environmental Conservation Proposed Regulation 6 NYCRR Part 490 projections for New York City and Long Island are available when the NOAA gauge, "The Battery" or "Montauk Point" is selected.
- The New York City Panel on Climate Change 2013/2015 projections are available for The Battery (0518750) for New York City.
- The Maryland Climate Change Commission 2013 Projections are available when selecting a gauge in Maryland.
- The University of Maryland Center for Environmental Science 2018 Projections are available when selecting a gauge in Maryland.
- The CARSWG REGIONAL SEA LEVEL SCENARIOS FOR COASTAL RISK MANAGEMENT Report 2016
- The US Global Change Research Program 2017 (NOAA et al. 2017)

This calculator also develops the SLC curves between the user entered dates using equation #3 in ER 1100-2-8162.

About the Program
Climate change has the potential to affect all of the missions of the U.S. Army Corps of Engineers. The Climate Preparedness and Resilience Community of Practice develops and implements strategies, nationally consistent, and effective approaches and policies to reduce potential vulnerabilities to water infrastructure resulting from climate change and variability. We work in partnership on this effort with other Federal science and water management agencies, academic experts, the private sector, and other stakeholders.

Planning for Changing Sea Levels
Engineering Technical Letters
SLC User Manual
C0125

USACE Sea Level Change Curve Calculator (2017.55)

Project Name: Enter Project Name
Select Gauge: Boston, MA
Scenarios Source: USACE 2013

Output Units: ☐ Feet ☒ Meters
Output Datum: ☒ LMSL ☐ NAVD88
Critical Elevation #1 (meters): 0.00
Critical Elevation #2 (meters): 0.00
SLC Rate: NOAA 2006 Rates or enter rate (m/yr) Display Data
FEMA BFE (meters): Information 0.00 (MSL) Search for BFE here
Project Start Year: 2000
Interval Year: 1
Project End Year: 2100
User's Index (meters): 0.000 Description:
Datum Shift from NAVD88 to MSL: 0.09 meters
EWL Type: ☒ High ☐ Low
EWL Source: NOAA Website ☐ NOAA (GEV) ☒ USACE (Percentile) 100 yr difference (m) = 0.17
Plot EWL/BFE/Tides: None Select Curve: USACE High

Click on project area. The nearest gauge point will be used to develop SLC curves based on the selected scenario source.

note - there may be factors other than proximity to consider when selecting a gauge

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Setup of Sea Level Change (Obtain SLC Curve)

USACE Sea Level Change Curve Calculator (2017.55)

Project Name:

Select Gauge:

Scenarios Source:

Output Units: ☐ Feet ☒ Meters

Output Datum: ☒ LMSL ☐ NAVD88

Critical Elevation #1 (meters): MSL - Description:

Critical Elevation #2 (meters): MSL - Description:

SLC Rate: ? or enter rate (m/yr)

FEMA BFE (meters): ? Information (MSL) Search for BFE here

Project Start Year:

Interval Year:

Project End Year:

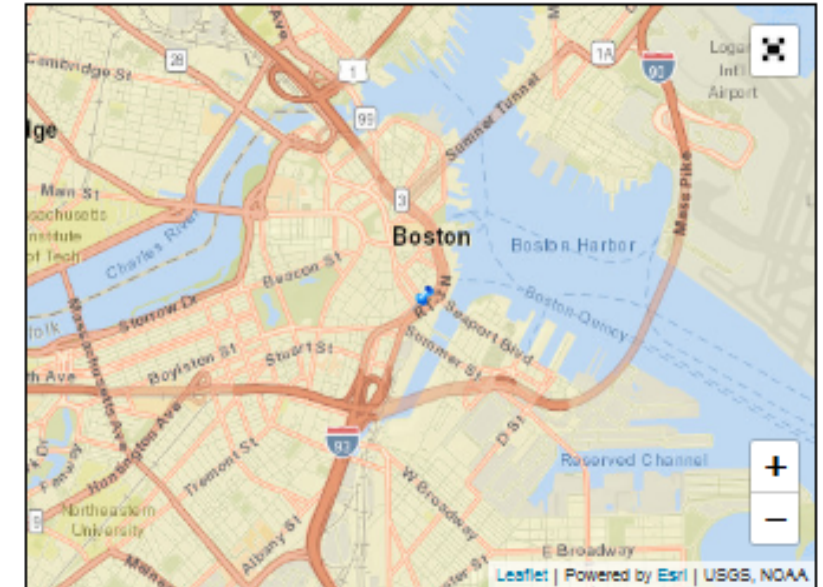
User's Index (meters): ? Description:

Datum Shift from NAVD88 to MSL: 0.09 meters

EWL Type: ☒ Highs ☐ Lows

EWL Source: NOAA Website ☐ NOAA (GEV) ☒ USACE (Percentile) 100 yr difference (m) = 0.17

Plot EWL/BFE/Tides: Select Curve:



Click on project area. The nearest gauge/grid point will be used to develop RSLC curves based on the selected Scenario Source

*** note - there may be factors other than proximity to consider when selecting a gauge ***

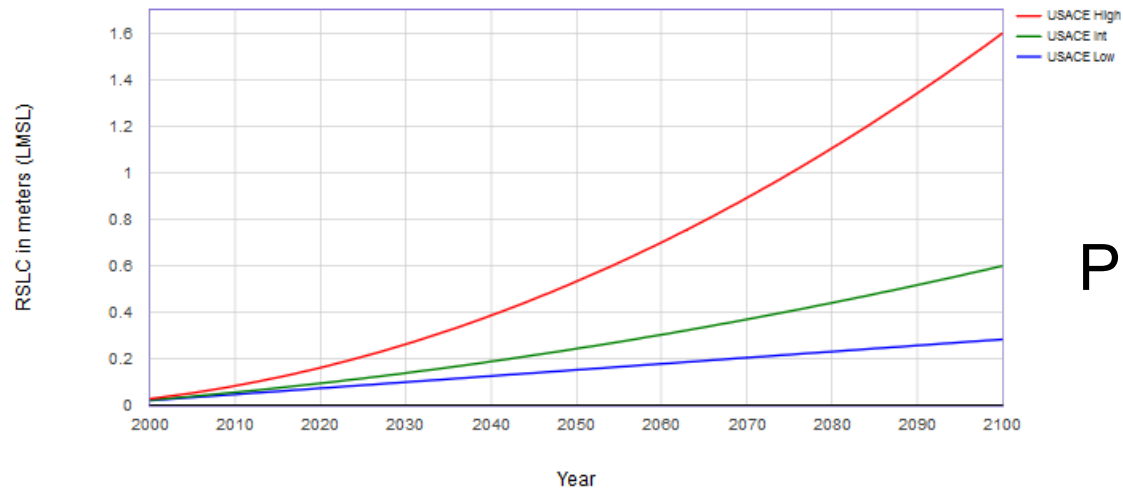
- Compliant
- Non-Compliant
- Inactive



Setup of Sea Level Change (Obtain SLC Curve)

8443970, Boston, MA
NOAA's 2006 Published Rate: 0.00263 meters/yr

Estimated Relative Sea Level Change Projections - Gauge: 8443970, Boston, MA



Print Curve

Print Curves

8443970, Boston, MA
NOAA's 2006 Published Rate: 0.00263 meters/yr
All values are expressed in meters relative to LMSL

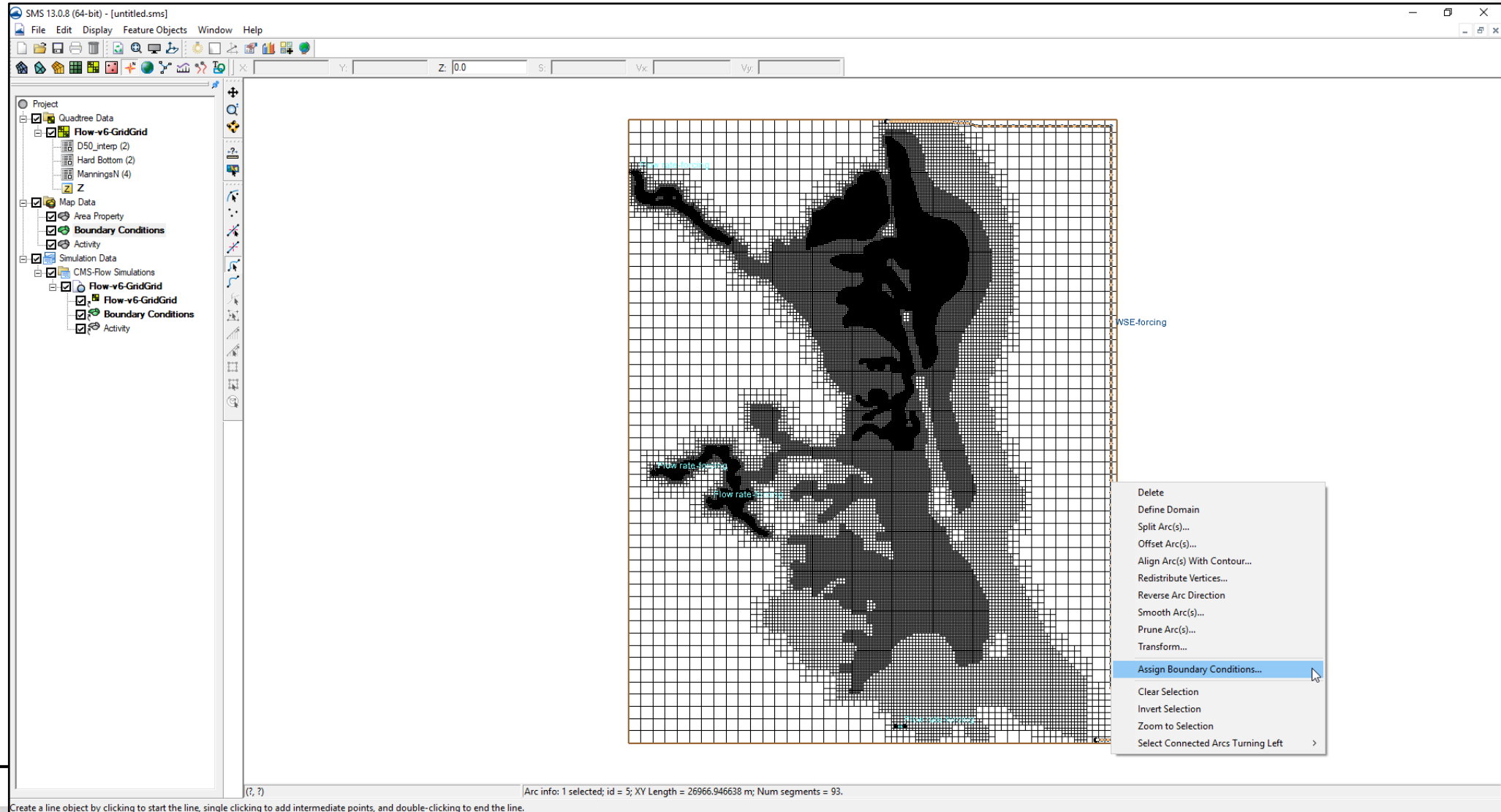
Year	USACE Low	USACE Int	USACE High
2000	0.02	0.02	0.03
2001	0.02	0.03	0.03
2002	0.03	0.03	0.04
2003	0.03	0.03	0.04
2004	0.03	0.04	0.05
2005	0.03	0.04	0.05
2006	0.04	0.04	0.06
2007	0.04	0.05	0.07
2008	0.04	0.05	0.07
2009	0.05	0.05	0.08
2010	0.05	0.06	0.08
2011	0.05	0.06	0.09

2062	0.18	0.32	0.74
2063	0.19	0.32	0.76
2064	0.19	0.33	0.78
2065	0.19	0.34	0.79
2066	0.20	0.34	0.81
2067	0.20	0.35	0.83
2068	0.20	0.36	0.85
2069	0.20	0.36	0.87
2070	0.21	0.37	0.89
2071	0.21	0.38	0.91
2072	0.21	0.38	0.93
2073	0.21	0.39	0.95
2074	0.22	0.40	0.98
2075	0.22	0.41	1.00
2076	0.22	0.41	1.02
2077	0.22	0.42	1.04
2078	0.23	0.43	1.06
2079	0.23	0.43	1.08
2080	0.23	0.44	1.11
2081	0.23	0.45	1.13
2082	0.24	0.46	1.15
2083	0.24	0.46	1.18
2084	0.24	0.47	1.20
2085	0.25	0.48	1.22
2086	0.25	0.49	1.25
2087	0.25	0.49	1.27
2088	0.25	0.50	1.29
2089	0.26	0.51	1.32
2090	0.26	0.52	1.34
2091	0.26	0.53	1.37
2092	0.26	0.53	1.39
2093	0.27	0.54	1.42
2094	0.27	0.55	1.44
2095	0.27	0.56	1.47
2096	0.27	0.57	1.50
2097	0.28	0.57	1.52
2098	0.28	0.58	1.55
2099	0.28	0.59	1.58
2100	0.28	0.60	1.60

Print Table

Print Table

Setup of Sea Level Change (Work with SMS to Specify Open Boundary Condition)



Setup of Sea Level Change

(Work with SMS to Specify Open Boundary Condition)



Browser tabs: (9 unread) - lqu52197@yahoo... X Harmonic Constituents - NOAA X +

Address bar: <https://tidesandcurrents.noaa.gov/harcon.html?unit=0&timezone=0&id=8423898&name=Fort+Point&state=NH>

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Station Info ▾ Tides/Water Levels ▾ Meteorological Obs. Phys. Oceanography OFS

Harmonic Constituents for 8423898, Fort Point NH

Constituent #
Order in which the National Ocean Service lists the constituents

Name
Common name used to refer to a particular constituent, subscript refers to the number of cycles per day

Amplitude
One-half the range of a tidal constituent

Phase
The phase lag of the observed tidal constituent relative to the theoretical equilibrium tide

Speed
The rate change in the phase of a constituent, expressed in degrees per hour. The speed is equal to 360 degrees divided by the constituent period expressed in hours

Description
The full name of the tidal constituent

Showing Harmonic Constituents for
8423898 Fort Point, NH ▾

Data Units ☐ Feet
☒ Meters

Timezone ☐ Local
☒ GMT

Submit

Please refer to the [Tide and Current Glossary](#) for definitions of terms. Amplitudes are in meters. Phases are in degrees, referenced to GMT. Z_0 (MSL): 0 meters

Constituent #	Name	Amplitude	Phase	Speed	Description
1	M2	1.314	105.9	28.984104	Principal lunar semidiurnal constituent
2	S2	0.181	136.2	30.0	Principal solar semidiurnal constituent
3	N2	0.294	76.1	28.43973	Larger lunar elliptic semidiurnal constituent
4	K1	0.135	203.3	15.041069	Lunar diurnal constituent
5	M4	0.018	324.5	57.96821	Shallow water overides of principal lunar constituent
6	O1	0.114	187.1	13.943035	Lunar diurnal constituent
7	M6	0.009	134.7	86.95232	Shallow water overides of principal lunar constituent

Help... OK Cancel

ment Center •

Export CMS-Flow Files



The screenshot shows the SMS 13.0.8 (64-bit) - [merrimack.sms] interface. The left sidebar displays a project tree with the following structure:

- Project
 - Quadtree Data
 - Flow-v6-GridGrid
 - D50_interp (2)
 - Hard Bottom (2)
 - ManningsN (4)
 - Z
 - Map Data
 - Area Property
 - Boundary Conditions
 - Activity
 - Simulation Data
 - CMS-Flow Simulations
 - Flow-v6-GridGrid
 - Flow-v6-GridGrid (selected)
 - Boundary Conditions
 - Activity

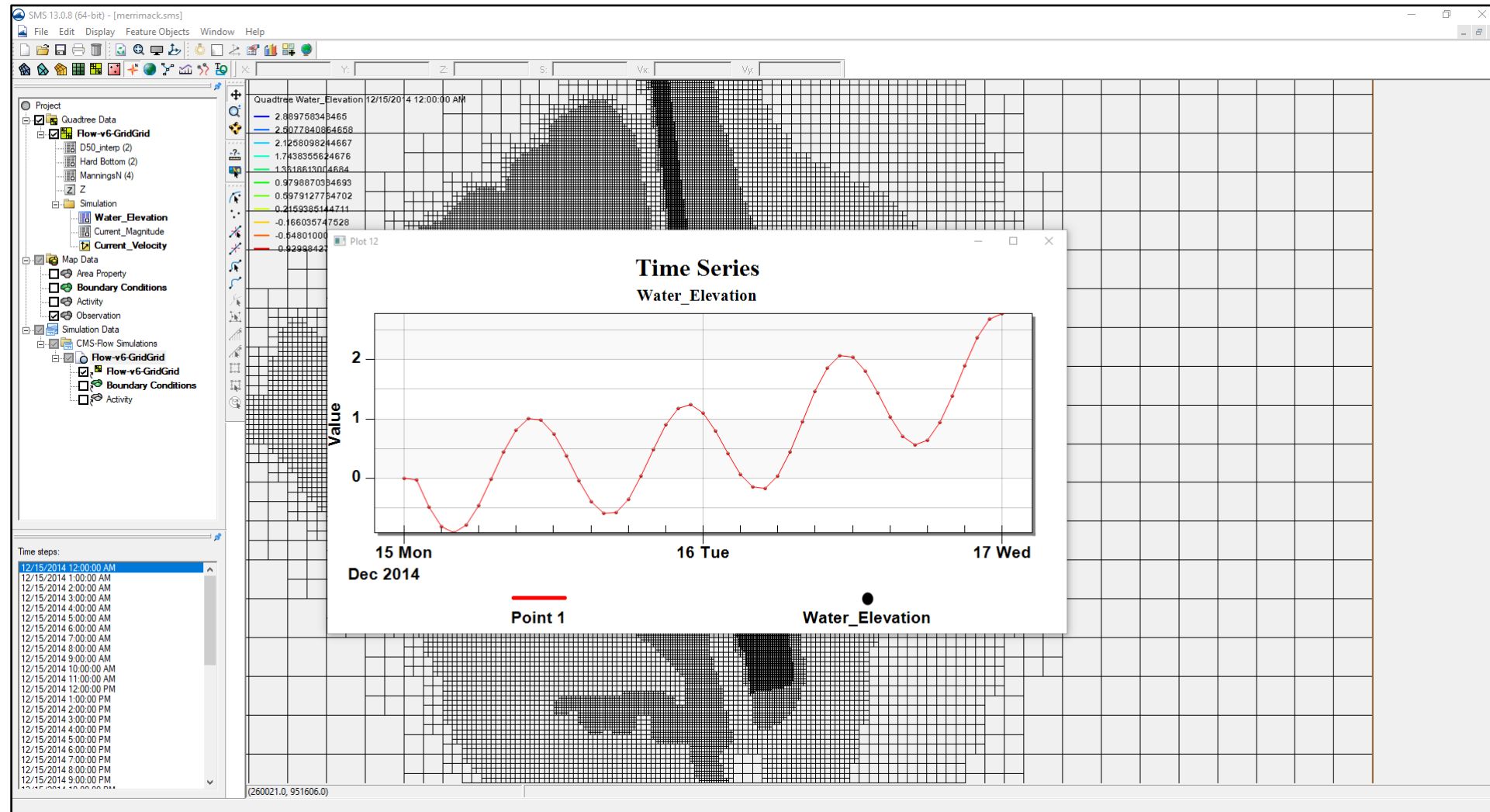
A context menu is open for the selected 'Flow-v6-GridGrid' item, showing the following options:

- Delete
- Duplicate
- Rename
- Simulation Run Queue...
- Model Control...
- Model Check...
- Export CMS-Flow** (highlighted)
- Launch CMS-Flow
- Save, Export, and Launch CMS-Flow
- Properties...

The main window displays a map of a river network with a grid overlay. Labels on the map include 'Flow rate forcing', 'Flow rate forcing', 'Flow rate forcing', 'Flow rate forcing', and 'WSE-forcing'.

Save Project -> Export CMS-Flow -> Launch CMS-Flow

Model Simulation





References

Modeling Sea Level Change Using the Coastal Modeling System

Li, H. and Brown, M. (2019)

<https://erdc-library.erdc.dren.mil/xmlui/handle/11681/33204>



US Army Corps
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Modeling Sea Level Change Using the Coastal Modeling System

by Honghai Li and Mitchell E. Brown

ERDC/CHL CHETN-IV-119
June 2019

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes procedures to incorporate a sea level change (SLC) curve within the Coastal Modeling System (CMS) operated in the Surface-water Modeling System (SMS), version 13.0 (Aquaveo 2010). The defined procedures are demonstrated in a long-term modeling simulation configured around an idealized inlet.

INTRODUCTION: Increasing atmospheric concentrations of greenhouse gases are warming the atmosphere and oceans. The global warming and the rise in ocean temperature may gradually increase ocean volume and change sea level (Figure 1) (IPCC 2014). Potential global sea level rise (SLR) combined with coastal storms can drastically change the depth of navigation channels and introduce sediment into navigation channels through adjacent shore erosion. Recognizing the impacts of global climate change with potential SLR on coastal and estuarine waterways, measures need to be taken to assess risk and vulnerability of navigation projects, to conduct research and development that support a reduction of future operation and maintenance costs, and to develop adaptation strategies and management plans to support operations and maintenance practice (USACE 2011).

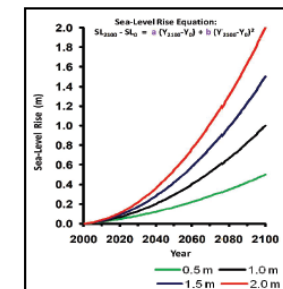


Figure 1. Projected 0.5, 1.0, 1.5, and 2.0 m SLR scenarios by the year 2100 (USACE 2011).

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