ERDC/CHL TR-14-6

US Army Corps
of Engineers®
Engineer Research and
Development Center

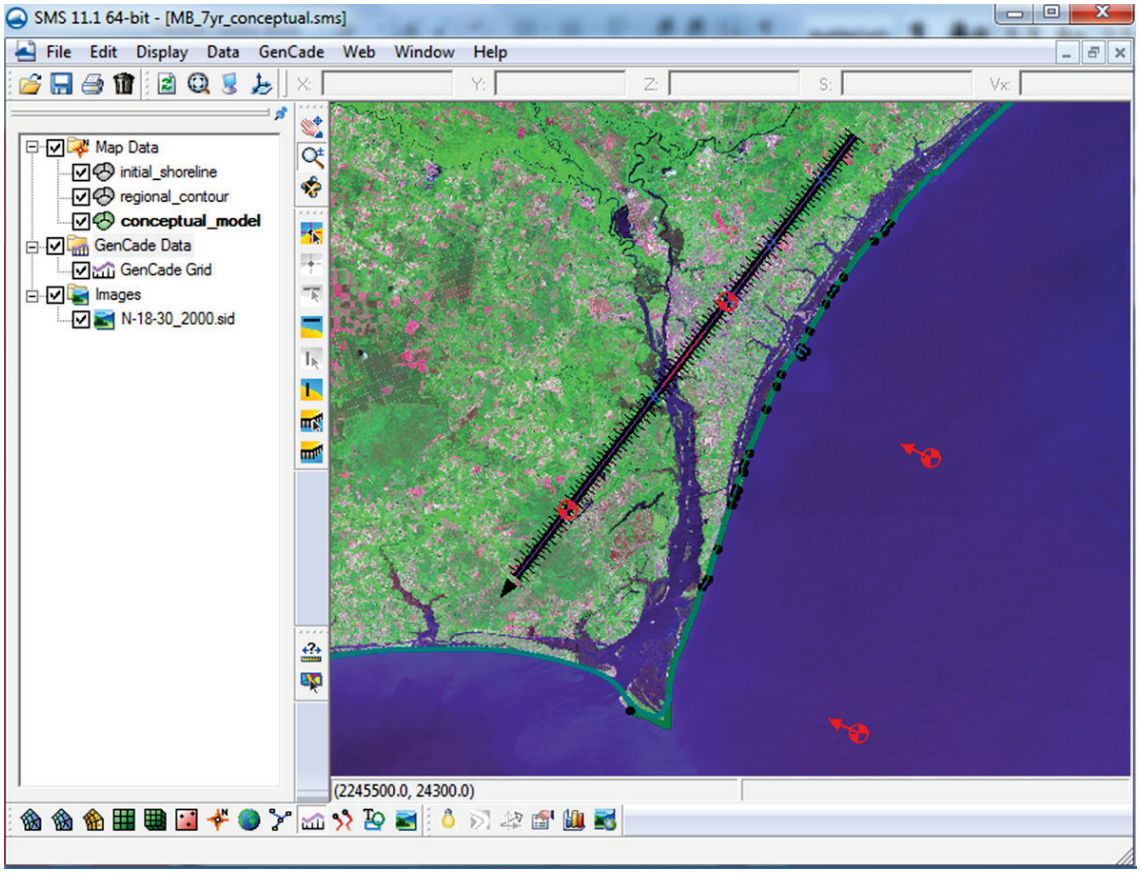
ERDC
INNOVATIVE SOLUTIONS
for a safer, better world

Coastal Inlets Research Program

Recommendations and Requirements for GenCade Simulations

Ashley E. Frey, David B. King, and Sophie Munger

August 2014



Coastal and Hydraulics Laboratory

The US Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at http://acwc.sdp.sirsi.net/client/default.

Coastal Inlets Research Program

ERDC/CHL TR-14-6
August 2014

Recommendations and Requirements for GenCade Simulations

Ashley E. Frey and David B. King

Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180-6199

Sophie Munger

Blue Science Consultants, LLC
P.O. Box 822101
Vicksburg, MS 39182

Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Abstract

This is the second report in a series describing applications with the new shoreline change and sand transport model, GenCade. It is considered as a companion report to the first report in the GenCade series, Frey et al. (2012a), and provides additional details that were not described in that report. This report describes the basic assumptions in GenCade, requirements to run the model, and recommendations about important GenCade capabilities. While all of the basic assumptions are discussed, this report also considers if the assumptions are satisfied and describes a procedure to follow when they are not. All of the required and optional input and output files are explained, and common user errors in model setup, with solutions, are detailed. These user errors may not be evident to new users but are easily corrected. Although the model will run even if the recommendations are not followed, the results may not represent the regional system as well as if properly set up. The recommendations section explains specific capabilities like the regional contour and the Inlet Reservoir Model (IRM) and topics such as project work flow and grid cell spacing. By following these recommendations, the user will produce better results. Finally, the path forward for the model and future guidance are discussed.

Contents

Abstract ... ii

Figures and Tables ... v

Preface ... ix

Unit Conversion Factors ... xi

List of Symbols and Abbreviations ... xii

1 Introduction ... 1

1.1 Overview ... 1
1.2 GenCade development history ... 2
1.3 Status of existing GenCade documentation ... 2
1.4 Purpose of additional documentation ... 3
1.5 Report organization ... 4

2 Basic Assumptions ... 5

2.1 Description of basic assumptions ... 5
2.1.1 Assumption 1 ... 6
2.1.2 Assumption 2 ... 9
2.1.3 Assumption 3 ... 11
2.2 Model assumptions at a study site ... 12
2.3 Procedure for cases that violate basic assumptions ... 14

3 GenCade Requirements ... 16

3.1 Basic requirements to run GenCade ... 16
3.1.1 Required input files ... 16
3.1.2 Optional input files ... 27
3.1.3 GenCade Model Execution ... 29
3.1.4 Output files ... 31
3.2 Common setup mistakes ... 33
3.2.1 SMS license problems ... 33
3.2.2 Failure to properly define each feature ... 34
3.2.3 Mistakes when merging coverages in the conceptual model ... 38
3.2.4 Improper placement of structures ... 40
3.2.5 Gated boundary condition mistakes ... 49
3.2.6 Incorrect input waves ... 51
3.2.7 Incorrect time-step ... 56
3.2.8 Failure to modify model control ... 58
3.2.9 Executable location ... 62
3.2.10 Path names and placement of input files ... 62
*3.2.11 Opening *.gen files and *.sms files in the SMS* ... 63

4 Recommendations for GenCade Applications 67
4.1 Work flow for a GenCade project 67
4.1.1 Introduction 67
4.1.2 Project initiation 69
4.1.3 Collection of input data 70
4.1.4 Model setup 70
4.1.5 Calibration, validation, and sensitivity testing 71
4.1.6 Production runs 73
4.1.7 Analysis and interpretation of results 74
4.1.8 Final report 74
4.2 Standards for cell spacing 74
4.2.1 Cell spacing for constant resolution 74
4.2.2 Variable cell spacing 75
4.3 Angle between shoreline and *x*-axis 87
4.4 Stability parameter 92
4.4.1 Stability parameter error messages 92
4.4.2 Solutions for stability parameter issues 94
4.4.3 Understanding the stability parameter 98
4.5 ISMOOTH 99
4.5.1 Number of cells in the offshore contour smoothing window (ISMOOTH) 99
4.5.2 Definition of ISMOOTH 100
4.5.3 Determination of optimal ISMOOTH value 100
4.5.4 Other considerations 104
4.6 Regional contour 104
4.6.1 What is a regional contour? 104
4.6.2 When should a regional contour be used? 106
4.6.3 How is the shape of a regional contour generated? 108
4.6.4 Example 114
4.7 Inlet Reservoir Model 119
4.7.1 Introduction 119
4.7.2 Analytical model 121
4.7.3 Initial volumes and equilibrium volumes 126
4.7.4 Attachment bars 129
4.7.5 Bypassing coefficient 132
4.7.6 Example 134

5 Summary and Future Guidance 142

References 144

Report Documentation Page

Figures and Tables

Figures

Figure 1. GenCade control volume (from Frey et al. 2012a). 6
Figure 2. Files section of *.gen file. 17
Figure 3. Model setup section of *.gen file. 18
Figure 4. Waves section of *.gen file. 19
Figure 5. Beach setup and boundary condition section of *.gen file. 20
Figure 6. Groins section of *.gen file. 20
Figure 7. Seawall section of *.gen file. 21
Figure 8. Detached breakwater with constant transmission in *.gen file. 21
Figure 9. Detached breakwater for variable transmission in the *.gen file. 22
Figure 10. Beach fills section of *.gen file. 23
Figure 11. Bypass operations section of *.gen file. 24
Figure 12. Inlets section of *.gen file. 25
Figure 13. Partial sample *.shi file. 26
Figure 14. Partial sample *.wave file. 27
Figure 15. Partial sample *.shdx file. 28
Figure 16. Partial sample *.shr file. 29
Figure 17. Example of GenCade simulation in the SMS. 30
Figure 18. Example of GenCade simulation in command prompt. 30
Figure 19. Partial example of output in *.slo (data extend both downward and to the right). 31
Figure 20. Example of output for transport rates. 32
Figure 21. Example of output for *.qtr file. 32
Figure 22. Example of output for *.off file. 33
Figure 23. Registration window in the SMS. 34
Figure 24. Equilibrium volumes set to 0.00001. 36
Figure 25. Incomplete inlet warning box. 37
Figure 26. Initial shoreline and regional contour opened in same coverage. 39
Figure 27. Error when groins less than two cells apart. 41
Figure 28. Error when groin placed next to a boundary. 41
Figure 29. Error when diffracting structure overlap. 42
Figure 30. Warning for overlapping breakwaters. 43
Figure 31. Top: detached breakwater cell information for corrected placement. Bottom: detached breakwater information for illegal placement. 44
Figure 32. Groin in conceptual and GenCade models. 45
Figure 33. Seawall arc in conceptual and GenCade models. 46
Figure 34. Top: seawall cells corrected by GenCade. Bottom: seawall cells manually changed by the user. 47

Figure 35. Manually adjusted seawall in the GenCade model. 48
Figure 36. Seawall in the GenCade model with variable resolution. 49
Figure 37. Gated boundary condition error message. 50
Figure 38. Error message with pinned boundary and groin. 51
Figure 39. Wave information in the Wave Events window. 52
Figure 40. Five-column wave information pasted incorrectly. 53
Figure 41. Wave information pasted incorrectly. 54
Figure 42. Proper wave data format for use with the Import button 54
Figure 43. Warning message for incorrect wave information input when using the Import button 54
Figure 44. Warning message for errors in wave files. 57
Figure 45. Error message when waves not included in simulation. 57
Figure 46. *Model Setup* tab with default settings. 59
Figure 47. Error message related to default start and end dates. 59
Figure 48. Defaults for *Beach Setup* tab (in USCS units). 60
Figure 49. Defaults for *Seaward BC* tab. 61
Figure 50. Defaults for *Lateral BC* tab. 61
Figure 51. GenCade simulation window displays executable version. 63
Figure 52. Opening the SMS project file allows the user to view both the conceptual and GenCade models. 64
Figure 53. Only the GenCade grid is viewable with the *.gen file. 65
Figure 54. Default setting for variable grid cell spacing. 76
Figure 55. Setup for idealized variable cell-spacing case (Example 1). 76
Figure 56. Shoreline change for cases with maximum cell size of 100 ft for Example 1 (vertical black line at 4 miles is a groin; horizontal black line between 4.5 and 5 miles is the inlet) 78
Figure 57. Zoomed-in view of simulations with maximum cell spacing of 100 ft for Example 1. 79
Figure 58. Zoomed-in view of simulations with maximum cell spacing of 250 ft for Example 1. 80
Figure 59. Zoomed in view of simulations with maximum cell spacing of 500 ft for Example 1. 80
Figure 60. Shoreline change for cases with maximum cell spacing of 330 ft for Example 2 83
Figure 61. Zoomed in view of shoreline change for cases with maximum cell spacing of 330 ft for Example 2. 83
Figure 62. Zoomed-in view of shoreline change for cases with maximum cell spacing of 820 ft for Example 2. 85
Figure 63. Zoomed-in view of shoreline change for cases with maximum cell spacing of 1640 ft for Example 2. 85
Figure 64. Comparison of shoreline change for different maximum bias and maximum cell sizes for Example 2. 86
Figure 65. Straight shoreline and grid *x*-axis idealized case. 88
Figure 66. Straight shoreline rotated 25° from the grid *x*-axis. 89
Figure 67. GenCade *x*-axis and concave shoreline. 91
Figure 68. Example of GenCade model simulation with six stability warnings. 93
Figure 69. Stability parameter warning in the *.prt file. 94

Figure 70. Example of smoothed offshore contour. 100

Figure 71. Test case of a groin field under constant wave forcing: a) ISMOOTH = 5; b) ISMOOTH = 21; c) ISMOOTH = 41; d) ISMOOTH = 101. 102

Figure 72. GenCade project without structures: the ~62.1-mile-long grid in black; the initial shoreline in yellow. The insert shows shoreline protrusion near an inlet. 103

Figure 73. Measured shoreline change (in black) and shoreline change calculated with ISMOOTH = 11 (in blue); ISMOOTH = 101 (in red). 103

Figure 74. Idealized GenCade results for a smooth concave shoreline for a 25 yr model run: A) without a regional contour and B) with a regional contour; C) with two groins without a regional contour and D) with two groins and with a regional contour. The regional contour is shown in dashed black. 106

Figure 75. Shoreline around Ponce de Leon Inlet near Daytona Beach on the northeast coast of Florida. 107

Figure 76. Onslow Bay, NC. 115

Figure 77. Historical shorelines at Onslow Bay (1849–1873, 1925–1946, 1925–1946, 1970–1988, 1997, 2004); left) regional view; right) showing migration of Rich Inlet and New Topsail Inlet (1849–1873 and 1997 over LandSat image from 2000). 116

Figure 78. Smoothing of the 1997 shoreline near Beaufort Inlet using 10 (in yellow) and 100 (in red) points in the smoothing window. 117

Figure 79. Final regional contour at Onslow Bay, NC. 117

Figure 80. Shoreline near Beaufort Inlet, showing regional contour (in red) and GenCade grid (in black). 118

Figure 81. Calculated shoreline change with (red) and without (orange) the regional contour compared to the observed shoreline change (blue) for the same period. 119

Figure 82. Schematic of the interaction between the morphological elements at an inlet. 120

Figure 83. Normalized shoal volume growth curves for all shoals having the same equilibrium volume. 124

Figure 84. Normalized shoal volume curves, showing the effect of differing equilibrium shoal volumes. 126

Figure 85. Inlet entrance morphology: a) East Pass, FL, 1990. Distance (W_C) between the tips of the jetties is ~ 960 ft. figure from Carr and Kraus (2001); b) Shinnecock Inlet, NY, 1997. The jettied inlet channel is ~790 ft wide. Figure from Kraus (2002). 127

Figure 86. Impact of the location and width of the attachment bar on the final calculated shoreline (in red) and the transport rate at the beginning of the simulation (in blue). The initial shoreline position is shown in black. a) Attachment bar is one cell wide and next to the inlet; b) attachment bar is one cell wide and located six cells downdrift of the inlet; c) attachment bar is five cells wide and located next to the inlet. 130

Figure 87. Schematic of the bypass coefficient. 132

Figure 88. The effect of the bypassing coefficient near an inlet. 133

Figure 89. St. Johns County, FL, and the USACE projects: Vilano Beach Feasibility Study; St. Augustine Beach Shore Protection Project; St. Augustine Inlet Navigation Project. 134

Figure 90. GenCade grid in black for the St. Augustine inlet optimization study with the initial shoreline in yellow. 136

Figure 91. Reported ebb-shoal volumes in the solid lines. Extrapolated volumes shown in the dashed line. Measurement using the 26 ft (black) and 30 ft (gray) depth contours. 137

Figure 92. GenCade grid near St. Augustine Inlet. The 1986 initial shoreline is in yellow, regional contour in orange, and attachment bars in blue. 138
Figure 93. Measured (black) vs. calculated (red) profile volume change for the calibration period of 1986–1999. 139
Figure 94. Shoal recovery rate calculated for recurrent 5 yr (left) and 10 yr (right) mining scenarios. 139
Figure 95. Ebb-tidal delta volume for alternatives A1, A2, A3, and A4. 141

Tables

Table 1. Acceptable formats for wave information under copy/paste option. 52
Table 2. Default setting for variable cell spacing for Example 1. 77
Table 3. Listing of and amount of time to run cases for Example 2. 82
Table 4. Summary of grid *x*-axis vs. shoreline angle analysis. 90
Table 5. Coefficients for the Walton and Adams formula. 128
Table 6. Dredging and placement scenarios. 140
Table 7. Ebb-tidal delta volume after 50 yr simulation and the percent difference. 141

Preface

This study was performed by the Coastal Inlets Research Program (CIRP), which is funded by the Operation and Maintenance (O&M) Navigation business line of the Headquarters, U.S. Army Corps of Engineers (HQUSACE). The CIRP is administered for Headquarters by the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Vicksburg, Mississippi, under the Navigation Program of HQUSACE. Jeffrey A. McKee is HQUSACE Navigation Business Line Manager overseeing the CIRP. W. Jeff Lillycrop, CHL, is the ERDC Technical Director for Navigation. Dr. Julie Rosati, CHL, is the CIRP Program Manager.

The CIRP's mission is to conduct applied research to improve the USACE's capabilities to manage federally maintained coastal navigation inlets, which are present on all coasts of the United States including the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, Great Lakes, and U.S. territories. The objectives of the CIRP are to advance knowledge and provide quantitative predictive tools to (a) support the management of federal coastal inlet navigation projects to facilitate more effective design, maintenance, and operation of channels and jetties to reduce the cost of dredging and (b) preserve the adjacent beaches and estuary in a systems approach that treats the inlet, beaches, and estuary as sediment-sharing components. To achieve these objectives, the CIRP is organized in research work units conducting a wide range of applied Research and Development (R&D) related to waves, hydrodynamics, and sediment-transport and morphology-change modeling specifically for estuaries, navigation and inlet structures, laboratory and field investigations, and technology transfer.

The CIRP has developed GenCade, a one-dimensional numerical model that calculates shoreline change and wave-induced longshore sand transport. Although the model theory is described in a previous technical report (Frey et al. 2012a), it became evident that additional documentation and guidance are necessary for GenCade. This report provides a new user more recommendations and discusses requirements necessary to run GenCade based on the experiences of the GenCade development team.

This report was prepared by Ashley E. Frey of the Coastal Engineering Branch (CEB) and David B. King of the Coastal Processes Branch (CPB), ERDC-CHL, and Sophie Munger, Blue Science Consultants, LLC, and sponsored by Texas A&M University, Corpus Christi, Texas. The work was performed by the CEB of the Navigation Division (HN) and the CPB of the Flood & Storm Protection Division (HF). At the time of publication, Tanya Beck was Acting Chief of CEB; Dr. Jackie Pettway was Chief of HN. Mark Gravens and Dr. Ty Wamsley were chiefs of CPB and HF, respectively. Dr. Julie Rosati, Ken Connell, Rusty Permenter, and Mark Gravens reviewed this report. Dr. Edmond Russo and José E. Sánchez were the Acting Deputy Director and Director of CHL, respectively, during the study and preparation of this report.

COL Jeffrey R. Eckstein was ERDC Commander. Dr. Jeffery P. Holland was ERDC Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

List of Symbols and Abbreviations

A	Inlet cross-sectional area
a, b	Correlation coefficients related to energy of offshore waves near inlet
a_1, a_2	Dimensionless parameters
BC	Bypassing coefficient
BERMHT	Average berm height
C_f	Coefficient for flood shoal volume
C_{gb}	Wave group velocity at breaking
CERC	Coastal Engineering Research Center
CIRP	Coastal Inlets Research Program
CMS	Coastal Modeling System
D_{50}	Median grain size
D_B	Berm elevation
D_C	Closure depth
DBDEP1, DBDEP2	Depth at starting and ending breakwater cell
DBI1, DBI2	Beginning and end of detached breakwater
DBW	Detached breakwater
DBY1, DBY2	Distance from grid to detached breakwater
DCLOS	Closure depth
DRDAY	Number of days of dredging event
DT	Time-step
DTSAVE	Saved time-step
DX	Cell size
ERDC	Engineer Research and Development Center
FEMA	Federal Emergency Management Agency
GENUNITS	Units used in GenCade (USCS or SI)
GUI	Graphical User Interface
H	Wave height
H_b	Breaking wave height
IMOR	Dredging event
INIFILE	Initial shoreline data file
IREG	Regional contour flag
IRM	Inlet Reservoir Model
ISMOOTH	Wave transformation contour smoothing window
ISWBEG	Beginning of seawall reach
ISWEND	End of seawall reach

K_1, K_2	Longshore sand transport calibration coefficients
LBCTYPE	Lateral boundary condition type
LMOVPER	Shoreline displacement over time at left boundary
LMOVY, RMOVY	Left and right boundary condition shoreline displacement
MHW	Mean High Water
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
NUMWAVES	Number of waves
NX	Number of cells in domain
P	Tidal prism
PRFILE	Print file
PROJDIR	Project directory
PRWARN	Print file warning
Q	Longshore sand transport rate
q	Sand source or sink
Q_{ba}	Sand transport from bypass bar to attachment bar
Q_{ce}	Sand transported to ebb shoal from channel
Q_{cf}	Sand transport to flood shoal from channel
Q_{eb}	Sand transport from ebb to bypass bar
Q_{ic}	Sand transported into channel
Q_{ie}	Sand transported into ebb shoal
Q_{in}	Sand transported to inlet
Q_j	Sand trapped by jetty
Q_{lst}	Transport rate
Q_{out}	Sand transport from attachment bar to downdrift beach
R_s	Stability parameter
REGFILE	Regional contour data file
SIMDATE	Simulation end date
SIMDATS	Simulation start date
SMS	Surface-water Modeling System
SWG1, SWG2	Distance from grid to seawall
T	Wave period
T_{ebb}	Timescale for ebb shoal
THETADEL	Angle offset for waves
TRANDB	Constant transmission for breakwater
USACE	U.S. Army Corps of Engineers
USCS	U.S. Customary System Units
USGS	U.S. Geological Survey

V	Volume of sand stored in ebb shoal
V_a	Attachment bar volume
V_b	Bypass bar volume
V_e	Ebb shoal volume
V_f	Flood shoal volume
V_x	Sand volume
V_{xq}	Sand equilibrium volume
WAVEID	Wave gauge cell number, depth, and number of unique events
WIS	Wave Information Study
x	Distance alongshore
Y_{gro}	Length of jetty
Y_{nxt}	Shoreline position next to structure
Y_{vir}	Virtual shoreline position inside inlet channel
YDG/YDNG	Distance from grid to seaward tip of groin
α_b	Breaking wave angle
ε_1, ε_2	Diffusion coefficients

1 Introduction

1.1 Overview

GenCade (GENESIS + Cascade) is a one-dimensional (1D) shoreline change, sand transport, and inlet sand-sharing model developed by the Coastal Inlets Research Program (CIRP). The numerical model combines the regional-scale, planning-level design calculations of Cascade (Larson et al. 2003) with the project-scale, engineering design-level calculations of GENESIS (Hanson and Kraus 1989). GenCade was developed to combine and improve upon the capabilities of Cascade and GENESIS. More background of Cascade and GENESIS and the capabilities of GenCade are included in the GenCade Technical Report (Frey et al. 2012a). The GenCade technical report (Frey et al. 2012a) will be referred to as Report 1 for the remainder of this report.

GenCade can be run as a module within the Surface-Water Modeling System (SMS), a graphical user interface (GUI). There are two interfaces for GenCade in the SMS. The first is the conceptual model. All spatial components and physical features to be mapped and incorporated to the grid are set up and defined in the conceptual model. The grid *x*-axis, shorelines, all structures, inlets, and wave information are input into the conceptual model. The conceptual model is geographically referenced so that the grid and other features may be constructed on top of aerial photographs. This makes the process more intuitive and less prone to errors. Once the conceptual model is complete, the user will convert the conceptual model into the 1D grid domain, which is referred to as the GenCade model. In the GenCade model space, all of the real-world coordinates are translated to model grid coordinates and positions are referenced to cell numbers. The shape and position of some of the structures may change slightly depending on how the user specifies grid cell size and resolution of features along the grid. The user may make small changes in the GenCade model to any of the features added in the conceptual model, but these changes will not affect the conceptual model inputs. Before running a simulation, the model control parameters need to be specified in the GenCade model-control dialogue window in the SMS. Once the user saves the project in the GenCade model, a number of GenCade input files are created. GenCade simulations may also be executed outside of the SMS GUI by launching the executable and GenCade control file (*.gen) in a Microsoft DOS (MS-DOS) command

window or by dragging and dropping the GenCade control file onto the GenCade executable in the Microsoft Windows environment.

After the simulation is complete, a series of output files is created in the specified print-file output directory (the default directory is the same directory as the input files). Several of these output files may be opened in the SMS for viewing.

1.2 GenCade development history

GenCade Version 1 was released in April 2012. A new executable was released in September 2012, which included a few improvements to the code. That release, GenCade_v1r3.exe, is considered the official release for GenCade Version 1 and is the version included in the SMS 11.1 package. In addition, a version with a modified subroutine for T-groins (GenCade_v1r4.exe) was released in June 2013. Although this version is not included in the SMS package for GenCade, it is available for free from any of the authors and can be downloaded from the Coastal Inlets Research Program (CIRP) website[1]. GenCade is available in SMS 11.1 and will be available in any subsequent versions of the SMS. The GenCade module is not available in previous versions of the SMS. SMS 11.1 was available in beta beginning in October 2012 and was fully released in April 2013.

SMS 11.1 may be downloaded from the Aquaveo website[2]. That installation will include the release version of GenCade. More information about obtaining a license is provided in Section 3.2.1. If the user is interested in a development version with more features or possible bug fixes, those executables (GenCade_v1r4.exe and subsequent releases) will be available on the CIRP website[1].

1.3 Status of existing GenCade documentation

To date, there are several forms of GenCade documentation for new users. First, Report 1 (Frey et al. 2012a) provides the most detailed documentation. It includes model theory, standard benchmark cases, and a user's guide. A second source of documentation is the CIRP Wiki which is accessed through the CIRP website[3]. The CIRP Wiki provides technical

[1] http://cirp.usace.army.mil/products/gencade.php

[2] http://www.aquaveo.com/downloads?tab=2#TabbedPanels

[3] http://cirp.usace.army.mil/

documentation, interface and user's guide information, and describes recently completed GenCade studies. There are pages discussing background, input and output files, waves, boundary conditions, frequently asked questions, a user's guide, and a simple example. In October 2012, a series of GenCade webinars was presented. These webinars covered basic topics and demonstrations. The presentations, files, supplemental material, and audio/video are available for download on the CIRP webpage. In addition to this documentation, technical reports and technical notes have been published for recently completed projects at Onslow Bay, North Carolina (Frey et al. 2012b), St. Johns County, Florida (Beck and Legault 2012), and Sargent Beach and Matagorda Peninsula, Texas (Thomas and Dunkin 2012; Rosati et al. 2013). All of the documentation mentioned is available for download from the CIRP website[1].

1.4 Purpose of additional documentation

As mentioned previously, Report 1 (Frey et al. 2012a) and a GenCade wiki page provide guidance for new users. However, there are a few reasons it is necessary to have additional guidance and new documentation available. Report 1 (Frey et al. 2012a) describes model theory, standard benchmark cases, an application, and includes a user's guide. Although background on the model's theory is provided, there is no discussion of how the theory relates to setting up and running the model. Also, the user's guide goes through each step of how to set up and run a simple case, but no requirements or recommendations are given. For example, if a new user encounters a problem when trying to run GenCade, the existing guidance does not provide information on how to resolve it. At this time, that user would either need to resolve the issue personally or call one of the developers. While some users may be able to review the input files and locate the problem, many others may not be able to achieve resolution due to time and funding constraints of the project.

Additionally, GenCade is a one-line model, and it is bounded by a number of basic assumptions common to similar one-line models. Unfortunately, some new users may not fully understand or appreciate what these assumptions mean or how they restrict the types of projects that GenCade can solve. Experienced engineers who have used similar one-line models understand the basic assumptions but for various reasons may be unable to apply more sophisticated 2D or 3D models to the project site. In this case, it is necessary to provide guidance on how to best apply GenCade in

locations where the active physical processes challenge the constraints of one-line model theory.

For these reasons, the GenCade development team found it necessary to provide additional user guidance. This technical report is the first of the new guidance reports to be published and includes recommendations and requirements to execute simulations with GenCade. This technical report is considered an expansion of Report 1 (Frey et al. 2012a); therefore, users should refer to that report before reviewing the information here. Additionally, most of the sections of this report reference specific pages of Report 1 (Frey et al. 2012a). It is recommended that the user have both reports available when beginning a project. This technical report is meant to provide generic guidance for setting up and running GenCade without errors. Many of the topics discussed in this report are based on issues encountered by the GenCade development team or other users. Further guidance is planned that will be site specific. This new guidance will provide information about how well GenCade can model a specific site, the calibration and validation procedure, defining a region, and analyzing statistics based on GenCade results. A technical report is also planned to describe the internal and external wave models that can be utilized to provide wave forcing for GenCade.

1.5 Report organization

This report is organized into five chapters:

- Chapter 1 presents an overview of GenCade and the purpose of this report.
- Chapter 2 describes the basic assumptions, discusses how to assess whether or not assumptions are satisfied at a study site, and provides guidance on how to best move forward with GenCade project-site conditions that do not fully agree with model assumptions.
- Chapter 3 presents basic requirements to run GenCade.
- Chapter 4 provides a number of recommendations and clarifications that can improve modeling results.
- Chapter 5 summarizes the report and describes other published guidance and planned documentation.

2 Basic Assumptions

2.1 Description of basic assumptions

GenCade belongs to a class of shoreline change models known as one-line models. The one-line model concept is based on the premise that the beach profile shape remains constant as the entire profile translates seaward or landward so that a local gradient in longshore transport rate creates a local volume change that is directly related to a change in the cross-shore position of the shoreline. That is, for a sandy beach without other sources or sinks, the difference in the longshore transport rate entering and leaving an alongshore model grid cell is directly proportional to the shoreline advance or retreat in that cell over that model time-step. The shoreline contour is the line referenced in the name of the model class: one-line.

All one-line models are based upon a general set of standard assumptions. The list of assumptions that is presented in page 7 of Frey et al. (2012a) is repeated here:

- The beach profile shape remains constant.
- The shoreward and seaward depth limits of the profile are constant.
- Sand is transported alongshore by the action of breaking waves and longshore currents.
- The detailed structure of the nearshore circulation is ignored.
- There is a long-term trend in shoreline evolution.

Pages 7–15 of Frey et al. (2012a) provide a good discussion of these assumptions and of the underlying sediment transport equations that are used to drive the model. The modeler may wish to review that text before reading further. The following discussion examines these assumptions in greater detail.

For the discussion below, the above assumptions are re-packaged into three basic requirements for application of this one-line model:

1. A standardized volume approach can be used to relate the differential transport to the change in shoreline position (with consideration of other sources and sinks).

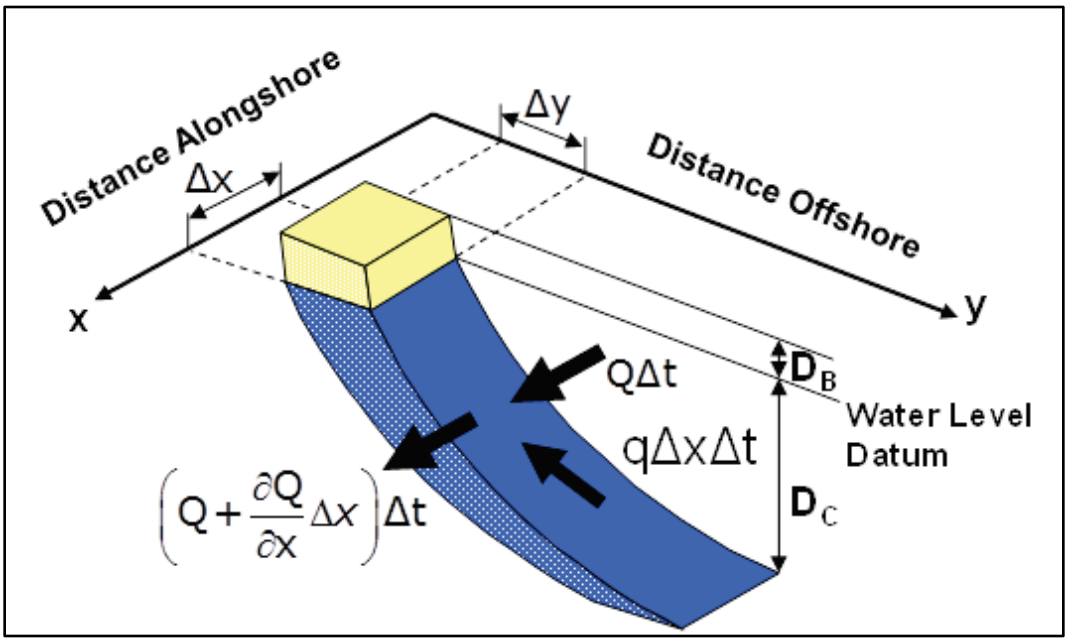
2. The long-term planform evolution of the shoreline is dominated by longshore transport processes, and the methodology used to calculate the longshore sediment transport rate is appropriate for the project site and the purposes of the study.
3. All portions of the beach within the project area contain a sufficient volume of sand such that non-erodible surfaces (hard bottoms) are never exposed.

2.1.1 Assumption 1

A standardized volume approach can be used to relate the differential transport to the change in shoreline position.

The basic relationship that the model uses to convert the differential transport rate to a change in shoreline position is described in Equation 1 of Frey et al. (2012a). It is equivalent to the statement that at each GenCade grid cell for each time-step, the change in the cross-shore position of the shoreline is equated to the (volume of material entering the grid cell minus the volume of material exiting it) divided by the cell width and cell height. The cell height is the vertical distance from the berm to the depth of closure. This is shown schematically in Figure 1, which is copied from Figure 2a of Frey et al. (2012a).

Figure 1. GenCade control volume (from Frey et al. 2012a).



The actual shape of the profile is not required to make this calculation. This can be clarified with a thought exercise by taking a deck of cards and sliding the cards on top of each other so that the deck's edge produces the arbitrary shape of a beach profile. Sliding the cards on top of each other does not change the volume of the deck, so the volume of material contained between a profile and one that is shifted in the cross-shore direction without change of shape can be calculated as the cell height times the specified grid cell length in the alongshore direction times the cross-shore profile-shifted distance (i.e., Volume = Height × Length × Width, which is the equation for the volume of a box).

The berm height is normally obtained as an average or representative value from beach profiles, where there is a distinct change in slope between the berm crest and the foreshore slope. The depth of closure is normally obtained either from equations (Hallermeier 1981; Kraus and Harikai 1983; Birkemeier 1985; Kraus 1988; Houston 1995) or from the representative depth where changes in profiles close out. Care should be taken in choosing these values as they are used to calculate the volume of the profile which in turn produces shoreline position at every grid cell at every time-step. To a certain extent, biases in the choice of these volume-defining values can be compensated for during calibration by the appropriate adjustment of the K1 term (which modulates sediment transport rates), but this will not account for alongshore elevation variability and does not relieve the modeler of the responsibility for making well-considered choices for their values.

Inherent in the first assumption is the concept that the beach profile maintains a rigid shape and adjusts to erosion or accretion by having the entire shape shift landward or seaward, respectively. This concept is never completely satisfied in nature. The passage of every breaking wave on a typical beach drives sand shoreward under the wave crest and then seaward under the wave trough. Thus, the beach profile is in a state of constant flux that is not directly related to longshore transport processes. At longer time scales, on the order of hours to days, occasional large storms will typically flatten the beach profile by transporting sediment from the berm and dune into the sub-aqueous portion of the profile (the surfzone). For many storms, the cross-shore nodal point is near mean sea level (MSL) (i.e., the volume of material removed from the upper beach above this point is roughly equivalent to the accretion volume in the surfzone bars at elevations below this point). Thus, dramatic storm-

induced upper profile erosion (coinciding with massive damage to seaside infrastructure) can occur with little to no change in shoreline position. Beach profile recovery from a storm occurs more slowly, typically on the order of weeks to months. On seasonal time scales, differences in *summer* and *winter* beach profiles have been recognized as typical of many beaches since the mid-20th century (Shepard 1950).

In spite of the complicating effects of cross-shore sand transport, there are two factors that allow the rigid profile concept to be a reasonable approximation in many circumstances. The first has to do with differing time scales for coastal processes. Although it is possible to run GenCade for relatively short periods of time (days, weeks, months), a typical model simulation spans multiple years. The usual assumption is that over a time scale of years, cross-shore fluctuations average out. Beach slope is a function of grain size (see Chapter 7 of Dean and Dalrymple (2002) for a discussion of equilibrium beach slope), so the beach at a particular study site can be expected to maintain an average preferred profile shape over time. However, many study sites do not have an adequate archive of historical beach profiles to evaluate this assumption.

When setting up GenCade, all available historical shorelines should be analyzed (along with accompanying beach profiles, if available) in order for the modeler to get a sense of the shoreline response over time. Shorelines obtained in the aftermath of major storms are likely atypical and should only be used with caution in the model. Beginning and ending shorelines used for model calibration and validation should be several years apart and obtained during the same season (ideally late summer or late winter), if possible. The starting shoreline used in production runs should also be from this same season. GenCade modeling simulations spanning subyear time intervals are not recommended due to these known seasonal beach change processes which are not captured within the constraints of one-line model theory and assumptions. If subyear model runs are required, additional care in evaluating this assumption should be documented.

The second factor is that MSL is positioned vertically at a location that is approximately near the middle of the volume box between the berm at the top and the depth of closure at the bottom. GenCade will still calculate the shoreline position correctly if a deficit volume in the subaerial portion of the beach equals the subaqueous surplus volume and vice versa. While it is possible that both the onshore berm and surfzone bars could erode (or

both accrete) while the swash zone does the opposite, this type of profile behavior is less typical than a transfer of material between the subaerial berm and the subaqueous bars. Thus, while the MSL contour is the preferred *shoreline* for GenCade modeling, data availability often dictates that other contours (mean high water, berm edge, etc.) are used.

2.1.2 Assumption 2

The long-term planform evolution of the shoreline is dominated by longshore transport processes, and the methodology used to calculate the longshore sediment transport rate is appropriate for the project site and the purposes of the study.

Within GenCade, the heart of the formula used to calculate the alongshore sediment transport rate is the Coastal Engineering Research Center (CERC) formula (Frey et al. 2012a (Equation 2, therein)). This fundamental surfzone-wide (total) longshore transport equation was first derived in the late 1960s (Komar 1969; Komar and Inman 1970) from earlier pioneering work by Bagnold (1963). It became known as the CERC formula after it was discussed in detail in the Shore Protection Manual (Coastal Engineering Research Center (CERC) 1973).

Numerous alternative total longshore transport rate formulas have also been proposed, and each has its own proponents. The limitations of the CERC formula are well known (Komar 1988; Bodge and Kraus 1991). The CERC formula has been criticized for its simplistic description of a complex process, particularly its lack of a transport rate dependence upon grain size. (This issue has been addressed with equations to modify the K calibration coefficient for large grain beaches (e.g., Schoonees and Theron 1993; King 2006)). With adequate calibration, the CERC formula can estimate longshore sediment transport rates within ± 50%, but without calibration, the CERC formula only provides an accuracy of one to two orders of magnitude (Greer and Madsen 1978; Fowler et al. 1995).

However, many studies using both lab and field data that compared the predictive skills of the CERC formula with other, more complex models have failed to identify any longshore transport model as having consistently superior predictive skills or any other model that was consistently clearly superior to the CERC formula (King and Seymour 1989; Wang et al. 1998; Haas and Hanes 2004; Smith et al. 2009; Ari Güner et al. 2013). The fact that the CERC formula competes well against other, more complex models

has been termed “the CERC formula paradox” and discussed extensively by Nielsen (1988, 1992). Thus, the simplicity of the CERC formula in GenCade works to its advantage by allowing the code to run faster while producing model results that are as good as or superior to those of alternative models over a broad range of surfzone conditions.

In GenCade, the K1 parameter is equivalent to the K parameter in the CERC formula. The adjustment of this term during model calibration will impact the transport rate along the entire GenCade study domain.

The GenCade transport relationship also contains a second term (a function of the change in breaking wave height in the alongshore direction, dH/dx), which was first introduced by Ozasa and Brampton (1980) (see also Kraus 1983; Kraus and Harikai 1983) (refer to Equation 4 in Frey et al. (2012a) for a description of the GenCade transport formula). This second term can have a significant impact on the transport rate where there is a steep, local alongshore gradient in the breaking wave height. This term plays an important role in the vicinity of breakwaters and jetties but not along most open coastlines, where dH/dx is essentially zero. In GenCade, this term is multiplied by the K2 coefficient. The adjustment of the K2 parameter during calibration can assist in fine tuning the shoreline response in the vicinity of structures without making substantial transport changes elsewhere along the shoreline.

Most of the other features in GenCade can be thought of as adjustable tools that will differentially modify the transport rate along the grid to produce results that mimic the shoreline behavior of the prototype. The inclusion of hard structures (groins and breakwaters) slows the transport rate in their vicinity, piling up sand on their upstream side and reducing the supply on the downstream side. The external wave feature, if used, will provide the model with alongshore variability in the breaking wave height and angle (model forcing terms) that is caused by known wave refraction over an irregular offshore bathymetry. Other forcing-term adjustments can be made by the appropriate inclusion of tidal and/or wind stress currents in the surfzone. The input parameter ISMOOTH (number of cells in offshore contour smoothing window) adjusts breaking wave heights and angles primarily in the vicinity of hard structures and thus works in concert with K2. The lateral boundary conditions have the greatest impact on the transport rate at the ends of the model domain. The regional

contour will have an impact at any location where it is not parallel to the GenCade *x*-axis.

Another consequence of Assumption 2 is that the longshore transport relationship is expected to be the primary driver of long-term shoreline change. If a series of shoreline position plots representing several years or decades of shoreline change show shoreline change rates that vary significantly in space and time in seemingly arbitrary ways (as some beaches do), it will likely be difficult to set up a GenCade model that produces meaningful results. In these cases, the impacts of the local cross-shore transport or updrift sediment supply may outweigh the impacts due to longshore transport, which is the only type of transport that is presently considered in the GenCade model. In other cases there may be significant single or periodic man-made impacts to the beach of which the modeler is unaware.

If, on the other hand, an analysis of the shoreline positions over time shows a consistent trend in shoreline change rates in space and time and dramatic changes to the trend have a reasonable explanation (e.g., the opening of an inlet, the position of a groin, the addition of a beach fill, the permanent sand loss due to a dune-overwash storm event), then GenCade has the potential to produce very reasonable results. In addition, locations having consistent long-term erosion problems are the most common locations where GenCade modeling is required.

2.1.3 Assumption 3

All portions of the beach within the project area contain a sufficient volume of sand such that non-erodable surfaces (hard bottoms) are never exposed.

The model predicts the amount of material transported in each grid cell during each time-step, assuming that there is sufficient sand to transport. This prediction cannot be accurate if there is insufficient erodible material available for transport. Because this is not always known, model-derived transport rates are sometimes referred to as potential transport rates.

Shorelines with ample material for transport are generally characterized as having wide, sandy beaches with long, gently curving, arcuate shorelines. The key criterion is that regardless of the amount of erosion that occurs at any location within the model domain over the entire length of the model

run, no non-erodible hard bottom features are exposed. Some shorelines clearly do not meet this definition, for example, the coastline north of Portland in Maine. This is a region of rocky shorelines interspersed with occasional pocket beaches along the landward edges of bays, frequently near river mouths that provide small amounts of locally derived sediment. Small islands also frequently have sand-starved beaches.

However, it may be difficult to differentiate a beach that has a nearly sufficient sediment supply from one that is fully sufficient. Non-erodible material on beaches is typically in the form of exposed bedrock outcrops, consolidated mud or peat layers (e.g., from lagunal deposits exposed when a barrier island rolls over itself), or biologically derived reefs. Small subaqueous outcrops may be visible in aerial photographs or may manifest themselves as small-scale, abrupt changes in the shoreline orientation or beach profile. However, be aware that other factors, such as erosional hotspots caused by bathymetry-induced wave refraction patterns outside the surfzone, may create similar shoreline signatures. In some cases, it may be possible to model these natural outcrops in GenCade as a groin or breakwater. In other cases it may be appropriate to model them using a minor sink term.

2.2 Model assumptions at a study site

It should be clear from the discussion above that it is unreasonable to expect that the one-line model assumptions will be completely satisfied at any study site. This, however, should not be interpreted to mean that application of a one-line model is without value. All models that attempt to describe the behavior of real-world systems are, to a greater or lesser degree, approximations. To the extent that they are reasonable approximations, they can provide a level of guidance for understanding and predicting the behavior of these systems, particularly when comparing differences among alternatives.

At the beginning of a new project, a modeler's greatest challenge is usually locating and formatting the data needed as GenCade model inputs. These data may include aerial photographs, shoreline positions, representative beach profiles, sediment budgets, wave data, and engineering activities. Beginning with the acquisition of the basic information about the study site, the modeler should begin the process of coming to understand the general nature of the site, the issue(s) to be addressed through modeling, and how limitations of one-line models will affect calculations given the

project setting and goals. A deep understanding of processes and knowledge of site history will help guide the modeler through different phases of the project.

Part of this process is to evaluate the project site in terms of the assumptions inherent in the model. This is rarely so straightforward as to be able to say that the parameters of the site perfectly agree with or are in total opposition to the model assumptions. Rather, in most cases the agreement can be expected to qualitatively range somewhere from moderate to good. In many cases, the modeler is not without recourse. The modeler may be able to adjust model inputs, model setup and procedure, or develop post-model analysis to reduce the level of uncertainty in the results. In some cases, this procedure can be fairly straightforward and automatic by selecting the most appropriate set of shorelines for use in calibration, verification, and production runs. In other cases, it may require some creative design, for example, in the location of the grid *x*-axis or the time span of the model run. The following section discusses a case of this type.

The acceptable level of agreement between a study site and the model assumptions is also a function of the nature of the questions which the model results are expected to address. For example, an agreement may be judged acceptable if the answers being sought are of the preliminary, scoping type or where the purpose of the study is the identification of the better of two alternative coastal sites for some development project. However, the same agreement could be judged as poor and require extensive efforts to minimize the disagreement if important engineering decisions will be based upon the results, such as the detailed design of a beach fill project.

As part of this process, it is incumbent upon the modeler, as it is for any scientist, to check results with general understanding and simple tools. The modeler has the greatest understanding of the weaknesses and limitations of the methodology and must communicate the results and associated uncertainty. Modeling studies should not focus on supplying deterministic answers to the problems being investigated. Rather, they should focus on supplying statistical estimations of future conditions. A heuristic approach to modeling studies is recommended over a deterministic approach.

The use of one-line models in the analysis of longshore sediment transport, in the prediction of shoreline behavior, and in the design of coastal projects has not been free from controversy. The controversy has been part of a larger discussion as to the appropriate human response to dynamic shorelines that may be experiencing significant rates of long-term erosion or accretion. One viewpoint is that beaches are naturally dynamic systems, and beach erosion is rarely a problem until mankind starts building structures adjacent to the shoreline. The corollary to this viewpoint is generally that the appropriate role of government and society is to not allow the construction of such structures (see, for example, Kaufman and Pilkey 1979). A few of the more significant studies that discuss the limitations of GENESIS and specifically criticize the way that model assumptions have been addressed in the past include Pilkey et al. (1993), Young et al. (1995), Thieler et al. (2000), and Cooper and Pilkey (2007). Finkl (2002) provides a broad overview of the debate on the value of one-line shoreline change models, particularly GENESIS, as it unfolded in the pages of the *Journal of Coastal Research* during the 1990s. This paper provides many references to both the original articles and the rebuttal discussions.

It is important for today's GenCade modelers to be aware of the variety of alternative viewpoints, to seek middle-ground areas where compromise can be reached, and to evaluate and incorporate the model criticisms so that model applications can become more scientifically rigorous. One-line models are most reliable when calibrated and validated and applied to compare relative performance for different alternative designs.

2.3 Procedure for cases that violate basic assumptions

There are some cases that violate model assumptions where it may be necessary to run GenCade simulations. One example of a recent project where the GenCade basic assumptions were violated is Sargent Beach and Matagorda Peninsula, Texas. Both Sargent Beach and Matagorda Peninsula have experienced critical erosion in recent years. The main goal of the most recent study (Rosati et al. 2013) was to determine the feasibility of structural solutions to reduce erosion. However, unlike most sandy barrier islands along the southern Texas coast, Sargent Beach is mostly comprised of cohesive sediment overlain by a thin layer of fine-grained sand (Stauble et al. 1994). The presence of cohesive sediments disregards the basic assumptions of any one-line shoreline change model, but there were no other available models that would more appropriately evaluate the proposed alternatives than GenCade.

The first phase of the Sargent Beach and Matagorda Peninsula project was to investigate the coastal processes and determine which potential structural solutions could be successful. This phase involved an analysis of previous work, development of a sediment budget, and development of initial GenCade input data. During this phase, breakwaters, groins, bypassing systems, and beach nourishment were modeled in a scoping-level effort to evaluate potential solutions to reduce erosion. After the first phase, it was determined that breakwaters at Sargent Beach and groins at Matagorda Peninsula were most likely effective in reducing erosion with limited impacts to adjacent beaches.

More detailed numerical modeling took place during the second phase of the study. At Sargent Beach, GenCade simulations with breakwaters of different lengths, different distances offshore, and different gap widths were simulated. Different groin lengths, spacing intervals, and numbers of groins were simulated at Matagorda Peninsula. In addition to GenCade simulations, a Coastal Modeling System (CMS) numerical model was developed. The CMS computed morphology change and calculated currents which helped determine the recommended structure parameters.

In addition, all model results were considered qualitatively. Although the model results showed a rate of erosion during the simulation, each alternative was compared qualitatively, and emphasis was placed on the relative trends (erosion or accretion) and how the alternatives compared to each other (which alternative predicted the least or most erosion).

Finally, by using GenCade and the CMS together with engineering judgment, a preliminary design for the breakwaters and groins was developed. Since no model can accurately predict shoreline change for a beach with mixed sand and cohesive sediments, an adaptive approach for project implementation including a small demonstration project to evaluate design options and monitoring of performance was recommended. Once a successful design has been determined, subsequent phases of breakwater construction will continue. More information about this project, the GenCade alternatives, and the monitoring and implementation plans are included in the Sargent Beach technical reports (Thomas and Dunkin 2012; Rosati et al. 2013).

3 GenCade Requirements

This chapter focuses on requirements to successfully run GenCade within the SMS framework or as a stand-alone executable using the command prompt. At the simplest level, several files are necessary to execute a simulation. This chapter will discuss common user errors that cause errors during a simulation or prevent the executable from starting. The purpose of this chapter is to help new users understand which parts of the GenCade setup are commonly executed incorrectly and to help prevent them from making those errors.

3.1 Basic requirements to run GenCade

3.1.1 Required input files

Several input files are necessary to run a GenCade simulation. Once the user saves the project in the GenCade model of the SMS, these input files will be created automatically. At minimum, the GenCade control file (*.gen), the GenCade initial shoreline file (*.shi), and at least one GenCade wave forcing file (*.wave) are required to execute a successful simulation. These are ASCII files that can be opened with any text editor. Pages 106–107 of Report 1 (Frey et al. 2012a) describe the GenCade file-suffix naming convention.

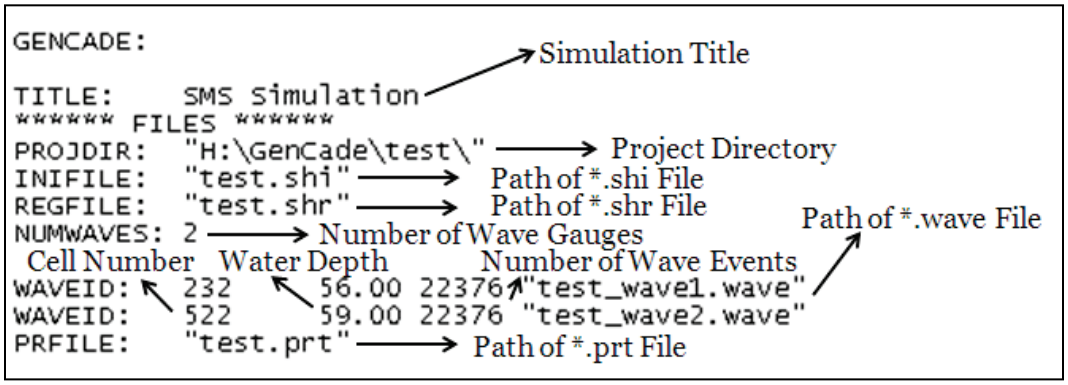
3.1.1.1 Control file

The *.gen file is the control file. It lists all of the information necessary to run the simulation including project directory information, grid setup, model control settings, engineering activities, and structures. Any changes saved in the GenCade model will modify the control file. However, it is sometimes necessary to open the *.gen file to gain a better understanding of the model control parameters.

The first section of the control file lists the project directory information for the other input files. The name of each file is specified in between quotation marks. In the simplest case, the *.shi file, representing the initial shoreline position, will be shown. In more complex cases, additional input files, including the *.shr file representing the regional contour position, will be included in this section of the control file. NUMWAVES represents the number of wave gauges on the grid. Each wave gauge (WAVEID) is

specified separately. The three numbers for each wave gauge are the cell number, water depth, and number of wave events. The path information of the *.prt (print) file is also shown in this section. This part of the control file is illustrated in Figure 2.

Figure 2. Files section of *.gen file.



The project directory (PROJDIR) is not recognized by GenCade. It does not affect the input to the model, rather it is read by the SMS to specify the locations of the input files. If the user wants to change the directory of the files while running outside of the SMS, the default directory is the directory where the *.gen file is located (if no path is specified in the input or output file cards). Alternately, the user may specify input directories by adding a path in quotes before each of the input files names (INIFILE, REGFILE, WAVEID). Similarly, the user may specify a nondefault output file directory by adding an output file path to the PRFILE card (inside quotes and before the file name).

The second section includes the model setup. The first line of this section specifies the units of the simulation in feet or meters. All linear values in the *.gen file (other than the effective grain size, *D50* (millimeters (mm))) will be in these units. GENUNITS refers to the choice between U.S. Customary System Units (USCS) and SI units. If the USCS is chosen, all of the linear measurements are in feet. Volume measurements are in cubic yards. When SI units are chosen, linear measurements are in meters and volume measurements are in cubic meters. Other information listed here is the x and y coordinates of the grid origin, the azimuth, the number of cells in the domain, the cell spacing (or –1 if variable resolution is utilized), simulation start and end date, time-step, K1, K2, ISMOOTH, and whether or not the case has a regional contour. DT and DTSAVE are specified in hours. The azimuth refers to the orientation of the grid x-axis, NX is the

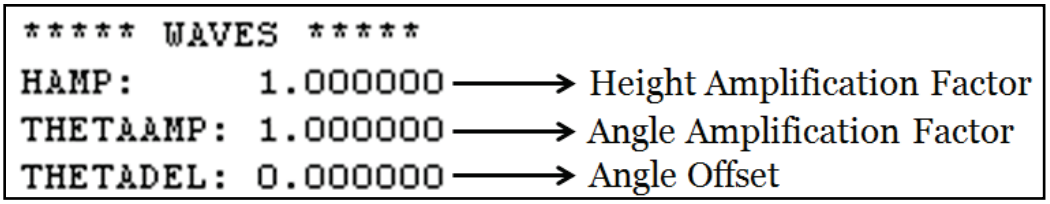
number of cells, and DX is the cell size. SIMDATS is the simulation start date, and SIMDATE is the simulation end date. In Figure 3, DT is 0.5 hour (hr) and DTSAVE is 168 hr (or 1 week). K_1 and K_2 are the longshore sand transport calibration coefficients. PRTOUT represents the output to the print file while PRWARN is the print file warning. The PRWARN default is "f" which means that only the first warning will be listed in the print file. When PRWARN is "t", each warning will be shown. For example, when a particular case has many instabilities at many time-steps, if "t"' is used for PRWARN, each instability warning will be shown in the print file. If "f" is chosen, then only the first instability will be shown. ISMOOTH, the number of cells in the offshore contour smoothing window, has a default of 11. If IREG is 1, the regional contour is on. The model setup section of the control file is shown in Figure 3. All of the parameters described previously are known as cards and can be modified by the user from the defaults used in the SMS. GenCade also has a number of advanced cards. These advanced cards are newer features that are not included in the interface. Instead, the user needs to manually add the advanced card to the *.gen file. An example of an advanced card is IWAVREGSMOOTH at the bottom of Figure 3.

Figure 3. Model setup section of *.gen file.

```
***** MODEL SETUP *****
GENUNITS:  (ft) ------> Units of Grid (meters or ft)
XO:        2378300.000000 ------> Grid Origin, X
YO:        230900.000000 ------> Grid Origin, Y
AZIMUTH:   217.500000 ------> Azimuth
NX:        615 ------> Number of Cells
DX:        300.000000 ------> Cell Size
SIMDATS:   19970921 ------> Simulation Start Date
SIMDATE:   20040827 ------> Simulation End Date
DT:        0.500000 ------> Time Step
DTSAVE:    168.000000 ------> Recorded Time Step for Output Files
K1:        0.600000 ------> K1
K2:        0.400000 ------> K2
PRTOUT:    t ------> Output to Print File
PRWARN:    f ------> Print File Warning
ISMOOTH:   100 ------> Cells in Smoothing Window
IREG:      1 ------> Regional Contour (1 = On, 0 = Off)
IWAVREGSMOOTH:307 ------> Regional Contour Smoothing
                          (Advanced Card)
```

The waves section is after the model setup. This section includes the information that is shown under *Input Wave Adjustments* in the *Seaward BC* tab of GenCade model control. The values in this section allow the user to adjust the wave height and angle. The angle offset, THETADEL, which adds (or subtracts, if negative) wave angles is in degrees. Figure 4 shows the waves section of the *.gen file with definitions for each card.

Figure 4. Waves section of *.gen file.



Information related to the beach setup is listed next (Figure 5). In this section, the user will find the median grain size (*D50*, in mm), the berm height, depth of closure, and the lateral boundary condition specifications. There are three types of lateral boundary conditions: pinned, gated, and moving. A pinned boundary condition means the beach will not move at the boundary. A gated boundary is implemented if a groin is specified at the boundary. When a moving boundary condition is chosen, the beach will move a cross-shore distance specified by the user. LBCTYPE (lateral boundary condition type) can be 0, 1, or 3. Zero represents a pinned boundary condition, 1 is gated, and 3 is a moving boundary condition. If a gated or moving boundary condition is chosen, additional information is necessary. For example, when a moving boundary condition is specified, the user must select the distance the boundary moves over a certain period of time. Both of these inputs are listed in the *.gen file. For example, LMOVY represents the movement of the left boundary condition relative to an offshore-looking observer, and LMOVPER represents the time selected that the boundary will move in terms of the simulation period, days, or time-step.

Engineering activities and structures are listed after the model control information. Groins are the first structure listed. Groins are represented by the cell index, length from the grid *x*-axis, and permeability. The user can create groins with or without a diffracting tip. If *Diffracting* is checked in the *Groins* menu in the GenCade model interface of the SMS, the user must enter the seaward depth of the groin. Figure 6 shows the groins section of the control file. The first four lines refer to a diffracting groin while the last three lines represent a non-diffracting groin. YDG and

YNDG both represent the distance from the grid *x*-axis to the seaward tip of the groin, for diffracting and non-diffracting groins, respectively. Permeability is a dimensionless factor between 0 and 1. Permeability is described in greater detail in pages 47–49 of Frey et al. (2012a).

Figure 5. Beach setup and boundary condition section of *.gen file.

```
***** BEACH *****
D50:        0.170000 ——→ Effective Grain Size
BERMHT:     4.500000 ——→ Average Berm Height
DCLOS:      26.500000 ——→ Depth of Closure
LBCTYPE:    3 ——→ Left Lateral Boundary Condition Type
     0 = Pinned
     1 = Gated
     3 = Moving
LMOVY:      50.000000 ——→ Shoreline Displacement
LMOVPER:    1 ——→ Shoreline Displacement Distance Per
     1 = Simulation Period
     2 = Day
     3 = Time Step
LGROINY:    0.000000
RBCTYPE:    1 ——→ Right Lateral Boundary Condition Type
RMOVY:      0.000000
RMOVPER:    1
RGROINY:    2000.000000 ——→ Length of Groin From
                            Shoreline to Seaward Tip
```

Figure 6. Groins section of *.gen file.

```
***** GROINS *****
IXDG:       100 ——→ Cell Index (Diffracting)
YDG:        38240.34234 ——→ Length from Grid
DDG:        5.000000 ——→ Seaward Depth
PDG:        0.100000 ——→ Permeability
IXNDG:      120 ——→ Cell Index (Non-diffracting)
YNDG:       37495.1249 ——→ Length from Grid
PNDG:       0.200000 ——→ Permeability
```

In the next section, each seawall reach is represented by a starting (ISWBEG) and ending cell (ISWEND) and the distance from the grid *x*-axis at the starting (SWY1) and ending cell (SWY2). This is the same information that is located in the GenCade model under seawall. Figure 7 shows the seawall information.

Figure 7. Seawall section of *.gen file.

```
***** SEAWALL *****
ISWBEG:    390 ----> Starting Cell
ISWEND:    395 ----> Ending Cell
SWY1:      40000.436664 ----> Distance from Grid at Starting Cell
SWY2:      40525.461362 ----> Distance from Grid at Ending Cell
```

The detached breakwaters section is next in the *.gen file. There are several equations that can be used for transmission, but the first cards are the same in all cases. First, the starting cell, ending cell, distance from the grid *x*-axis at starting and ending cell, and the depth at the starting and ending cell are entered. If constant wave transmission is chosen, the card TRANDB is included. It is the ratio of the height of the incident waves directly shoreward of the breakwater to the height directly seaward of the breakwater. In Figure 8, TRANDB is 0, which means no transmission. A value of 1 represents complete transmission.

Figure 8. Detached breakwater with constant transmission in *.gen file.

```
***** DETACHED BREAKWATERS *****
DBI1:      30 ----> Starting Cell
DBI2:      38 ----> Ending Cell
DBY1:      38249.23423 ----> Distance from Grid at Starting Cell
DBY2:      38210.32406 ----> Distance from Grid at Ending Cell
DBDEP1:    5.00000 ----> Depth at Starting Cell
DBDEP2:    5.00000 ----> Depth at Ending Cell
TRANDB:    0.00000 ----> Constant Transmission
```

When variable transmission is chosen for the detached breakwaters, a few extra cards are needed to run the simulation. After DBDEP2 (depth at the second cell), there is a new card called KTMETDB. This card tells GenCade which calculation to use for variable transmission: 0 means GenCade employs the methodology described in Ahrens (2001), 1 employs Seabrook and Hall (1998), and 2 employs d'Angremond et al. (1996). The required inputs for Ahrens (2001) and Seabrook and Hall (1998) are identical. Both

equations require the height of the freeboard (distance from MSL to the breakwater crest), the breakwater crest width, the seaward side slope, shoreward side slope, and the D50 of the armor stone. D50 in these cases is in meters or feet, depending on the units specification for the model. The only difference between the inputs for the d'Angremond equation (1996) compared to Ahrens (2001) and Seabrook and Hall (1998) is permeability is needed instead of D50. Figure 9 illustrates the correct cards for each variable transmission equation.

Figure 9. Detached breakwater for variable transmission in the *.gen file.

```
***** DETACHED BREAKWATERS *****
DBI1:      56 ---------> Starting Cell
DBI2:      62 ---------> Ending Cell
DBY1:      37023.23423 ---------> Distance from Grid at Starting Cell
DBY2:      37053.32406 ---------> Distance from Grid at Ending Cell
DBDEP1:    5.00000 ---------> Depth at Starting Cell
DBDEP2:    5.00000 ---------> Depth at Ending Cell
KTMETDB:   0 ---------> Transmission
   0 = Ahrens
   1 = Seabrook & Hall
   2 = d'Angremond
HDB:       2.00000 ---------> Freeboard to MSL
BDB:       5.00000 ---------> Width
SSDB:      1.00000 ---------> Seaward Side Slope
SHSDB:     1.00000 ---------> Shoreward Side Slope
D50DB:     2.00000 ---------> D50 of Armor Stone

DBI1:      81 ---------> Starting Cell
DBI2:      89 ---------> Ending Cell
DBY1:      36582.23423 ---------> Distance from Grid at Starting Cell
DBY2:      36340.32406 ---------> Distance from Grid at Ending Cell
DBDEP1:    5.00000 ---------> Depth at Starting Cell
DBDEP2:    5.00000 ---------> Depth at Ending Cell
KTMETDB:   1 ---------> Seabrook and Hall
HDB:       2.00000 ---------> Freeboard to MSL
BDB:       5.00000 ---------> Width
SSDB:      1.00000 ---------> Seaward Side Slope
SHSDB:     1.00000 ---------> Shoreward Side Slope
D50DB:     2.00000 ---------> D50 of Armor Stone

DBI1:      103 ---------> Starting Cell
DBI2:      112 ---------> Ending Cell
DBY1:      36230.23423 ---------> Distance from Grid at Starting Cell
DBY2:      36123.32406 ---------> Distance from Grid at Ending Cell
DBDEP1:    5.00000 ---------> Depth at Starting Cell
DBDEP2:    5.00000 ---------> Depth at Ending Cell
KTMETDB:   2 ---------> d'Angremond
HDB:       2.00000 ---------> Freeboard
BDB:       5.00000 ---------> Crest width
SSDB:      1.00000 ---------> Seaward Side Slope
SHSDB:     1.00000 ---------> Shoreward Side Slope
PBD:       0.30000 ---------> Permeability
```

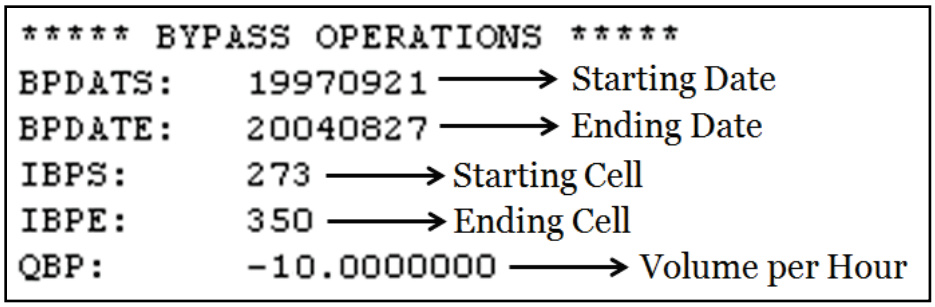
Each beach fill event needs five pieces of information: the starting and ending date, the starting and ending cell location, and the added berm width. Beach fills are often provided in terms of a volume. In order to convert the total fill volume to added berm width, the user must divide the volume by the total alongshore fill distance and the active profile height (berm height plus depth of closure). If the volume is in cubic yards, it is also necessary to convert from cubic yards to cubic feet in order to input the proper added berm width into GenCade. For example, the given beach fill volume is 200,000 yd^3. The alongshore placement distance is 10,000 ft, and the active profile (berm height plus depth of closure) is 25 ft. A volume of 200,000 yd^3 is equal to 5,400,000 ft^3. Once all of the values are in cubic feet or feet, the user can solve the equation which gives an added berm width of 21.6 ft. Additionally, the beach fill shown in Figure 10 is a single, rectangular beach fill. Although GenCade does not have the capability to input a beach fill in a trapezoidal shape, the user could create multiple beach fills with different added berm widths on either side of the main beach to mimic the shape of a trapezoidal beach fill.

Figure 10. Beach fills section of *.gen file.

```
***** BEACH FILLS *****
BFDATS:    19990301 ----> Starting Date
BFDATE:    19990430 ----> Ending Date
IBFS:      65 ----> Starting Cell
IBFE:      80 ----> Ending Cell
YADD:      38.710000 ----> Added Berm Width
```

The bypass operations section of the *.gen file is next and is similar to the beach fill section. A bypass operation refers to the amount of material that is either removed or added at a constant rate. A starting date, ending date, starting cell, and ending cell are needed for each bypass operation. Instead of entering the added berm width, the volume per hour is required. The volume is in cubic meters or cubic yards if GENUNITS is in meters or feet, respectively. In Figure 11, the specified bypassing rate is –10 yd^3/hr (–87,600 yd^3/yr). This means that a total of 10 yd^3 is removed between cells 273 and 350 each hour. If material is being moved from one location to another, two separate bypass operations, one positive and one negative, must be included in this section.

Figure 11. Bypass operations section of *.gen file.



The inlets section of the control file includes all of the information associated with each inlet. Figure 12 represents the typical inlets section for one inlet. The inlet starting and ending cell, the left bypassing bar starting and ending cell, and the right bypassing bar starting and ending cell are necessary. The inlet name must be in quotations to be read by the SMS. Additionally, the inlet starting and ending cell must be located above the inlet name in the *.gen file. The next part of the inlets section specifies the initial and equilibrium volume for each morphological feature. If there is a jetty at an inlet, the jetty bypassing coefficient must be included in the control file. In addition, the cell location, diffracting depth, and permeability of the jetty must be specified. Finally, the IMOR card represents a dredging event. For the IMOR card, 1 represents the left attachment bar, 2 represents the left bypassing bar, 3 is the ebb shoal, 4 is the flood shoal, 5 is the right bypassing bar, and 6 represents the right attachment bar. Figure 82 shows a schematic of all of the morphological elements at an inlet. In Figure 12, IMOR is 3 which means the ebb shoal is dredged. The starting date, ending date, number of days, and dredged volume must be defined. When a dredging event is added in the SMS, only the starting date, ending date, and volume must be specified. When the *.gen file is created, DRDAY (number of days dredged) is added to the file.

3.1.1.2 Initial shoreline file

Since GenCade calculates shoreline change, the model needs the initial shoreline position. There are four ways to generate an initial shoreline in GenCade. For a simple idealized case with a straight shoreline or a test case, the user may manually draw a shoreline in the conceptual model with the *Create Feature Arc* command. CAD files can be brought into the SMS and converted to a shoreline. After opening a CAD file in the SMS, the user should uncheck the layers that are not relevant to the GenCade features, right click on the CAD drawing layer in the SMS data tree and select *Convert->CAD->Map*, right click and change to a GenCade map coverage,

Figure 12. Inlets section of *.gen file.

```
***** INLETS *****
IINLS:     223 ----> Inlet Starting Cell
IINLE:     229 ----> Inlet Ending Cell
INLNAME:   "Masonboro" ----> Name of Inlet
IBYPL1:    222 ----> Left Bypassing Bar Start Cell
IBYPL2:    222 ----> Left Bypassing Bar Ending Cell
IBYPR1:    230 ----> Right Bypassing Bar Start Cell
IBYPR2:    230 ----> Right Bypassing Bar Ending Cell
VVSE:      4305000.000000 ----> Ebb Shoal Initial Volume
VVSF:      4305000.000000 ----> Flood Shoal Initial Volume
VVSBL:     3690000.000000 ----> Left Bypassing Bar Initial Volume
VVSBR:     3690000.000000 ----> Right Bypassing Bar Initial Volume
VVSAL:     307500.000000  ----> Left Attachment Bar Initial Volume
VVSAR:     307500.000000  ----> Right Attachment Bar Initial Volume
VVSEQ:     4305000.000000 ----> Ebb Shoal Equilibrium Volume
VVSFQ:     4305000.000000 ----> Flood Shoal Equilibrium Volume
VVSBQL:    3690000.000000 ----> Left Bypassing Bar Equilibrium Volume
VVSBQR:    3690000.000000 ----> Right Bypassing Bar Equilibrium Volume
VVSAQL:    307500.000000  ----> Left Attachment Bar Equilibrium Volume
VVSAQR:    307500.000000  ----> Right Attachment Bar Equilibrium Volume
JBCL:      1.000000 ----> Left Jetty Bypassing Coefficient
JBCR:      0.000000 ----> Right Jetty Bypassing Coefficient
IXDG:      223 ----> Cell Location of Left Jetty
YDG:       31004.687233 ----> Distance from Grid for Left Jetty
DDG:       15.000000 ----> Diffracting Depth
PDG:       0.300000  ----> Permeability
IXDG:      230 ----> Cell Location of Right Jetty
YDG:       30825.173681 ----> Distance from Grid for Right Jetty
DDG:       15.000000 ----> Diffracting Depth
PDG:       0.000000  ----> Permeability
IMOR:      3  ----> Dredged Shoal
IDREDS:    19980305  ----> Starting Dredge Date
IDREDE:    19980429  ----> Ending Dredge Date
DRDAY:     56 ----> Number of Days
DREDV:     1672227.000000 ----> Dredged Volume
```

and select the relevant features and right click to assign those features to the initial shoreline. If the site location has shorelines in shapefile format, the user may bring those shoreline shapefiles directly into the conceptual model of the SMS. The final option involves the creation of the *.cst file which is a text file with *x*- and *y*-coordinates of each point along the shoreline. More information about using shapefiles as the shoreline and setting up the *.cst file can be found in Frey et al. (2012a). Once the user saves a project in the conceptual model, the initial shoreline (*.shi) file is created. A sample *.shi file is shown in Figure 13. The header states that this file is the INITIAL SHORELINE DATA FOR GENCADE. The heading also includes the number of cells in the grid (as specified by NX and shown

in Figure 3) and the title of the simulation. Beneath the four header lines, there is a number in the file that represents each cell of the grid. The value for each cell number is the cross-shore distance between the grid *x*-axis and the initial shoreline. For example, in Figure 13 below, the distance between the GenCade *x*-axis and the shoreline at the first cell is 27269.849. The file does not display units, but the units are the same as specified in the SMS (either feet or meters). Each row of the file has 10 values that represent 10 sequential, cross-shore, initial cell shoreline positions. This format continues until the end of the grid. In a case with 102 cells, the first 10 rows after the 4-row header will include 10 values while the 11th row will have 2 values.

Figure 13. Partial sample *.shi file.

```
*********************************************
 INITIAL SHORELINE DATA FOR GENCADE:
 615 Offsets - TITLE:SMS Simulation
*********************************************
 27269.849 27241.409 27209.004 27175.627 27141.738 27121.795 27081.132 27048.123 27013.853 26919.380
 26826.790 26896.045 26903.235 26883.452 26853.229 26826.241 26806.603 26777.150 26749.844 26720.273
 26685.279 26666.051 26635.245 26608.910 26572.097 26545.679 26525.508 26515.885 26497.417 26488.489
 26470.858 26459.354 26444.122 26423.701 26401.287 26408.603 26409.074 26426.131 26424.577 26427.353
 26445.652 26465.686 26494.916 26519.939 26568.439 26648.968 26709.371 26763.071 26737.741 26735.840
 26793.868 26700.893 26683.474 26695.849 26708.223 26720.597 26732.972 26745.346 26757.720 26770.095
 26782.469 26794.843 26830.308 26978.798 27067.147 27068.867 27028.873 26963.311 26874.664 26773.356
 26666.721 26557.232 26435.963 26322.550 26232.652 26156.332 26079.520 25983.667 25882.030 25817.191
 25745.486 25660.568 25585.445 25568.101 25529.108 25464.431 25454.070 25423.724 25391.186 25376.177
 25368.899 25310.743 25286.490 25261.032 25229.535 25212.811 25211.521 25210.834 25192.423 25183.549
 25155.753 25142.222 25139.020 25149.358 25152.457 25145.482 25151.972 25150.817 25158.692 25149.505
 25166.805 25163.991 25163.933 25172.652 25172.972 25188.311 25213.000 25236.265 25243.806 25264.562
 25276.830 25286.201 25291.992 25305.094 25316.459 25327.144 25338.383 25347.109 25359.110 25381.193
 25375.808 25404.638 25406.244 25412.640 25435.914 25479.052 25500.965 25473.262 25474.950 25476.545
 25489.918 25527.260 25541.478 25546.251 25565.084 25586.367 25577.686 25562.095 25584.253 25606.411
```

3.1.1.3 Waves file

The last file that is necessary in every GenCade simulation is the *.wave file (wave height, period, and direction). Report 1 (Frey et al. 2012a) provides step-by-step details of how to enter wave information in the SMS, so those instructions will not be included here. After saving the GenCade model in the SMS, a *.wave file is created for each representative wave gauge. Wave Information Study (WIS) wave information is a common input for GenCade, so most cases will have one to five wave gauges and one to five *.wave files. However, for locations that have more spatially dense wave datasets available, the project may have more *.wave files. Presently, there must be fewer than 400 wave files. The naming convention for wave files is based on the order of the waves on the grid. The *.wave file representing the wave gauge located at the lowest cell number closest to the origin of the grid is named *project_wave1.wave*. The next *.wave file along the grid is named *project_wave2.wave* and so on.

Each *.wave contains five columns of information. Column one represents the date in YYYYMMDD format while column two shows the time in HHMM as referenced to a 24 hr clock. The third column is the wave height. The default measurement for wave height is meters regardless of the user-defined units for GenCade. While GenCade can run with wave height measured in feet, this option must be initiated by an advanced card in the *.gen file instead of within the SMS. If this card is not added, the wave height is in meters. The fourth column is wave period in seconds and the fifth column is the wave direction. The user may enter the wave direction in meteorologic, oceanographic, Cartesian, or shore-normal convention in the SMS, but the direction will be converted to shore-normal when the project is saved. Therefore, the final *.wave file will include the wave direction in shore-normal convention. Figure 14 shows the format of an example *.wave file. Figure 2 shows the number of wave gauges along with the cell number, water depth, number of wave events, and the *.wave file name for each gauge are included in the *.gen file.

Figure 14. Partial sample *.wave file.

```
19970101 0 0.46 5.72 -0.30
19970101 100 0.38 5.94 8.70
19970101 200 0.37 6.16 15.00
19970101 300 0.37 6.35 19.10
19970101 400 0.40 6.48 21.80
19970101 500 0.45 6.24 41.30
19970101 600 0.00 4.87 101.40
19970101 700 0.00 4.66 112.10
19970101 800 0.00 4.64 113.30
19970101 900 0.00 4.71 109.60
19970101 1000 0.00 4.80 105.80
19970101 1100 0.00 4.91 103.60
19970101 1200 0.00 5.01 102.40
19970101 1300 0.00 5.03 103.20
19970101 1400 0.00 5.00 105.50
19970101 1500 0.00 4.98 108.00
19970101 1600 0.00 4.94 109.80
19970101 1700 0.00 4.91 111.50
19970101 1800 0.00 4.87 114.10
19970101 1900 0.00 4.91 114.30
19970101 2000 0.00 4.89 114.80
19970101 2100 0.00 4.86 114.50
19970101 2200 0.00 4.85 113.50
19970101 2300 0.00 4.90 112.30
19970102 0 0.00 5.16 106.10
```

3.1.2 Optional input files

Some cases may require additional input files. Although the heading refers to these files as optional, these files must exist if they are included in the *.gen file. When the user specifies variable grid cell resolution, a new file, called *.shdx, is created. The format of this file is very similar to the *.shi file. The header for this file is DX SHORELINE DATA FOR VARIABLE GRID FOR GENCADE. The heading also includes the number of cells and

the title of the simulation. Each number represents each cell in the simulation. The value for each cell is the cell size in the units specified by the user. For example, in Figure 15, the first 169 cells are 149.737 ft in width. From cells 170 to 198, the cell size decreases to the smallest cell size of 9.994 ft. In the example shown in Figure 15, the user specified the maximum cell size as 150 ft and the minimum cell size as 10 ft. However, these cell sizes will be adjusted slightly based on the user-specified total length of the grid *x*-axis. When a constant cell spacing is used, that spacing is specified in the *.gen file under DX. GenCade is notified that variable spacing is used with a DX value of –1.

Figure 15. Partial sample *.shdx file.

```
************************************************
 DX SHORELINE DATA FOR VARIABLE GRID FOR GENCADE:
 837 Sizes - TITLE:SMS Simulation
************************************************
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737
 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 149.737 143.957
 130.870 118.972 108.157 98.324 89.386 81.260 73.873 67.157 61.052 55.502
 50.456 45.869 41.699 37.908 34.462 31.329 28.481 25.892 23.538 21.398
 19.453 17.684 16.077 14.615 13.287 12.079 10.981 9.982 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994 9.994
```

When a regional contour is present, a *.shr file is created as an input. This file is the identical format to the *shi file. The first line in the header states REGIONAL SHORELINE DATA FOR GENCADE while the second line specifies the number of cells and gives the simulation title. Figure 16 shows an example *.shr file. In addition to the *.shr file, the *.gen file must notify GenCade that a regional contour is being used. This is done through the IREG card (shown in Figure 3). The default IREG is 0, which means that there is no regional contour. When a regional contour exists in the SMS, the IREG value will change to 1. If the user is working outside of the SMS, both the REGFILE and the IREG value must be specified independently.

Figure 16. Partial sample *.shr file.

```
**************************************************
REGIONAL SHORELINE DATA FOR GENCADE:
604 Offsets - TITLE:SMS Simulation
**************************************************
28143.085 27839.067 27595.177 27375.210 27155.244 26934.140 26709.019 26483.898 26258.777 26030.548
25801.546 25572.545 25343.543 25156.692 24972.646 24788.599 24608.960 24436.168 24263.376 24090.585
23917.793 23748.190 23583.657 23419.123 23254.590 23090.056 22925.523 22749.833 22569.388 22388.943
22208.498 22038.781 21878.005 21717.229 21556.453 21395.678 21236.622 21080.398 20924.174 20767.950
20611.727 20463.785 20323.395 20183.005 20042.615 19902.225 19761.241 19616.149 19471.058 19325.966
19180.874 19035.782 18897.974 18761.125 18624.277 18487.429 18350.580 18223.442 18097.098 17970.755
17844.411 17718.067 17599.398 17481.935 17364.472 17247.009 17129.546 17015.720 16904.531 16793.341
16682.151 16570.962 16475.327 16395.668 16316.010 16236.351 16156.692 16050.051 15889.338 15728.624
15567.911 15407.197 15246.484 14991.958 14731.044 14470.130 14209.216 13946.136 13680.881 13415.626
13153.362 12952.303 12751.243 12514.478 12179.006 11763.785 11408.602 11078.072 10669.318 10303.558
```

The final file that is only needed in certain cases is the water level (*.wl) file. This file is necessary in cases where detached breakwaters with time-dependent wave transmission are present. Water levels are needed for the transmission equations. The first two columns of the file are in the form of date (YYYYMMDD) and time (HHMM) which are the same format for date and time used in the *.wave files. The final column includes the water level in meters or feet at each time. Once the project is saved in the SMS, the *.gen file will also include the *.wl file name and location.

3.1.3 GenCade Model Execution

When the user has finished setting up GenCade and all of the input files have been created, the user has the option to run the simulation in the SMS or through the command prompt. The simplest way to run a simulation is in the SMS. If the user set up the GenCade input data in the SMS, all of the input files will automatically be located in the proper location. A new GenCade simulation is executed by clicking on *Run GenCade,* which is in the *GenCade* pull-down window. A model-execution progress dialogue/window will appear showing the simulation progress (Figure 17). Although there is no bar with time remaining, the window does show when each year of the simulation is complete. Figure 17 shows both the *GenCade* menu and the window that opens while a simulation is in progress.

An option for users who want to run multiple simulations at once is to use the command prompt. To run the simulation from the command prompt, the GenCade executable must be copied to the directory containing the input files. If the *.gen file is opened, the user will notice the project directory (PROJDIR) near the top of the file. The project directory line is ignored when running outside of the SMS. For example, even if the PROJDIR references a different directory than the directory with the files and executable or the PROJDIR is deleted, the simulation will run through the command prompt. However, it is good practice to change the directory

Figure 17. Example of GenCade simulation in the SMS.

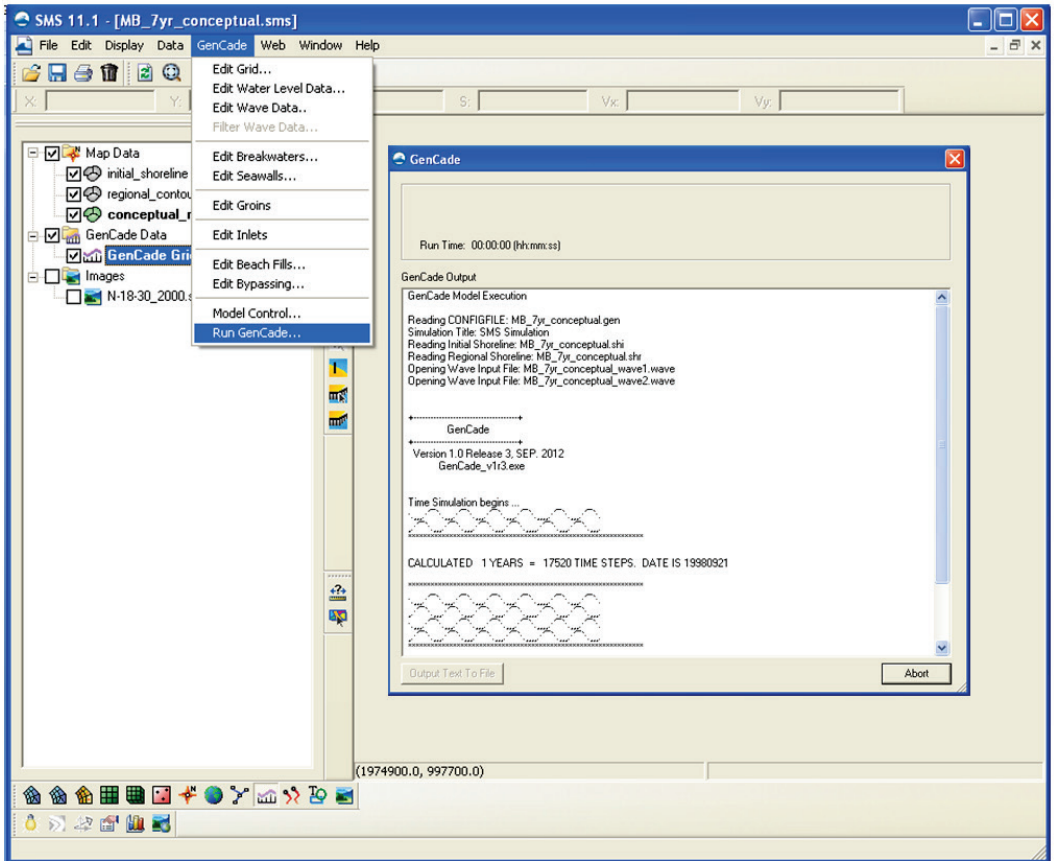
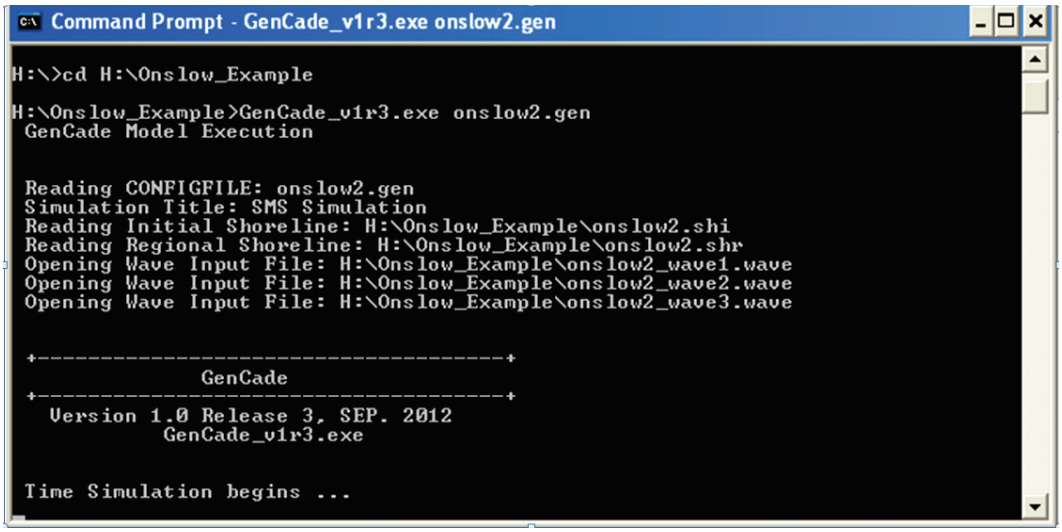


Figure 18. Example of GenCade simulation in command prompt.



path in the *.gen file when moving the input files to a different directory. To run the simulation through the command prompt, on the PC go to *All Programs->Accessories->Command Prompt*. When the command prompt window opens, navigate to the proper directory by using the

command *cd* (change directory to the folder including the input files). Once in the proper directory, enter the name of the executable followed by the name of the *.gen file as shown in Figure 18. Alternatively, the user can drag and drop the *.gen file onto a GenCade executable in the windows environment (e.g., Windows Explorer).

Multiple simulations can be executed in the SMS as well. However, it would likely consume considerably more memory (RAM), which is the reason why the command prompt is recommended when running several simulations at once.

3.1.4 Output files

There are a number of files that are created during a simulation run. The suffix-naming convention for these files is discussed in pages 106–107 of Report 1 (Frey et al. 2012a). The most detailed file is the print (*.prt) file. This file includes all of the output information for every cell (shoreline change, breaking wave angles, breaking wave height, gross and net transports, and volume change). The information can be viewed in a text editor. To make data access and visualization easier, the executable also produces the same data in separated-column formatted files (*.slo, *.mqn, *.mqr, *.mql, *.qtr, *.off). All of the column-formatted output files can be viewed in the SMS by opening them in the workspace.

The shoreline position (*.slo) file outputs the shoreline position (distance from *x*-axis to shoreline) at each cell on the grid. The output times are based on the recorded time-step (*DTSAVE* in Figure 3) entered under *Model Control*. The *.slo file can be opened and viewed in the SMS. More information about that capability is described in Frey et al. (2012a). The first column of Figure 19 shows the dates and the remaining columns show the shoreline positions at each grid cell. The rows show the shoreline positions at each time-step.

Figure 19. Partial example of output in *.slo (data extend both downward and to the right).

```
Shoreline Position Output
19970101      28513.23      28271.94      28021.91      27804.62      27611.21
19970108      28513.23      28265.05      28022.61      27807.01      27608.32
19970115      28513.23      28252.40      28022.03      27810.40      27603.27
19970122      28513.23      28247.31      28020.71      27810.91      27601.43
19970129      28513.23      28241.32      28017.74      27810.23      27599.40
19970204      28513.23      28239.88      28016.71      27809.75      27598.90
19970212      28513.23      28238.48      28015.54      27809.12      27598.39
19970219      28513.23      28233.80      28010.37      27805.49      27596.33
19970225      28513.23      28232.76      28008.96      27804.33      27595.76
19970304      28513.23      28230.93      28006.32      27802.05      27594.67
```

There are three output files that describe transport rates: mean annual net transport (*.mqn), mean annual transport rate to the left (*.mql), and mean annual transport rate to the right (*.mqr). All of the files are in the same format. The rates are output automatically after every year of the simulation. The last row in the file represents the mean annual transport rates. Additional dates can be output in the files by going to the *Print Date* box of the *GenCade Model Control* window. The date at the end of each year of the simulation is in the first column. The rate at each cell for each year is shown in the other columns and rows. The last row gives the transport rate averaged for each of the years for each cell. The units in these files are in cubic yards/year or cubic meters/year depending on whether the grid was set up in feet or meters. Figure 20 shows the mean annual transport rate to the left (*.mql file) for the first four cells in the grid. Notice that the last date is repeated; this date represents the average rate over all of the years. Since the *.mqn and *.mqr files are in the identical format, they are not shown here.

Figure 20. Example of output for transport rates.

```
Mean Annual Transport Rate to the Left
19960101        -117799.        -117799.        -116884.        -116359.
19970101        -174767.        -174767.        -174228.        -173765.
19980101        -110868.        -110868.        -110477.        -110143.
19990101        -113390.        -113390.        -113075.        -112744.
19991230        -145874.        -145874.        -145478.        -145087.
19991230        -132706.        -132706.        -132187.        -131778.
```

The net transport rate for each recorded time-step in the simulation is shown in the *.qtr (net transport rate) file. In the example file that follows (Figure 21), the recording time-step is one week, so this file provides more information than the mean annual net (*.mqn) file. The format of the file is the same as the mean annual transport files.

Figure 21. Example of output for *.qtr file.

```
Net Transport Rate
19970101             0.              0.              0.              0.
19970108        -68784.         -68784.         -26044.         -28495.
19970115         -3782.          -3782.           2175.           3065.
19970122        -38485.         -38485.         -32116.         -29777.
19970129       -194539.        -194539.         -25557.          87768.
19970204        156745.         156745.         185546.         207404.
```

During the GenCade simulation, the offshore contour (*.off) file is produced. The offshore contour is recalculated at each time-step based on the calculated shoreline. More details are provided in Report 1 (Frey et al. 2012a) and in Section 4.5 of this report. Figure 22 shows an example of the *.off file.

Figure 22. Example of output for *.off file.

```
Calculated Offshore Contour
19970101      28143.09      27839.07      27595.18      27375.21
19970108      29497.48      29194.56      28951.78      28732.91
19970115      29497.48      29194.56      28951.76      28732.89
19970122      29497.48      29194.55      28951.76      28732.88
19970129      29497.48      29194.55      28951.75      28732.87
19970204      29497.48      29194.55      28951.75      28732.86
```

When inlets are included in the simulation, an *.irv file is created for each separate inlet. Each *.irv file lists the volume in cubic yards or cubic meters for each shoal for each recorded time-step. The *.irv file also includes the flux of sediment into and out of each morphological element, which is described in pages 37–42 of Frey et al. (2012a). Although the file can be opened and viewed, it consists of too many columns to show in this report. Each *.irv file can be plotted in the SMS to visually view the volume changes for each shoal over the entire simulation.

3.2 Common setup mistakes

The developers are often contacted when new users encounter problems with the setup of their GenCade project. This section provides solutions to the most common problems.

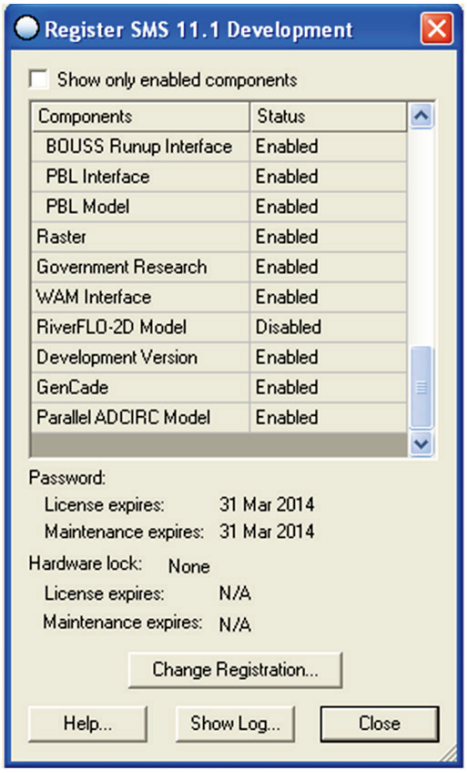
3.2.1 SMS license problems

When new users express interest in GenCade, they are referred to the Aquaveo website[1] to download SMS 11.1. Following the installation, many users assume that they can begin working with GenCade immediately. However, the GenCade module must be enabled before either the conceptual model or GenCade model can be used.

The most frequent confusion comes about when a new GenCade user already has SMS 11.1 installed and has an existing license for other models. That user may try to open an existing GenCade project in the SMS 11.1 and find that the project may not be opened. To determine if the existing license includes GenCade, go to *Help->Register*. In the window that pops up, uncheck the box that states *Show only enabled components* (Figure 23). Scroll down to *GenCade* which is near the bottom of the list. This window will report whether or not GenCade is enabled. If GenCade is disabled, the user will need a new license that includes GenCade.

[1] http://www.aquaveo.com/downloads?tab=2#TabbedPanels

Figure 23. Registration window in the SMS.



U.S. Army Corps of Engineers employees may request a license for SMS 11.1 with GenCade through the U.S. Army Engineer Research and Development Center Help Desk (email: sms@erdc.usace.army.mil). Other interested users should contact Aquaveo for support. If users have SMS 11.0, they may upgrade to SMS 11.1 for free. They would only need to purchase the GenCade interface (GenCade module and GenCade coverage in the map module) to start using GenCade. Aquaveo also provides evaluation licenses to test the product (http://evaluate.aquaveo.com/) before buying; Corps users can test GenCade with the evaluation license as well.

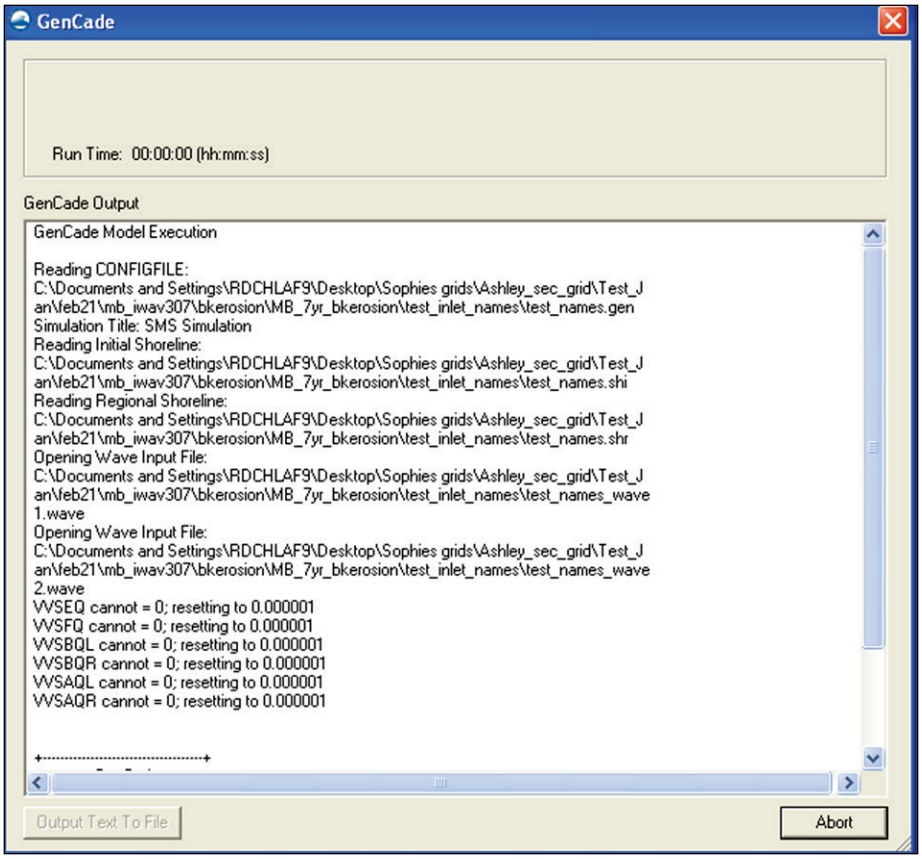
3.2.2 Failure to properly define each feature

When a feature is missing on the 1D grid but is present in the conceptual model, it might be because the feature is not properly defined in the conceptual model. Features representing structures or inlets should be created in the conceptual model. Each feature is created by drawing a feature arc and defined by opening the *GenCade Arc Attributes* window. If the user fails to define the arc attributes while in the conceptual model, the arc will not be considered during the conversion to the GenCade grid. A quick visual check of the conceptual model before converting to the

GenCade model should prevent this mistake. During the check, if any of the arcs are black, this means they have not yet been defined. Click on the arc, go to the *GenCade Arc Attributes* window and define the arc. Although the initial shoreline, regional contour, reference line, seawall, and attachment bar can be defined by the type of structure or line, other features require additional details.

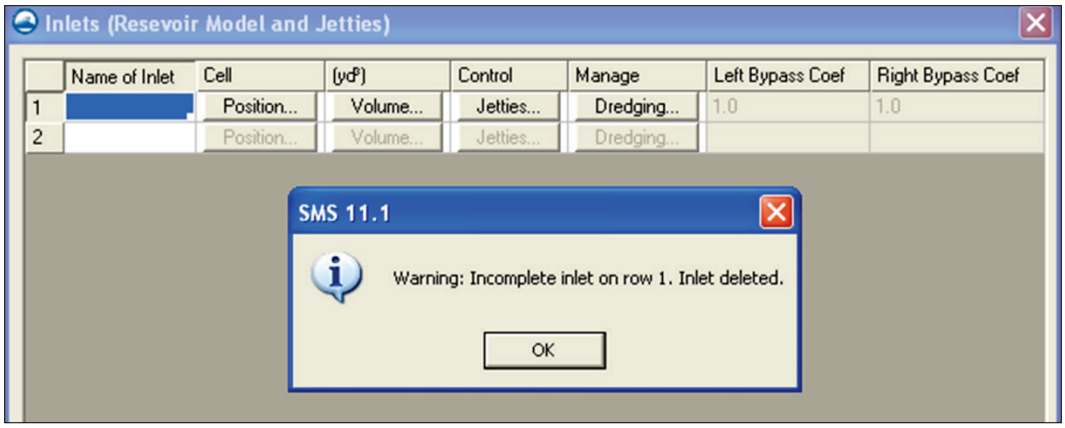
For example, when a feature is defined as an inlet, the user must enter the inlet name, shoal volumes, and dredging events. Usually, the name of each inlet in GenCade will match the actual name of the inlet. GenCade has the ability to read the inlet information correctly even if the inlet has multiple names (e.g., Carolina Beach Inlet). Conversely, a simulation may be a test case where the inlets do not have real names. Letters and/or numbers can be used to represent the name of each inlet; however, each inlet's name must be unique. The user must also define the initial and equilibrium volumes for each shoal (ebb, flood, left bypass, left attachment, right bypass, and right attachment). This should be done during the setup of the conceptual model. However, the user might not have all of these volumes available during conceptual model setup. Therefore, the user may choose to ignore the *Volume* tab when beginning to set up the model. This is not a problem until the user wants to run GenCade. If the user does not modify the shoals to values other than 0, the model will run, but a warning notice will be given. Once the model reads in all of the input files, it will reset each equilibrium shoal volume to 0.000001 (Figure 24). Checking for this notice is the best reminder to go back and change the shoal volumes. On the other hand, the user can check the *.gen file or go to *GenCade->Edit Inlets* to see the defined shoal volumes. Leaving both the initial and equilibrium volumes at 0 will give unusual results. The last attribute to assign in the inlets menu is dredging. Since some inlets are not dredged, specification of this attribute is optional. If dredging occurs, it is necessary to modify the *Begin Date* and *End Date*, select a *Shoal to be Mined*, and enter a *Volume*. At this time, the channel is not included as a dredged feature. Typically, the channel is considered as part of the ebb shoal in GenCade, so the ebb shoal may be dredged in place of the channel. If the user updates the dates and the shoal but forgets to enter a volume, the dredging event will be deleted after the user hits *OK* and leaves the *Dredging Events* window. For this reason, it is important to double check the dredging events.

Figure 24. Equilibrium volumes set to 0.00001.



Inlet characteristics may also be altered in the GenCade model; however, it is not recommended. One possible mistake that can occur in the inlet module relates to inlet naming. In the GenCade model, the user may choose to rename an inlet. If the user is working with several inlet alternatives (different dredging volumes or jetty lengths), the user may wish to identify each alternative with a separate inlet name to reduce any confusion. If this is done in the GenCade model, it is important to make sure the name has been saved under *Name of Inlet*. If the user deletes the inlet name instead of modifying it, a window will display the following: "Warning: Incomplete inlet on row 1. Inlet deleted." Figure 25 displays this warning. Even if the user tries to click the X at the top of the window, the inlet will be deleted. If the inlet is deleted, the user must replace all of the inlet information. Although it is rare to inadvertently delete an inlet, it is something that could happen to a newer user. In order to keep something like this from affecting the setup of GenCade or a simulation, it is important to save frequently. Although saving frequently will not prevent the deletion of an inlet, the user can open the saved version of the model which could prevent the user from needing to re-enter the inlet information.

Figure 25. Incomplete inlet warning box.



Groins and jetties have additional inputs under *GenCade Arc Attributes*. Both groins and jetties require the user to enter *Permeability*, select *Diffracting*, and enter a *Seaward Depth*. If the user fails to enter this information, GenCade defaults to a permeability of 0. The simulation will still run as expected, but the results at the structure may not be ideal. Before starting the simulation, it is best to review each structure and inlet under the *GenCade* menu.

For detached breakwaters, the user is required to enter depths, transmission equation, and additional attributes based on the specified transmission equation. If the user does not input this additional information, GenCade will use the default depths of 0 and constant transmission of 0. Although the GenCade simulation will run, these incorrect inputs will likely cause the model to crash. No user notice is issued if a GenCade simulation halts unexpectedly. The user may realize the model has crashed when the simulation takes an unrealistically long time to finish or the calculated shoreline does not exist when opened in the SMS. In order to minimize the possibility of a crash, the user should check the inputs for each structure before running GenCade. In the future, features will be added to the SMS to warn the user of these errors prior to simulation.

Last, beach fills and bypassing events need extra information in order to be included in a simulation. Both beach fills and bypassing events require a *Begin Date* and *End Date*. The beach fill requires an *Added Berm Width* while the bypass event requires the *Bypass Rate*. One easy mistake is to define an arc as a beach fill or bypass event but fail to define the other attributes. If this happens, the simulation will run as if the beach fill or bypass event does not exist. The default starting and ending date for the

beach fill or bypass event is the actual date that the simulation was created. If the user starts working on the model on 1 August 2013, the *Begin Date* and *End Date* will both be 01-Aug-2013. Since it is highly unlikely that a model will be run with the actual date included, this event will be ignored. If this does occur within the extent of the simulation, the default width or rate is 0, so it will not affect the simulation. Another important concept to consider is when the beach fill or bypass event is not entered completely in the conceptual model, the event will not be entered correctly in the GenCade model. It is necessary to include all of the information for beach fills and bypassing events in the conceptual and GenCade models before running the simulation. If any of the information is missing from the conceptual model, the beach fill or bypassing event will not be converted to the GenCade model. If any of the information is missing from the GenCade model, the simulation will not run as expected.

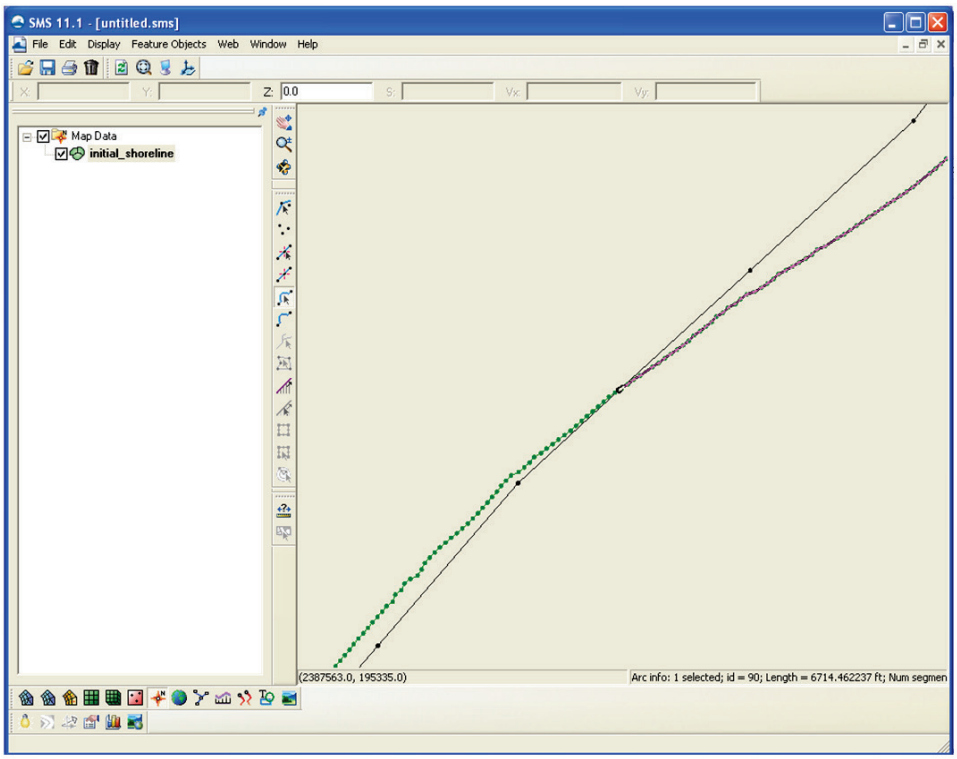
3.2.3 Mistakes when merging coverages in the conceptual model

In the SMS, a coverage represents a particular set of information similar to a layer in ArcGIS or a CAD drawing. When a simulation requires both an initial shoreline and a regional contour which are opened in the SMS in *.cst format, it is necessary to create two separate coverages and then merge these into a single coverage. The preferred approach is to open the initial shoreline first and then open the regional contour (or second arc) in a separate coverage. Once both the initial shoreline and regional contour have been opened in separate coverages, they may be merged into a single coverage by clicking on both coverages while holding the SHIFT key, right clicking, and selecting *Merge Coverages*. The process is described in detail in pages 112–118 of Report 1 (Frey et al. 2012a).

In the SMS, an initial shoreline or regional contour is classified as a *Feature* arc. If the initial shoreline is added to a new coverage and the regional contour is opened in that same coverage, each location where the initial shoreline and regional contour intersect will split each shoreline arc into multiple arcs. This is illustrated in Figure 26. In the figure, the initial shoreline is opened first, and the arc has been defined as the initial shoreline (green line). Instead of creating a new coverage and opening the regional contour there, the regional contour (black line) was opened in the same coverage as the initial shoreline. A new node, which represents the beginning or end of a feature arc, is created at every intersection between the two arcs. In Figure 26, there is a node dividing the feature arcs, and the initial shoreline arc to the right of the node is highlighted. Now there are two feature arcs

representing the initial shoreline and two feature arcs representing the regional contour. Although both feature arcs representing the initial shoreline can be defined as an initial shoreline in the conceptual model, only one of the arc segments will be converted to the GenCade model. If the user opens both the initial shoreline and the regional contour in the same coverage, the recommendation is to delete the arcs and restart the procedure from the beginning as described in Report 1 (Frey et al. 2012a).

Figure 26. Initial shoreline and regional contour opened in same coverage.



Please note that if the user manually draws either the initial shoreline or the regional contour, it is not necessary to create separate coverages and merge them. As long as the user does not click on the existing arc when manually drawing the new arc, each arc will remain a single arc. If the user clicks on the existing arc when drawing the new arc, a node will be created which will split the existing arc into two separate arcs. However, it is unlikely that the user would draw an arc representing the initial shoreline or regional contour unless the user was working with a simplified test case.

One problem that may occur after the coverages are merged is adding features to the incorrect coverage. At first, the initial shoreline and regional contour will be located in separate coverages. Once they are merged, a third coverage will be created that includes both the initial shoreline and regional

contour. Since this third coverage contains all of the data associated with both the initial shoreline and regional contour, it is the coverage in which the rest of the features should be added. The user may identify the coverage being used by viewing *Map Data* and observing which coverage is active (bold font or highlighted). The user may not notice which coverage is highlighted and may create an entire model in the wrong coverage (the coverage with either the initial shoreline or regional contour). If this occurs, the user can merge the updated coverage with the other coverage to create a new merged coverage. For example, a coverage with the initial shoreline, beach fills, and wave information may be merged with a coverage containing the regional contour. As long as the initial shoreline and the regional contour are not in the same coverage initially, it does not matter when coverages are merged.

3.2.4 Improper placement of structures

There are several restrictions on the placement of structures. Requirements and background for structure placement can be found in Report 1 (Frey et al. 2012a). The user can create improper placements in the conceptual model. During the conversion to GenCade, some of these placements will be modified while others will prevent a GenCade simulation from running.

One of the first non-viable placements is groins that are separated by less than two cells. GenCade will allow the user to create groins that are less than two cells apart in the conceptual model. The groins will remain in the same location after converting to the GenCade model. The only indication that this placement is not allowed is when the simulation is started. The GenCade output window will state "ERROR. GROINS MUST BE SEPARATED BY AT LEAST TWO CALCULATION CELLS. PLEASE CHANGE." The simulation will end immediately. Figure 27 shows groins separated by a single cell and the error. In the example shown in the figure, the cells are 100 ft in size. If variable grid cell resolution was used and the cell size around the groins was decreased to 25 ft, this simulation would run correctly.

Groins may not be placed next to a lateral boundary. Figure 28 illustrates this error. In this example, a groin is placed in the cell directly adjacent to the right boundary. The conceptual model will allow the user to place a groin next to a boundary and will not require any changes before starting the simulation. However, once the simulation begins, the user will receive an error message: "ERROR. GROIN NEXT TO GRID BOUNDARY. MOVE GROIN OR GRID ONE STEP IN EITHER DIRECTION." The easiest way

to resolve this error is to return to the conceptual model and move the groin so that it is two cells from the boundary. If the groin must remain in the existing position, the grid can be extended so that the groin is no longer directly adjacent to a lateral boundary.

Figure 27. Error when groins less than two cells apart.

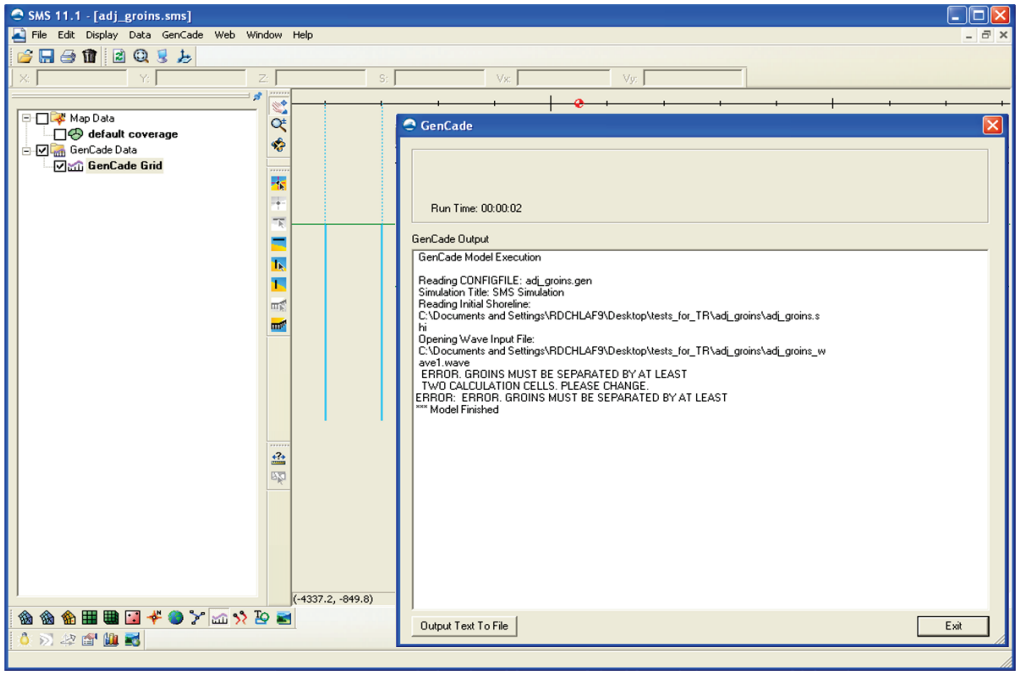
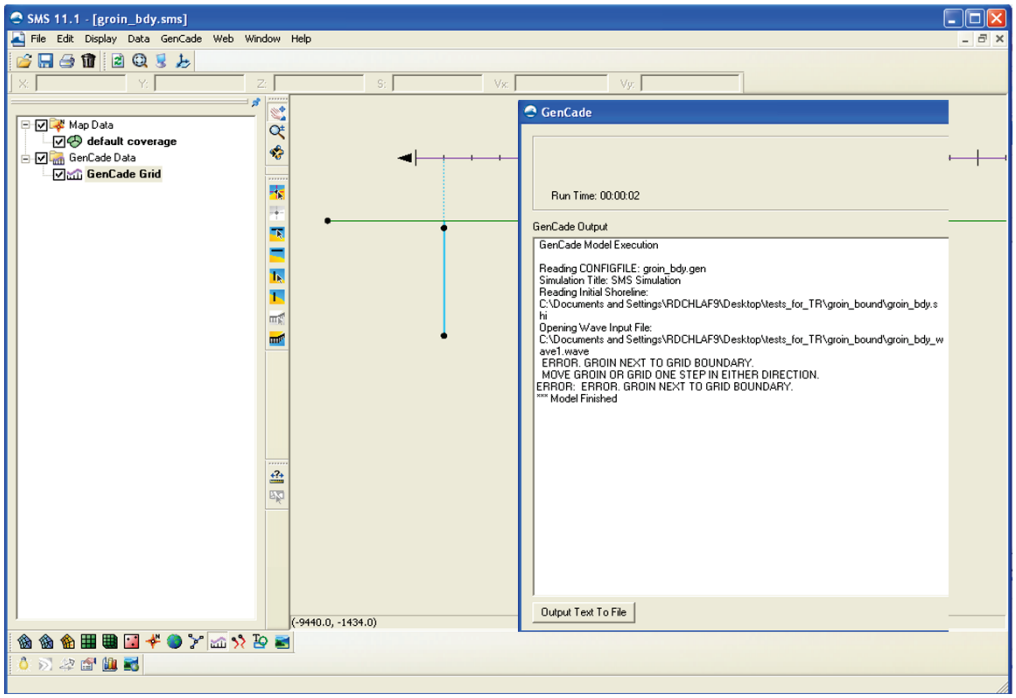
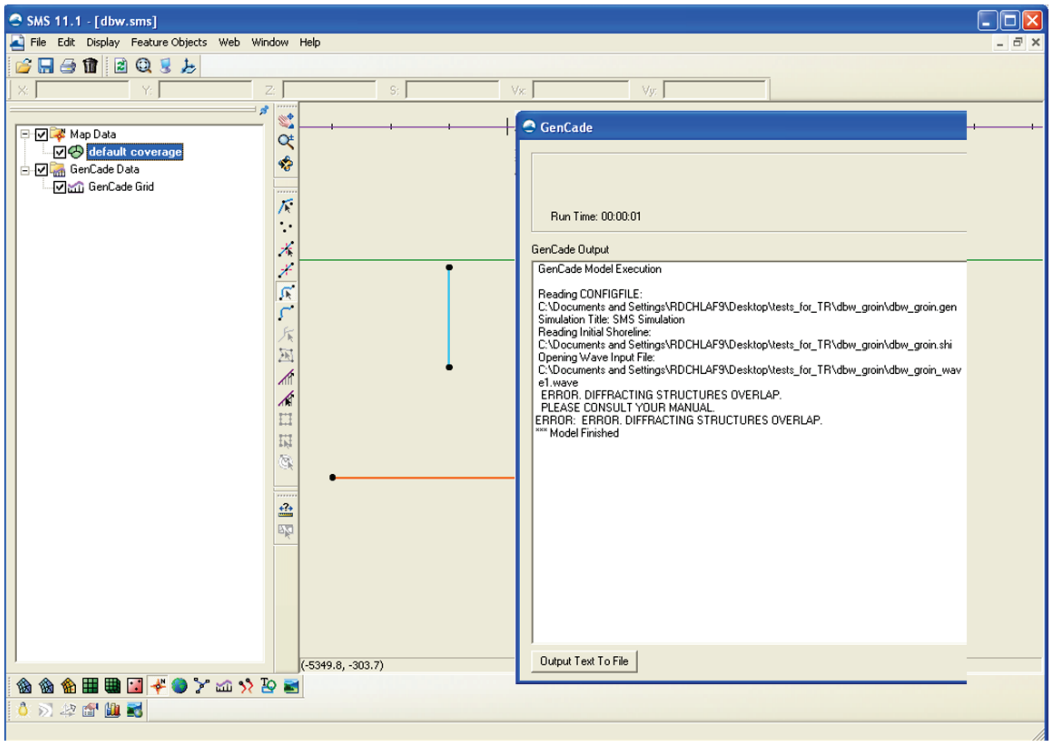


Figure 28. Error when groin placed next to a boundary.



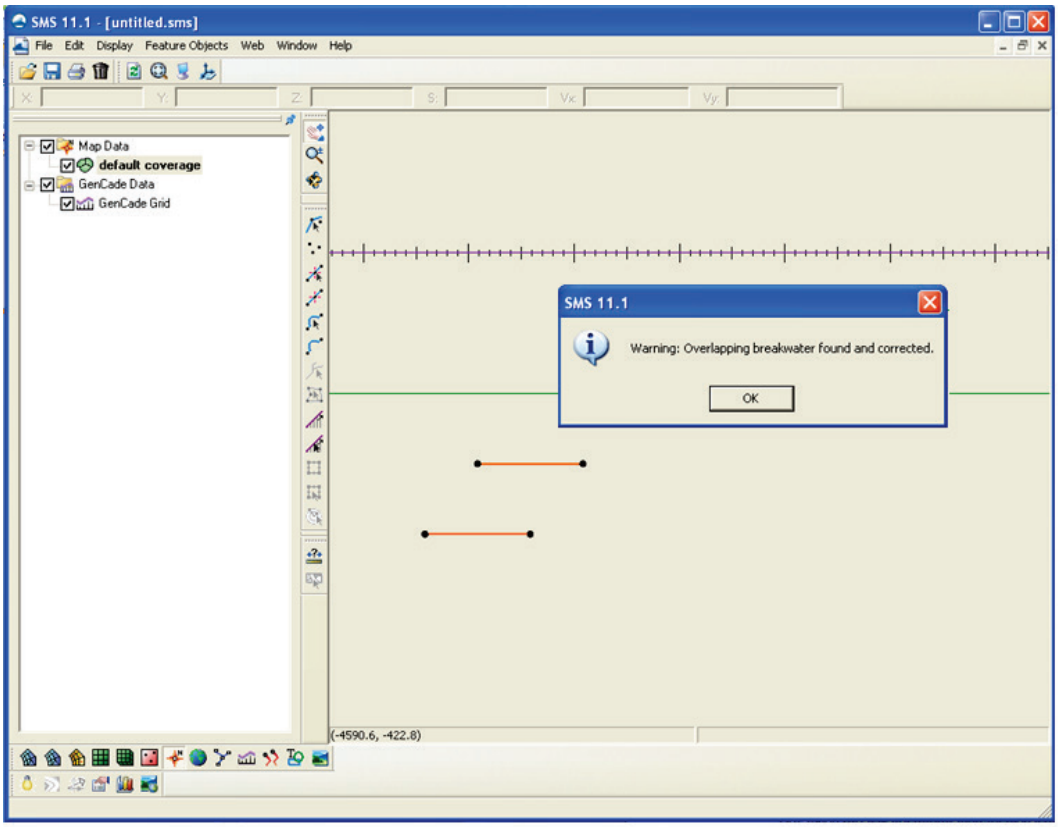
Another type of placement that is not allowed in GenCade is a diffracting groin behind a breakwater. A diffracting groin can be created directly behind a breakwater in the conceptual model, and the conceptual model will not provide any checks related to this non-viable placement prior to starting the model. If the user attempts to set up and run a simulation similar to the configuration shown in Figure 29, GenCade will fail to run and then produce the following error: "DIFFRACTING STRUCTURES OVERLAP." This error can be resolved by returning to the conceptual model and unchecking the box for *Diffracting* in the *Groins* window.

Figure 29. Error when diffracting structure overlap.



Finally, diffracting tips of breakwaters cannot overlap in GenCade. Similar to the other restrictions, the user can set up this configuration in the conceptual model. However, when the conceptual model is converted to the GenCade model, a message that states "Warning: Overlapping breakwater found and corrected" will pop up (Figure 30). For this particular placement, GenCade will revise the user's setup. For the example shown in Figure 30, the grid *x*-axis cell numbers increase from right to left, and the water is located south (below) of the shoreline. The user placed a 300 ft long breakwater approximately 200 ft offshore and a second breakwater of 300 ft at a distance of 400 ft offshore. The breakwaters overlap for a distance of 150 ft. If GenCade allowed this placement, the setup would look similar to the

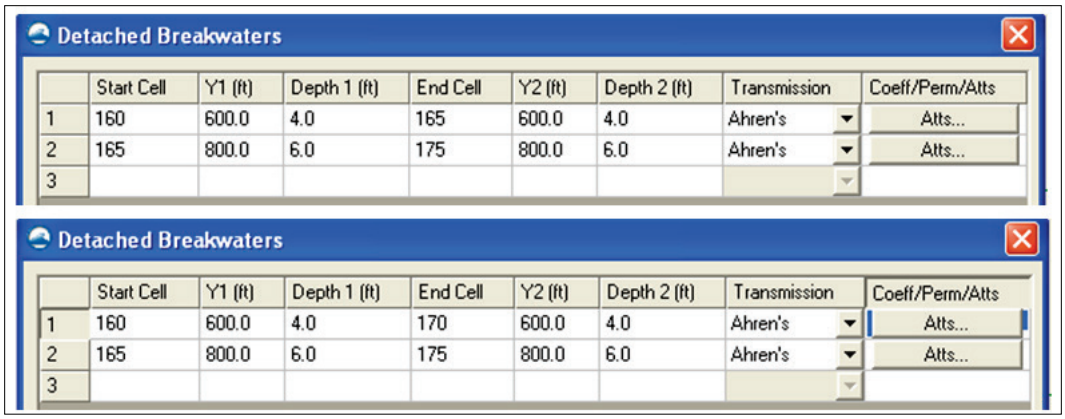
Figure 30. Warning for overlapping breakwaters.



bottom *Detached Breakwaters* window in Figure 31. In this case, each breakwater would exist across cells 165–170. Remember that *Y1* and *Y2* refer to the distance from the *x*-axis to the breakwater, so these are greater than the distance each breakwater is from the shoreline. GenCade does not allow this placement; the corrected placement for this example is shown in the top *Detached Breakwaters* window in Figure 31. Notice that the breakwater tips may occupy the same cell (cell 165). In this case, each breakwater has been shortened so that they do not overlap across cells.

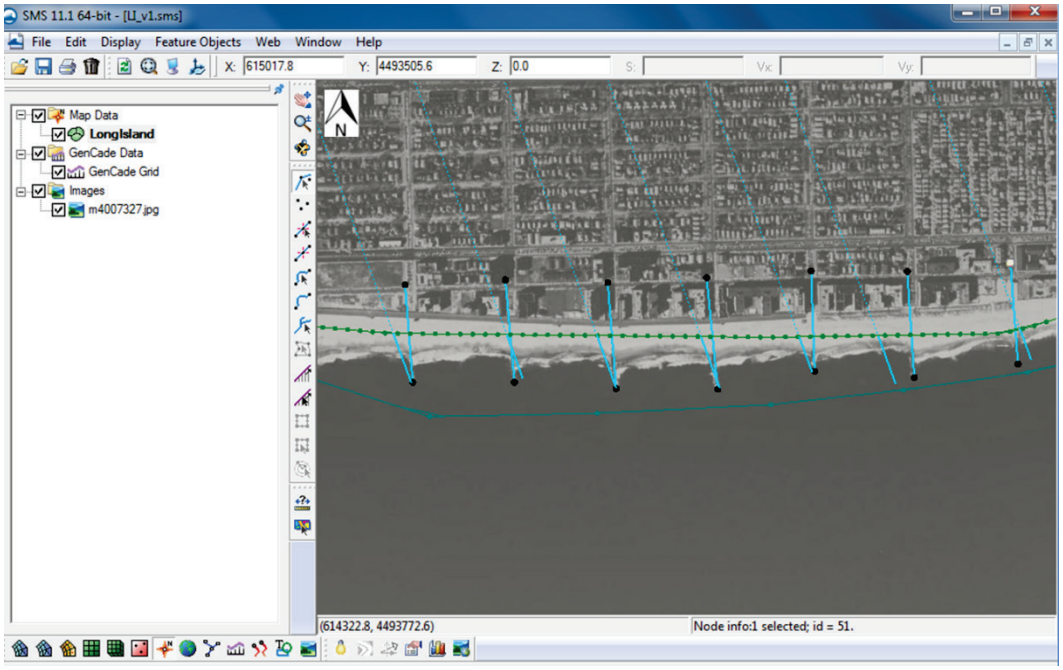
In addition to restrictions on placement of structures, structure shape in GenCade is also dependent on the grid *x*-axis orientation and resolution. When a GenCade grid is created, each groin is associated with a single cell. Groins are located at the cell walls. When the user converts from the conceptual model to the GenCade model, the shape of the groin may change. The only location GenCade takes into account during the conversion is the seaward tip of the groin. This location determines the length of the groin and the cell assigned to the groin. Each groin is perpendicular to the *x*-axis at the cell location. This is usually a reasonable assumption since groins are generally perpendicular to the shoreline, and

Figure 31. Top: detached breakwater cell information for corrected placement. Bottom: detached breakwater information for illegal placement.



the GenCade *x*-axis is typically laid out parallel to the shoreline. However, in some GenCade cases, the shoreline shape may differ from the *x*-axis orientation. In these cases, the groin would be perpendicular to the *x*-axis and not the shoreline. If the user sets up GenCade and notices that the location of the groin in the GenCade model is very different from the defined location in the conceptual model, the user can modify the location of the groin in the conceptual model. Since GenCade only takes the location of the seaward tip of the groin into account, this location can be moved to give a more accurate location. It is also possible to adjust the cell number and the distance from the *x*-axis to the seaward tip of the groin in the GenCade model. Changes in the GenCade model do not affect the conceptual model. Since the GenCade input data are developed from the conceptual model, it will cause confusion if the setup of the conceptual model is not identical to the GenCade model. For this reason, it is not recommended to make changes to the GenCade model without modifying the conceptual model. Figure 32 illustrates the difference in groin orientation between the conceptual model and the GenCade model. The blue lines with black nodes at each end that are oriented from north to south represent the groins created in the conceptual model. The blue lines that are oriented more from northwest to southeast represent groins as they exist in the GenCade model. Although the groins are perpendicular to the GenCade *x*-axis (not pictured), they are not perpendicular to the shoreline. Additionally, due to the cell size in this area, some of the offshore groin tips were shifted east or west to correspond with a particular cell. If the location and orientation of the groins in the GenCade model are not acceptable after making modifications to the seaward tip, the user should consider modifying the grid *x*-axis orientation to a more shore-parallel position.

Figure 32. Groin in conceptual and GenCade models.

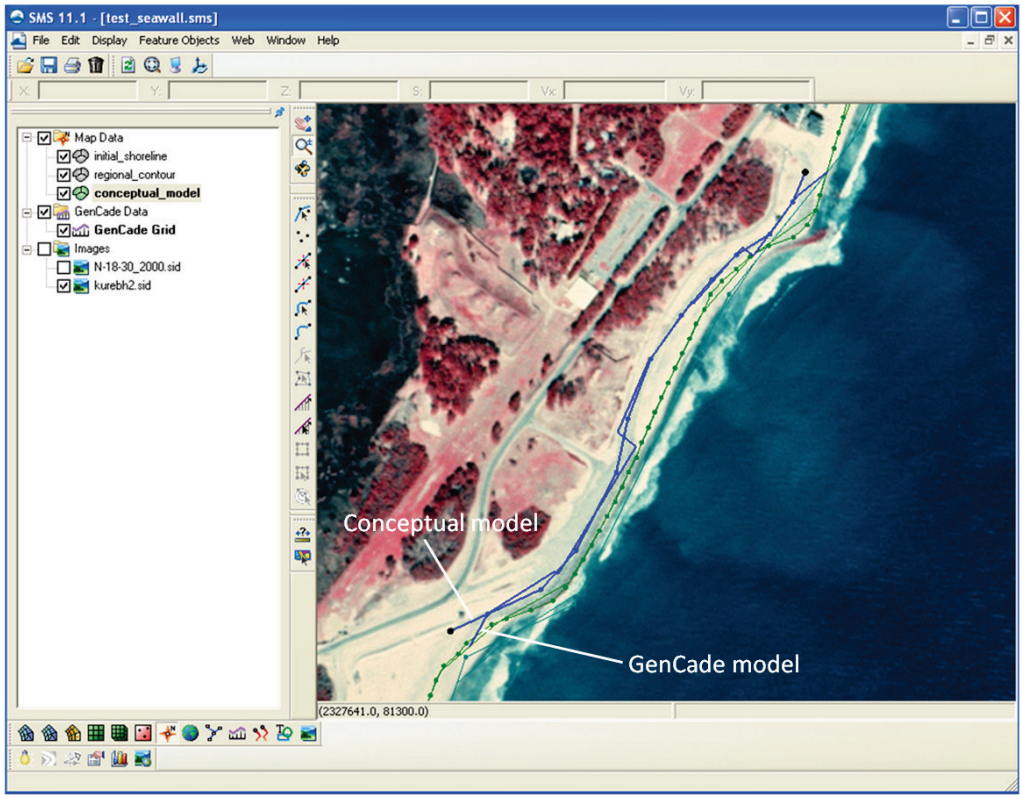


In this example, the cell size near the groins can be decreased, which will reduce the possibility of the groin being shifted east or west of the location in real-world coordinates.

In addition to the placement of groins, jetties, and breakwaters, extra care should also be taken when creating seawalls. First, seawalls must always be located landward of the shoreline. A simulation where the seawall is located seaward of the shoreline at the beginning will not run properly. When a seawall is created in the conceptual model, the user usually has an aerial photograph in the background that can be used to base the location of the seawall. In some instances, seawalls are not straight and are shaped more like a jagged shoreline.

When the conceptual model is converted to the GenCade model, a warning stating “Degenerate sea wall segment(s) ignored” may pop up. Figure 33 shows the seawall in both the conceptual model and GenCade model layers. The seawall in the conceptual model has black nodes at the ends and blue vertices. The seawall in the GenCade model is very jagged and intersects the initial shoreline at the first and last cell. The shape of the seawall in the GenCade model is different from the conceptual model. This is due to a large cell size around the seawall and the large number of vertices used to draw the seawall arc. When a seawall shape is converted from the conceptual model to the GenCade model, the distance from the *x*-axis to the

Figure 33. Seawall arc in conceptual and GenCade models.



seawall is represented at the cell center. When there are many vertices representing seawall position in the conceptual model, it is possible that the GenCade spacing is larger than the spacing of the vertices. If the cell spacing is 300 ft and the vertices are placed every 150 ft, 2 vertices from the conceptual model would be located within a single GenCade cell. The distance from each vertex along the seawall to the *x*-axis is calculated, and then this distance Y is shifted to the cell center to represent the seawall at the specific cell. When there are two vertices located within a cell, there will be two distances Y calculated at each cell center. For example, vertex 1 is a distance of 100 ft from the *x*-axis while vertex 2 is 200 ft from the *x*-axis. This results in *Y1* at that cell of 100 ft and *Y2* of 200 ft which looks like a jump in the position of the seawall (shown in Figure 32).

Unfortunately, when the cell spacing around the seawall is large, the conversion from the conceptual model to GenCade model may cause the seawall in the GenCade model to look different from the seawall in the conceptual model. There are two ways to improve the shape of the seawall in the GenCade model. The first involves using the *GenCade->Edit Seawall* command. The *Seawall* window will open, and the starting and ending cells and *Y1* and *Y2* can be seen. The top *Seawalls* window in Figure 34 shows

the values adjusted when converting from the conceptual model to the GenCade model. The *Y1* and *Y2* distances are based on the conversion from the specified coordinate system to distances in the *y* direction from the GenCade grid and are shown to a precision of nine decimal places (Figure 34). The GenCade model does not record *Y1* and *Y2* distances to that precision. GenCade only considers the distance from the *x*-axis for the seawall at the central point of the cell, so a different *Y2* and *Y1* in the same cell results in a spiky seawall. The quickest way to fix this manually is to match *Y1* and *Y2* at each cell. For example, the first segment of the seawall is from cells 492 to 493 where *Y1* is approximately 51064 ft and *Y2* is 51069 ft. The second segment is from cells 493 to 494. *Y1* at the center of cell 493 for the second segment is 51013 ft. This causes the location of the seawall to move farther landward at cell 493. The *Y1* at cell 493 for the second segment should be changed to be identical to *Y2* for the first segment. This same pattern should be followed for all of the segments. The bottom *Seawalls* window in Figure 34 shows the values adjusted manually.

Figure 34. Top: seawall cells corrected by GenCade. Bottom: seawall cells manually changed by the user.

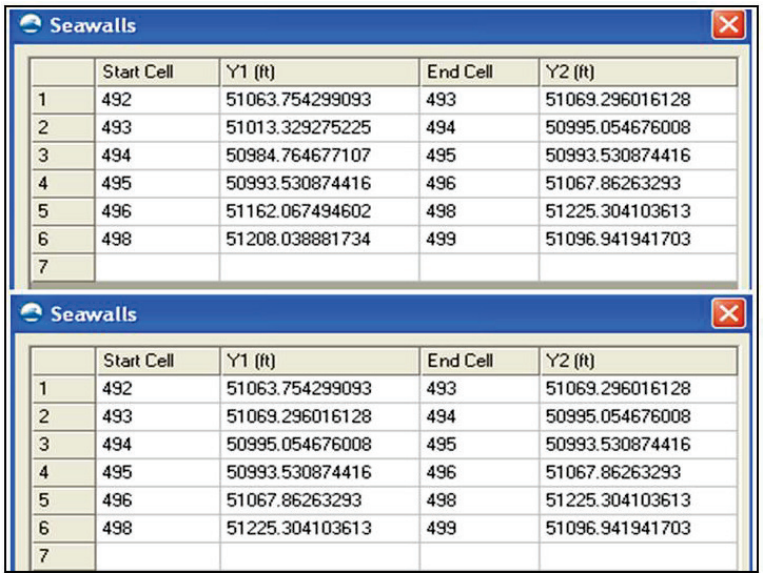
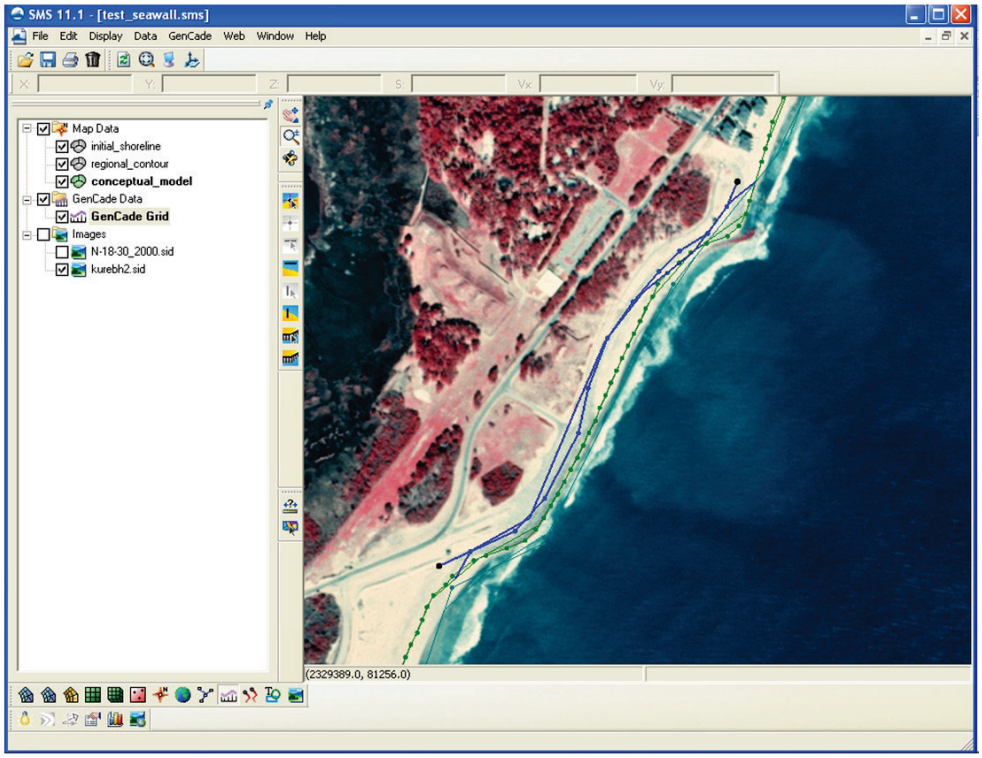


Figure 35 illustrates the location of the seawall after manually adjusting the *Y1* values. The seawall in the GenCade model is not identical to the seawall created in the conceptual model since several conceptual model seawall vertices are located within each GenCade cell, and not all of the vertices can be represented in the GenCade model; however, it is similar and should not cause instabilities in the model.

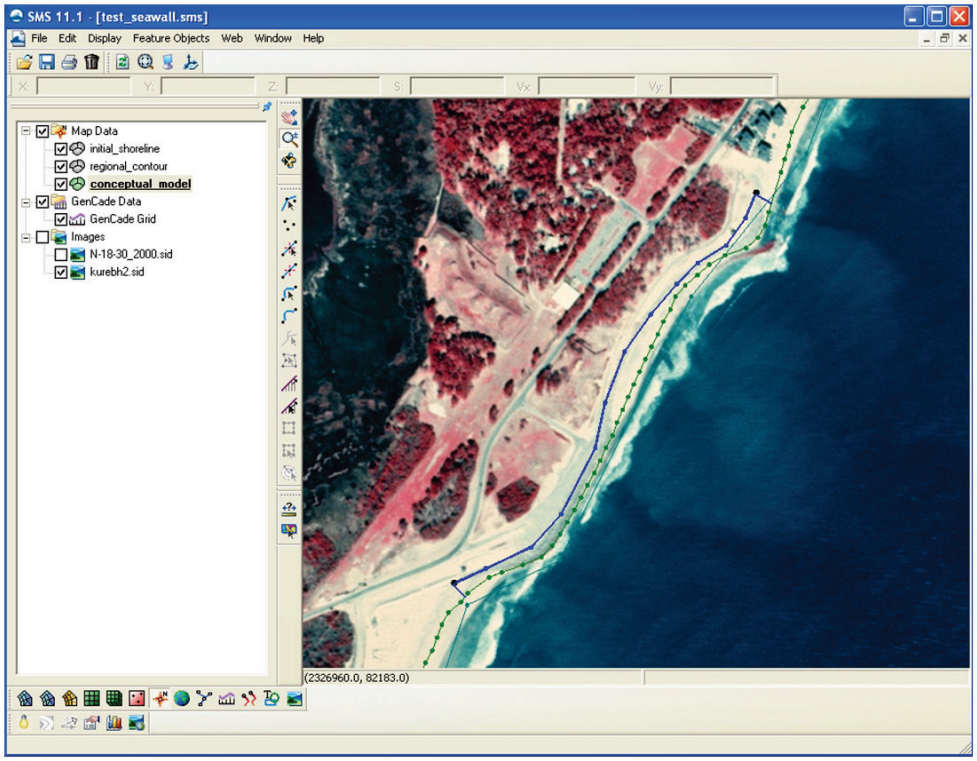
Figure 35. Manually adjusted seawall in the GenCade model.



If there are many conceptual model seawall vertices that would be represented by a single seawall cell position, the best option to improve the shape of the seawall in the GenCade model is to adjust the cell size near the seawall. The original cell size for this example is 300 ft. When variable resolution is used and the cell size near the seawall is decreased to 25 ft, the seawall generated in the GenCade model is identical to the seawall created in the conceptual model (Figure 36).

Please note that in Figure 36, it appears that the ends of the seawall in the GenCade model intersect the initial shoreline. This does not occur; it allows the user to visualize the extent of the seawall within the SMS. Since the distance from the *x*-axis to the seawall position is measured at the center of the cell, the intersection of the seawall to the initial shoreline occurs at the cell wall. This end position and distance from the *x*-axis is never calculated or stored and is not used at any point during the simulation.

Figure 36. Seawall in the GenCade model with variable resolution.



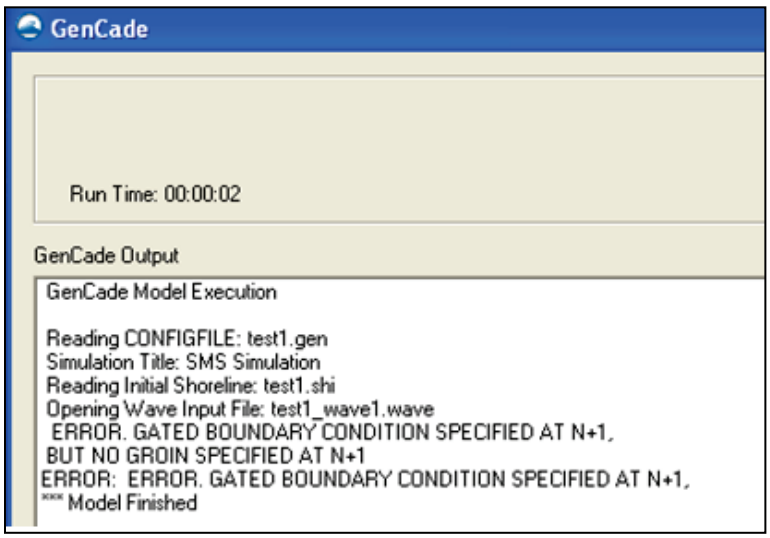
3.2.5 Gated boundary condition mistakes

In order to specify a gated boundary condition, two steps must be taken. First, a groin must be created at the boundary. Second, the *Lateral BC* in *Model Control* must be defined as *Gated*. If either of these steps is not taken, the model will not run as expected.

When specifying a gated boundary condition, there are a number of places that a mistake can be made. The first mistake may occur when creating a groin to represent a gated boundary condition. If the left boundary is the gated boundary, the groin will be located in cell 1. However, when defining the right boundary as a gated boundary, the groin is positioned at cell wall N+1 (the total number of cells in the grid plus 1). For example, a groin representing the right boundary would be located at cell 101 for a grid with 100 cells. If the groin is created at the boundary in the conceptual model and then the grid is converted to the GenCade model, the user should not experience any problems with the location of the right gated boundary. If the user adds the gated right boundary in the GenCade model and forgets that the groin needs to be located at N + 1, where N is the number of cells in the grid, then the model will not run. GenCade will output an error message stating “GATED BOUNDARY CONDITION SPECIFIED AT N+1,

BUT NO GROIN SPECIFIED AT N+1" (Figure 37). This means the boundary is defined as a gated boundary condition under *Model Control*, but the groin is not in the correct cell. In order to correct this mistake, adjust the location of the groin to N+1, or in this example, cell 101.

Figure 37. Gated boundary condition error message.

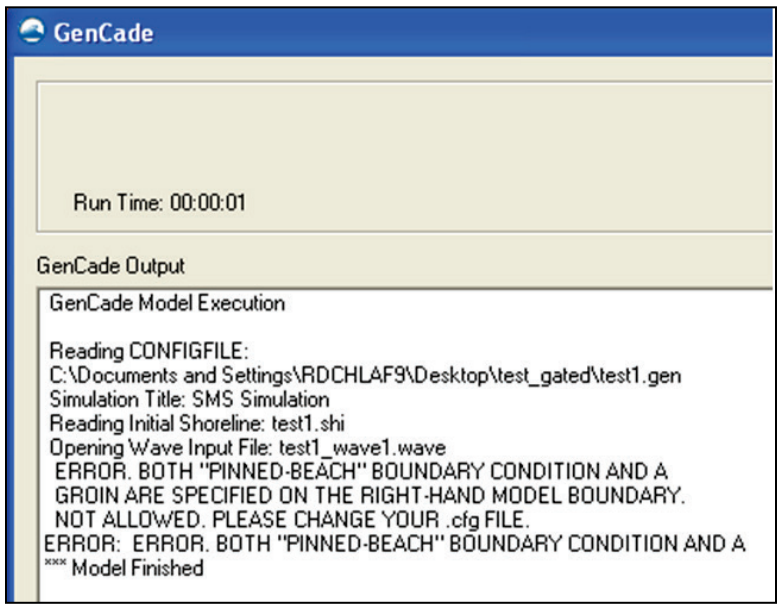


Another possible mistake is creating the groin but failing to define the boundary condition as gated. Once the user creates the groin at the boundary, then he or she will convert to the GenCade model. The user may forget to define the boundary condition under *Model Control->Lateral BC*. If this happens, the user has specified both a groin at the boundary together with the default boundary pinned-beach boundary condition which is not allowed, and GenCade will not execute. The error message will state "BOTH "PINNED-BEACH" BOUNDARY CONDITION AND A GROIN ARE SPECIFIED ON THE RIGHT-HAND MODEL BOUNDARY. NOT ALLOWED" (Figure 38). Changing the boundary condition from pinned to gated under *Lateral BC* and saving the changes will correct this error.

A final error related to the gated boundary condition occurs when the user defines the boundary as gated but fails to create a groin at the boundary. This error might be a little more difficult to catch because the simulation will still run. Even though a gated boundary condition is specified in the *.gen file, if no groin exists at the boundary, GenCade will treat the boundary as pinned. There are two ways to catch this error. First, the user may notice that no groin exists at the boundary in either the conceptual or GenCade model. Determining that a pinned condition (where there is no shoreline change at the boundary) was specified where there should be a

gated boundary is another way to find this error. This error can be remedied by returning to the conceptual model, creating a groin at the boundary, converting to the 1D grid, saving the updated grid, and running the new simulation.

Figure 38. Error message with pinned boundary and groin.



3.2.6 Incorrect input waves

Compiling the input wave information in the correct format is very important since GenCade is driven by the waves. Incorrect waves, whether the date, height, or direction, can drastically affect the results of a simulation.

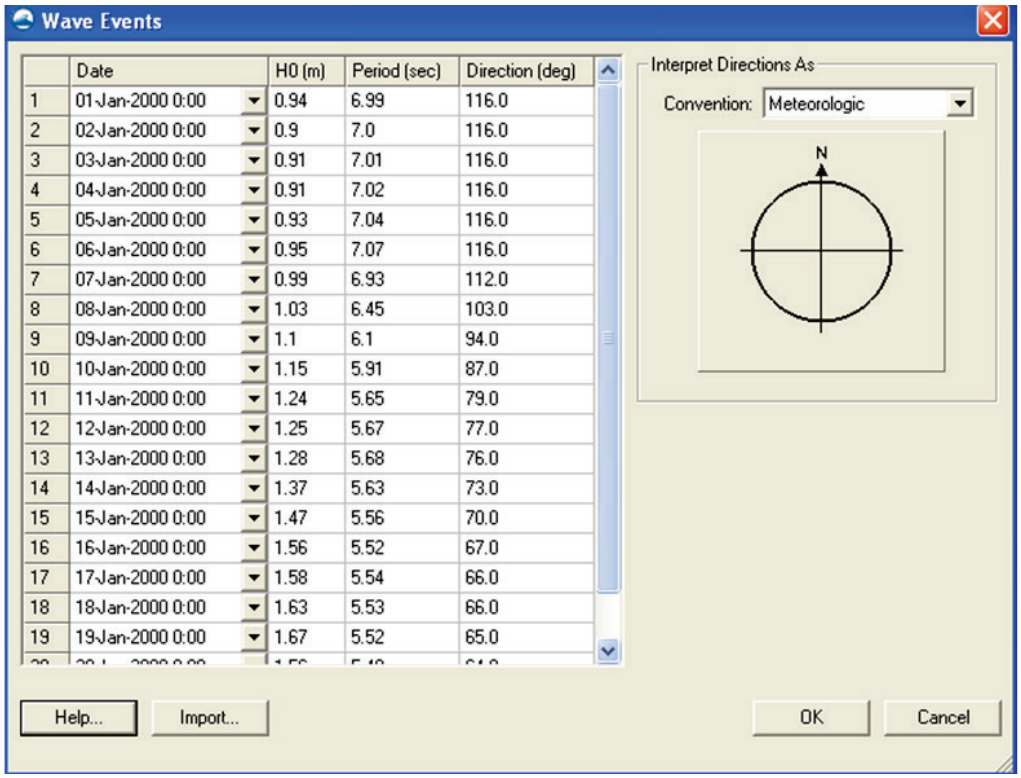
The instructions for wave input are described in Report 1 (Frey et al. 2012a), so some of the details will be omitted here. After a feature point is defined as a wave gauge, the *Wave Events* dialog must be completed. This is where the user can copy/paste or import the wave information from a text file. Copy/paste into the window is a nice option when the wave information is located in a spreadsheet. There are two formats that can be copied and pasted into the *Wave Events* window. The first format is MM/DD/YYYY HH:MM while the second is DD-MMM-YYYY HH:MM. Both formats are shown in Table 1.

Both of these formats will load into the window in DD-MMM-YYYY HH:MM format as shown in Figure 39. Although the *.wave files have a slightly different format, the SMS converts the wave information into the correct five-column format.

Table 1. Acceptable formats for wave information under copy/paste option.

1/1/2000 0:00	0.94	6.99	116
1/2/2000 0:00	0.9	7	116
1/3/2000 0:00	0.91	7.01	116
1/4/2000 0:00	0.91	7.02	116
1/5/2000 0:00	0.93	7.04	116
01-Jan-2000 00:00	0.93	7.04	116
02-Jan-2000 00:00	0.95	7.07	112
03-Jan-2000 00:00	0.99	6.93	103
04-Jan-2000 00:00	1.03	6.45	94
05-Jan-2000 00:00	1.1	6.1	87

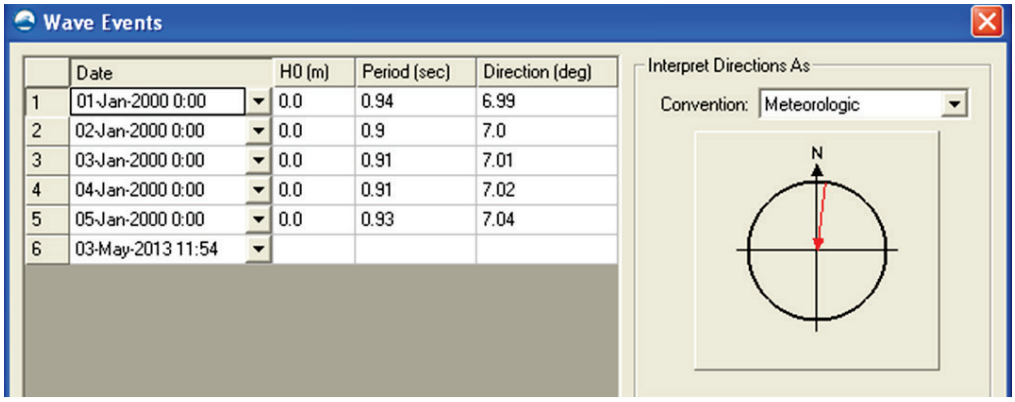
Figure 39. Wave information in the Wave Events window.



If wave information is pasted in an incorrect format, a number of problems can occur. For example, the user might specify the date as MM/DD/YYYY HH:MM but separate the day and time into two separate columns. If this happens, the SMS will only read the first four columns.

Instead of pasting in the format of Figure 39, the time will be under wave height, and the direction will be removed from the window as shown in Figure 40. If five columns are pasted, the time is zeroed out in the first column. This applies to pasting the wave information in the format of the *.wave file. Figure 39 and Figure 40 show the same wave information for rows 1–5. Notice in Figure 40 that all of the wave heights are 0 since the SMS reads the time as the wave height. The SMS will not flag this entry as incorrect, so it is important to double check the loaded wave information. The graphics window in the conceptual model also shows the direction of the first wave event for each wave gauge. At this point, the user might note that the direction is incorrect and return to the *Wave Events* window. Additionally, if the user clicks on any date in the *Wave Events* window, a red arrow shows the direction of the selected wave on the graphic under *Interpret Directions As*.

Figure 40. Five-column wave information pasted incorrectly.



Entering the date in the format YYYYMMDDHHMM is not permitted. Although the date fills only one column, the SMS cannot read this format. For example, if the user described the date of 1 January 2000, at 12:00 a.m. as 200001010000, the SMS would default the date as 30 December 1899, at 1:00 a.m. The wave height, period, and direction would be unaffected. Figure 41 illustrates how this format would look after pasting into the *Wave Events* window.

A second option for wave information is to use the *Import* button. This option allows the user to import the wave information from any text file on the computer. However, the format for these files is different from the copy/paste option. These files must be in the same format as the *.wave files. Each file needs five columns: date (in YYYYMMDD), time (in HHMM), height, period, and direction. The proper format is shown in

Figure 42. This is the only acceptable format to import wave information if using the *Import* button. If the user tries to import wave information in the same format as for copy/paste data, the SMS will not read the information, and an error message will open (Figure 43).

Figure 41. Wave information pasted incorrectly.

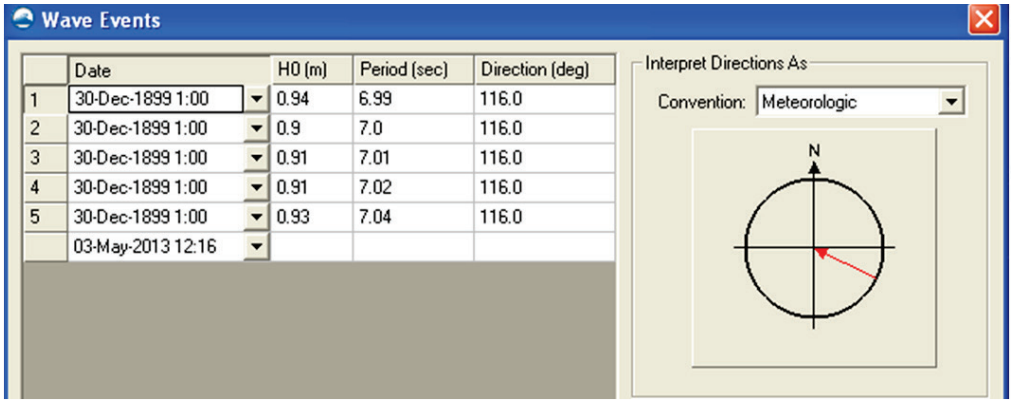


Figure 42. Proper wave data format for use with the Import button.

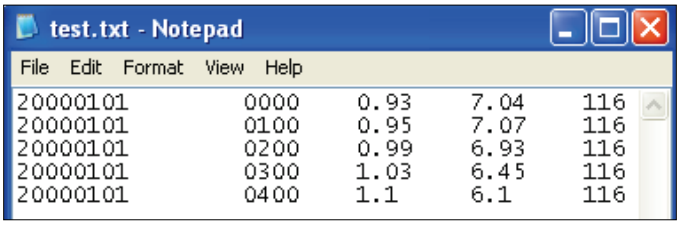
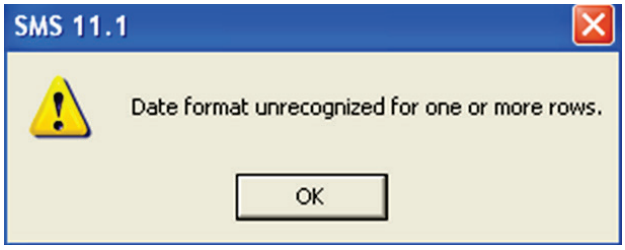


Figure 43. Warning message for incorrect wave information input when using the Import button.



Another possible issue with wave information is related to the dates chosen to represent the waves. The first date and time in the *.wave file should be identical to the first date and time in the simulation. If these are not the same, the model will run, but the waves will not represent the proper time and date in the simulation. For example, a simulation is calibrated for 5 yr between 1 January 1995, and 31 December 1999. Originally, the wave information matches these dates so that the first date in the *.wave file is 1 January 1995, at 12:00 a.m. and the last date is 31

December 1999, at 12:00 a.m. This simulation would result in the correct waves representing each date and time.

The user may choose to modify the dates under *Model Control*. For this example, the user did not have a specific date in 1995 that the data for the initial shoreline were collected, so 1 January was used as a placeholder. While working on the calibration, it was determined that the initial shoreline was surveyed on 1 July, 1995. When the dates for the simulation were changed, the wave information was not adjusted. GenCade assumes the first date in the wave file matches the starting date for the simulation. For this example, GenCade uses the wave information from 1 January 1995, for the starting date of the simulation, 1 July 1995, which means the incorrect waves are used for each date in the simulation. In order to resolve this issue, the user should develop a new wave file beginning with the wave data on 1 July 1995.

Date errors can be further illustrated with wave information and simulation dates that do not match at all. If the simulation dates are from 1990 to 1995 and the waves are from 1996 to 2001, the simulation would not run because that date is outside the range of the simulation. If the dates in the simulation and the wave files do not match, open the *Wave Events* window in the conceptual model, adjust the dates to match the dates in the simulation, reconvert to the 1D grid, and save the model. Before running a simulation, it is a good idea to check the dates of the simulation and the dates in each *.wave file to make sure the beginning dates match.

One of the most common problems for wave information input relates to importing the wave information in shore-normal convention. In Report 1 (Frey et al. 2012a), it is recommended to set up the grid in the conceptual model and convert to the GenCade grid before entering wave information. The reason for this recommendation is GenCade must know the shore (grid *x*-axis) orientation before shore-normal convention can be calculated. If wave information was entered in shore-normal convention before converting to the GenCade grid, GenCade would not know what shoreline (grid *x*-axis) angle shore-normal was related. Therefore, the shore-normal convention is not available during initial setup of the conceptual model. When the *Wave Events* window is opened, initially there are only three convention options: oceanographic, meteorologic, and Cartesian. Meteorologic is the default convention option.

However, some new users fail to realize that shore-normal is not an option for wave convention until after converting to a GenCade grid. In order to use shore-normal convention, first convert to the GenCade grid. Then return to the conceptual model by highlighting that coverage under *Map Data* in the data tree. Create the feature point for the wave gauge, enter the *Depth*, and select *Data*. The *Wave Events* window will open. On the right side of the window, click on the pull-down menu for *Convention*. The shore-normal convention will now exist. To add the wave gauge to the GenCade model, reconvert to the 1D grid.

Regardless of the convention of the wave information, it is always a good idea to double check the direction and the convention. It is easy to select the wrong convention in the drop-down menu. Other than checking the convention in the *Wave Events* window, the user can also look at each of the *.wave files. The convention of the wave direction will be converted to shore-normal in the *.wave files. The user can manually calculate the direction in shore-normal convention for the first time-step and check that the calculation matches the *.wave file. If the directions are different, an incorrect convention may have been selected.

Since it is recommended to enter waves after converting to the GenCade grid the first time, it is possible that a new user may forget to add the waves. The first notice that waves are missing will occur when the user attempts to save the model. A warning will pop up stating that there are inconsistent time values in the wave files (Figure 44). This warning will alert the user to a problem with the *.wave files. In a case where waves were not added, no *.wave files are created. If the user does not add the waves at this point, the second notification will occur at the beginning of the simulation. Instead of a successful simulation, an error message like in Figure 45 will pop up, and the simulation will be stopped. In order to run the simulation, add the waves, resave the model, and run.

3.2.7 Incorrect time-step

One of the user-specified parameters in *Model Control* under *Model Setup* is *Time Step*. Generally to start, the user should specify a time-step equivalent to the time-step in the wave files. For example, if there is a wave event every 3 hr, begin with a time-step of 3 hr. If that time-step is too large, the GenCade output window will write many instability warnings. Usually, when a large number of instabilities are expressed to the user, GenCade will not produce good quality results. An example of

this is a jagged calculated shoreline where the user knows the shoreline should not behave in that manner. One way to reduce the instabilities is to decrease the time-step. The user can read more about instabilities in Section 4.4 of this report.

Figure 44. Warning message for errors in wave files.

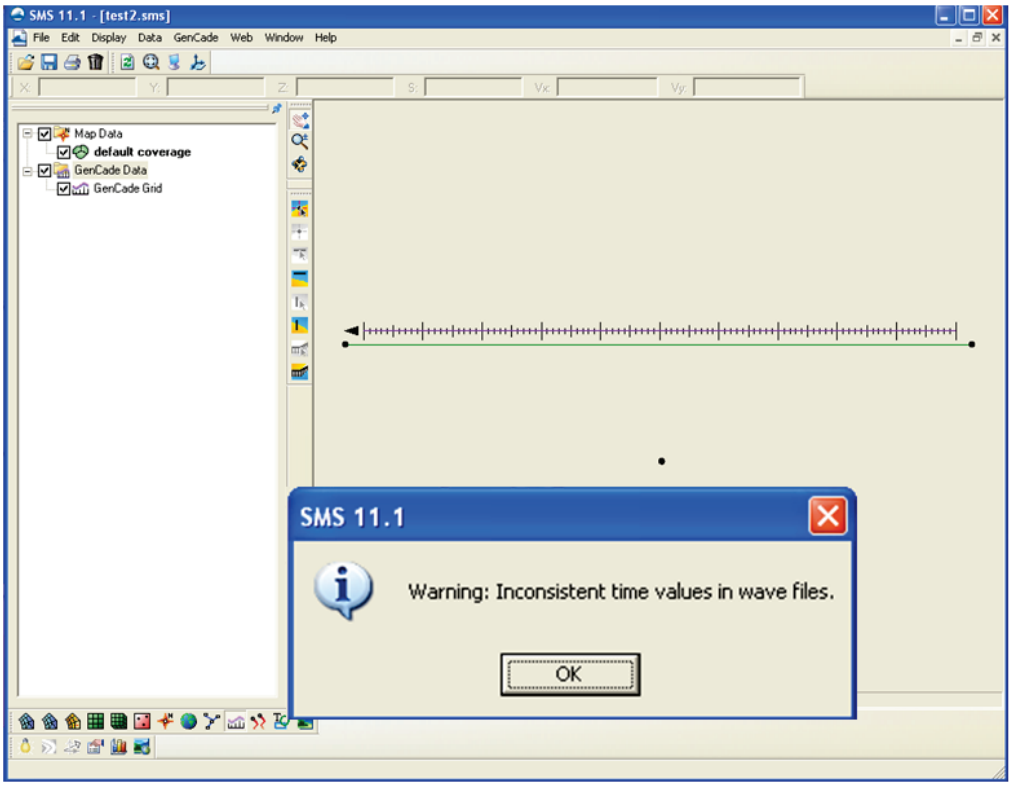
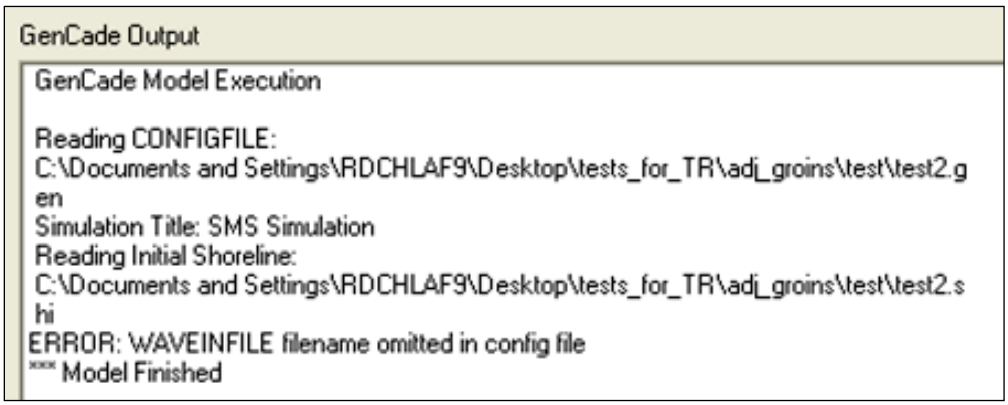


Figure 45. Error message when waves not included in simulation.



Once the time-step is decreased to less than the time-step in the wave files, it is possible to get another error. The wave time-step must be a multiple of the simulation time-step. For example, if a wave event occurs every 3 hr, the time-step could be 0.5, 1.0, 1.5 hr, or other multiples of 3 that are less

than or equal to 3. However, a time-step of 0.8 would not meet the requirements since 3 divided by 0.8 is 3.75. If the user tried to specify a time-step of 0.8 hr when the wave time-step was 3 hr, the model would not run. An error message stating "ERROR: ERROR. Wave time step not a multiple of simulation time step" would prevent the model from starting. In order to resolve this error, change the simulation time-step to a multiple of the wave time-step and save. Then the model will run as expected.

GenCade will fail to execute if the simulation time-step is larger than the wave time-step. When the user attempts to run the model with this occurring, the user will receive an error message stating "ERROR: ERROR. Simulation time step greater than wave time step." Reduce the simulation time-step to equal or less than the wave time-step to resolve this error.

3.2.8 Failure to modify model control

Since modification of the model control takes place in the GenCade model rather than the conceptual model, failure to modify the model control is one of the most common mistakes of new users. If the user does not modify the model control, default values are used.

However, GenCade will not run with the default values for the simulation start and end date. The default start and end date correspond to the time and date the user converted from the conceptual model to the GenCade model. Figure 46 shows an example of default settings under *Model Setup*. In this case, the *Start Date* and *End Date* are "05-May-2013 02:07 PM." The defaults for time and date correspond to the time and date the user converted to the GenCade grid. For this example, the conceptual model was converted to the GenCade grid on 5 May at 2:07 p.m. The *Start Date* and *End Date* are identical as defaults, so the simulation would be instantaneous if they are not changed. For that reason, the model will not run with the *Start Date* and *End Date* defaults. Figure 47 shows the error message associated with using the default start and end dates. In general, this error message means that the dates in the *.wave file do not match with the starting and ending dates for the simulation. To resolve this error, adjust the starting and ending date and save the simulation. The simulation will run as expected.

Figure 46. *Model Setup* tab with default settings.

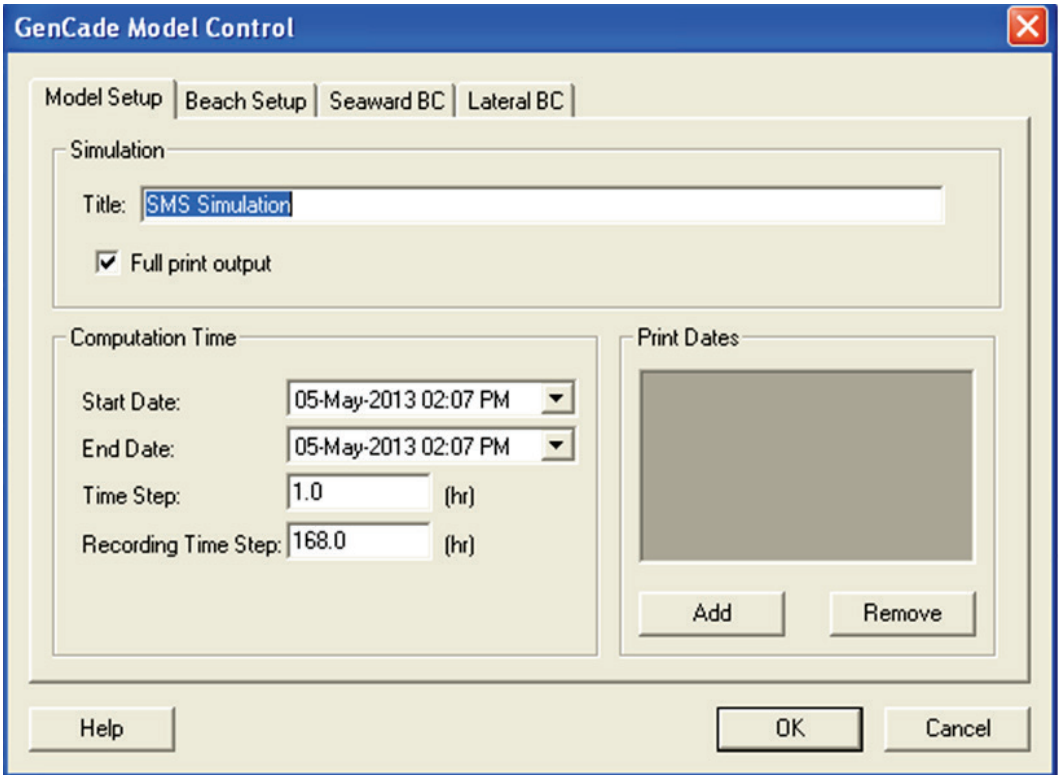
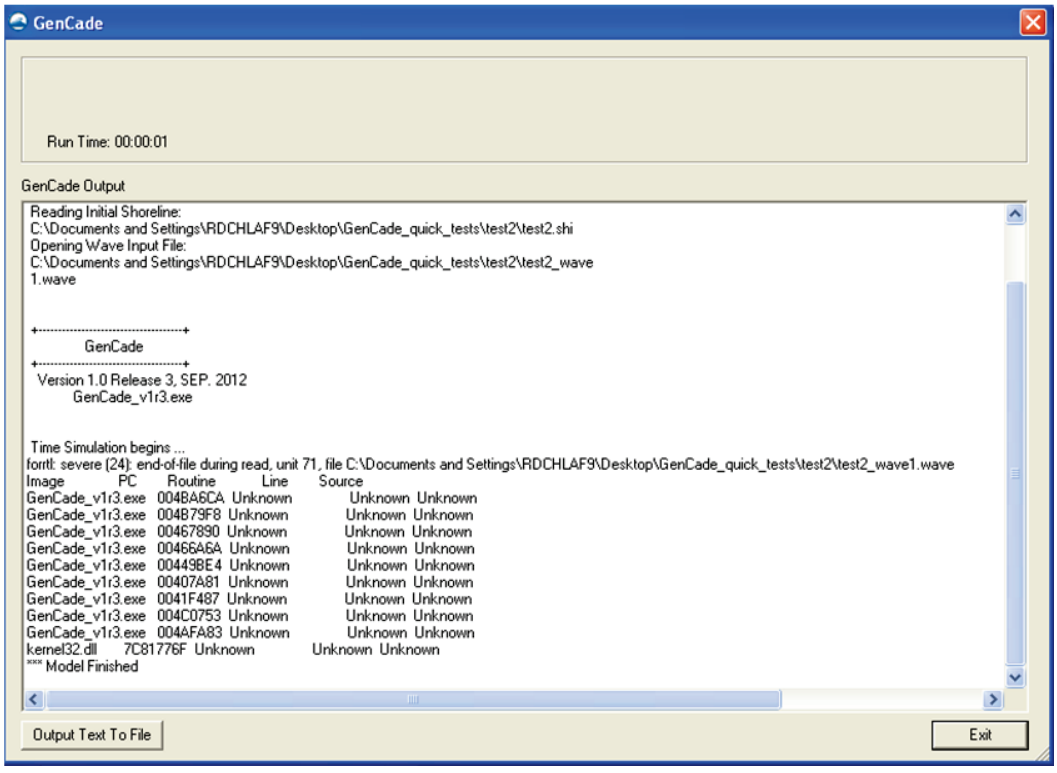


Figure 47. Error message related to default start and end dates.



If the user adjusts only the starting and ending date from the defaults, the model will run. However, it is highly unlikely that the remaining default specifications are appropriate for the simulation. In addition to the *Start Date* and *End Date* in the *Model Setup* tab, the *Time Step* and *Recording Time Step* are entered. The default for *Time Step* is 1.0 hr while the default for the *Recording Time Step* is 168 hr. The *Beach Setup* tab includes the *Effective Grain Size*, *Average Berm Height*, *Closure Depth*, *K1*, and *K2*, and their default values are 0.2 mm, 1.0 ft or 1.0 m, 10.0 ft or 10.0 m, 0.5, and 0.25, respectively, as shown in Figure 48. The defaults for parameters in the *Seaward BC* tab are as follows: 1.0 for *Height Amplification Factor*, 1.0 for *Angle Amplification Factor*, 0.0 for *Angle Offset*, Primary (1) for *Wave Components to Apply*, and 11 for *Number of Cells in Offshore Contour Smoothing Window (ISMOOTH)*. These defaults are displayed in Figure 49. The default lateral boundary condition for both the *Left Lateral BC* and *Right Lateral BC* is *Pinned* (Figure 50).

Figure 48. Defaults for *Beach Setup* tab (in USCS units).

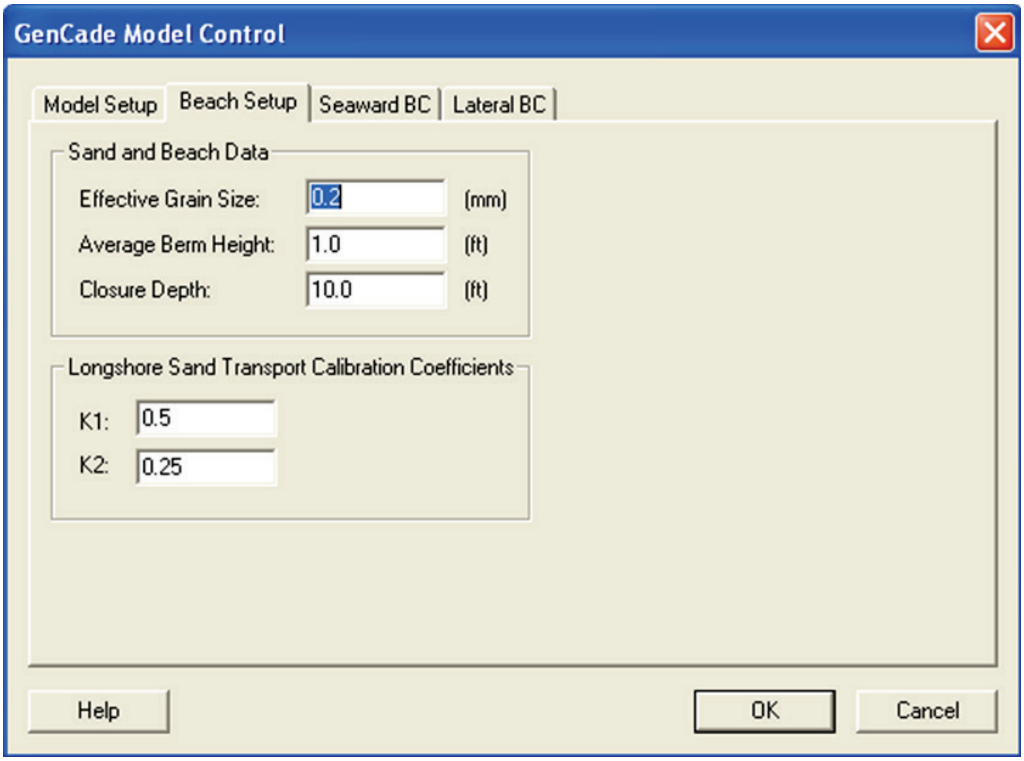


Figure 49. Defaults for *Seaward BC* tab.

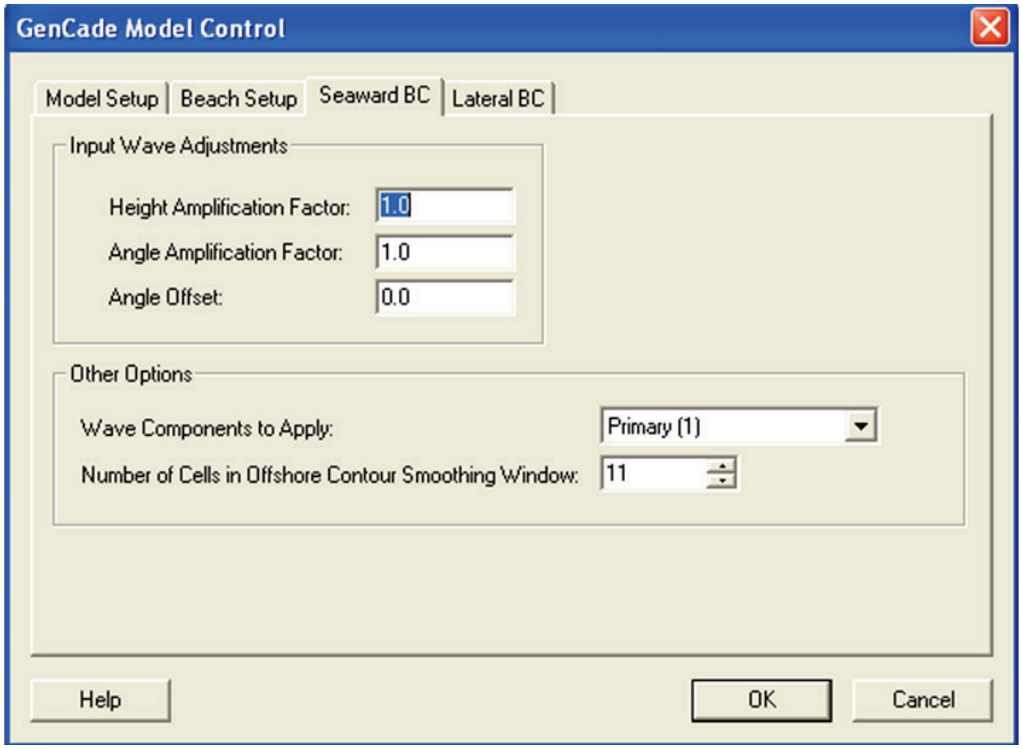
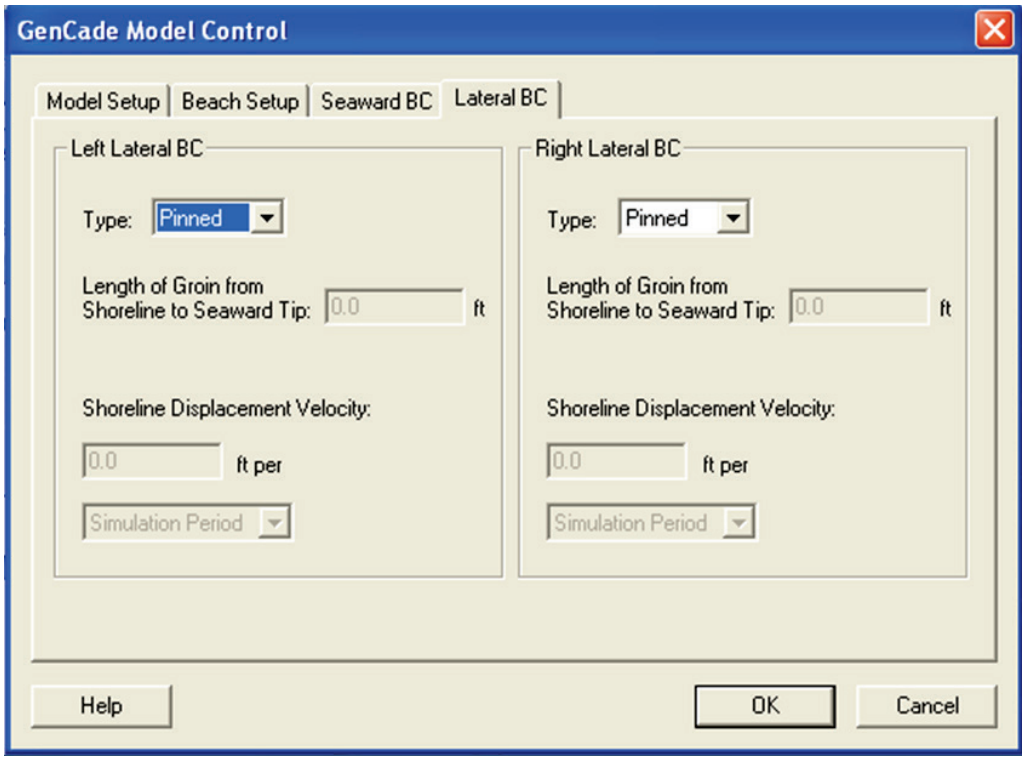


Figure 50. Defaults for *Lateral BC* tab.



3.2.9 Executable location

When SMS 11.1 is downloaded and installed on a machine, the GenCade executable is located under *Program Files\SMS11.1\models\GenCade*. Since the GenCade executable is part of the SMS 11.1 package, the path for the executable is automatically linked to GenCade under *Edit->Preferences->File Locations*. If the executable was not a part of the package, the user would need to browse for the location of the GenCade executable.

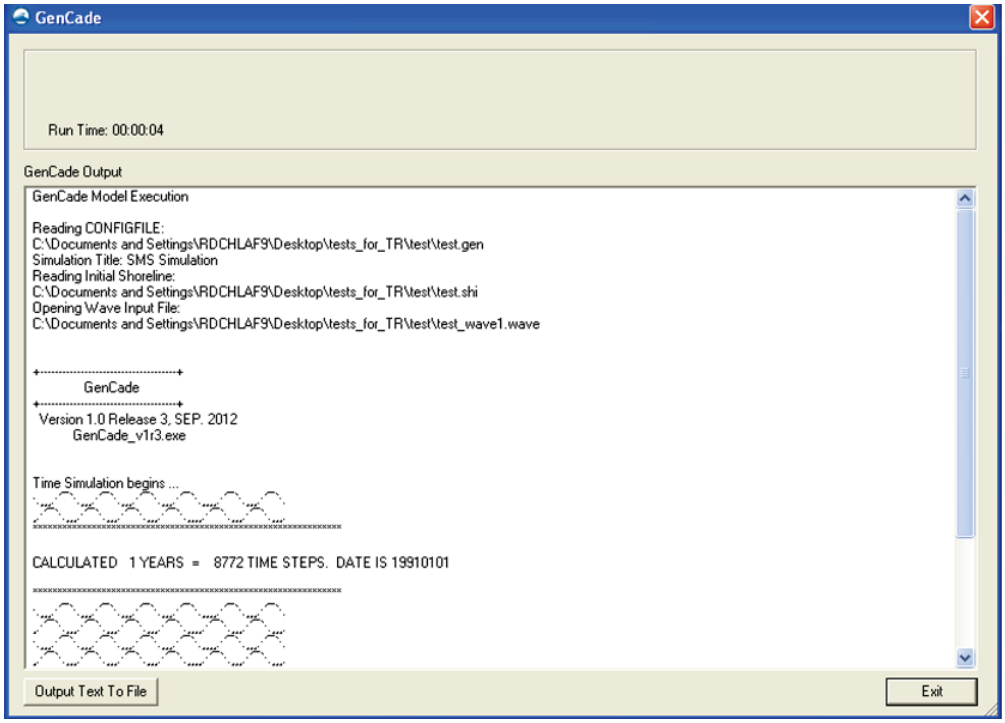
Please note that the GenCade executable included in the SMS was developed in 2012. A newer executable was developed in June 2013, which includes increased efficiency and several other improvements to the model. The GenCade development team continues to improve the efficiency and capabilities of the code, so a new executable may become available in the future. A more up-to-date executable can be downloaded from the CIRP Wiki or requested from any of the authors. If the user needs to use a new executable, within the SMS the user should click the executable location next to GenCade under *Edit->Preferences->File Locations*. The *Select model executable* window will open, and it is necessary to navigate to the location of the new executable.

When a machine has multiple executables, it is important for the user to keep track of which executable is being used. The easiest way to check the executable is through the *File Locations* window. When the simulation starts, the GenCade output window will state the executable version. For example, in Figure 51, the executable used was Version 1, Release 3, from September 2012. The top of the *.prt file also lists the executable used for the simulation. This is particularly helpful when viewing older GenCade simulations.

3.2.10 Path names and placement of input files

There are no restrictions in naming convention for GenCade files. Previously, when a GenCade file had a name with a period in it, the *.slo files would be created on the desktop instead of the specified folder. This was resolved when the Files section of the *.gen was modified. Now the PROJDIR line lists the path of the files. The other files included in the *.gen file do not list the path, only the name.

Figure 51. GenCade simulation window displays executable version.



One common mistake related to GenCade occurs when sending the files to another person. The PROJDIR represents the path of the files for use in the SMS. When the files are copied to another machine, it is highly unlikely that an identical path will exist. It is recommended to replace the path in PROJDIR in the *.gen file if working in the SMS. For example, if the path is "H:\GenCade\Test\" as in Figure 2 and the new location is "C:\GenCade_Test," remove the original path and type "C:\GenCade_Test\" instead. If working in the command prompt, change the path for each file in the *.gen file. Although the SMS can read the files and GenCade can be run with the incorrect path, it is good practice to modify the path if the location of the files has changed. If the user is working on a GenCade model and saves the files to a new location, the PROJDIR path will change automatically. The only time the user should manually adjust the path is when the files are copied to a new location on a computer or the files are saved to a new computer.

3.2.11 Opening *.gen files and *.sms files in the SMS

Once the project setup is finished and saved in the GenCade model, all of the input files will be created. These new files include the control file (*.gen). If the user receives files from another person, the user can open either the *.gen file or the *.sms file to view the setup. The *.sms file is

much larger, so sometimes only the input files are sent (*.gen, *.shi, *.shr, *.shdx, *.wave). If the user opens the *.sms project file, the user will see both the conceptual model and the GenCade model. Figure 52 displays an opened SMS project. Each of the shorelines and the conceptual model are saved under *Map Data,* and the aerial photograph is shown. The GenCade grid is also available. Since both the conceptual and GenCade models are included in the *.sms project file, the projection defined during creation of the conceptual model will exist each time the *.sms project is opened. On the other hand, if the user opens the *.gen file, the conceptual model will be omitted. This is because the control file does not contain any information related to the conceptual model. Figure 53 shows a project where only the *.gen file is opened. The GenCade data are available in the data tree, but none of the other relevant information is shown. Although the control file includes all of the features from the conceptual model, each feature is tied to a cell based on the GenCade model. The control file does specify the units in feet or meters, but it does not define what projection was used in the conceptual model.

Figure 52. Opening the SMS project file allows the user to view both the conceptual and GenCade models.

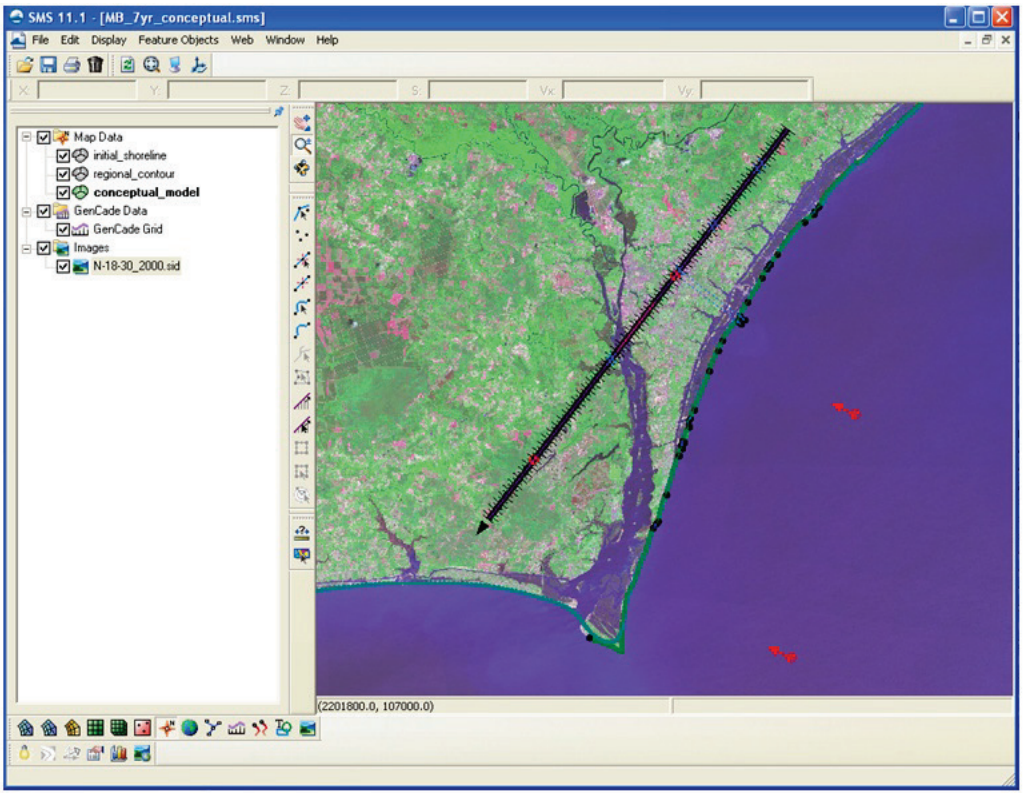
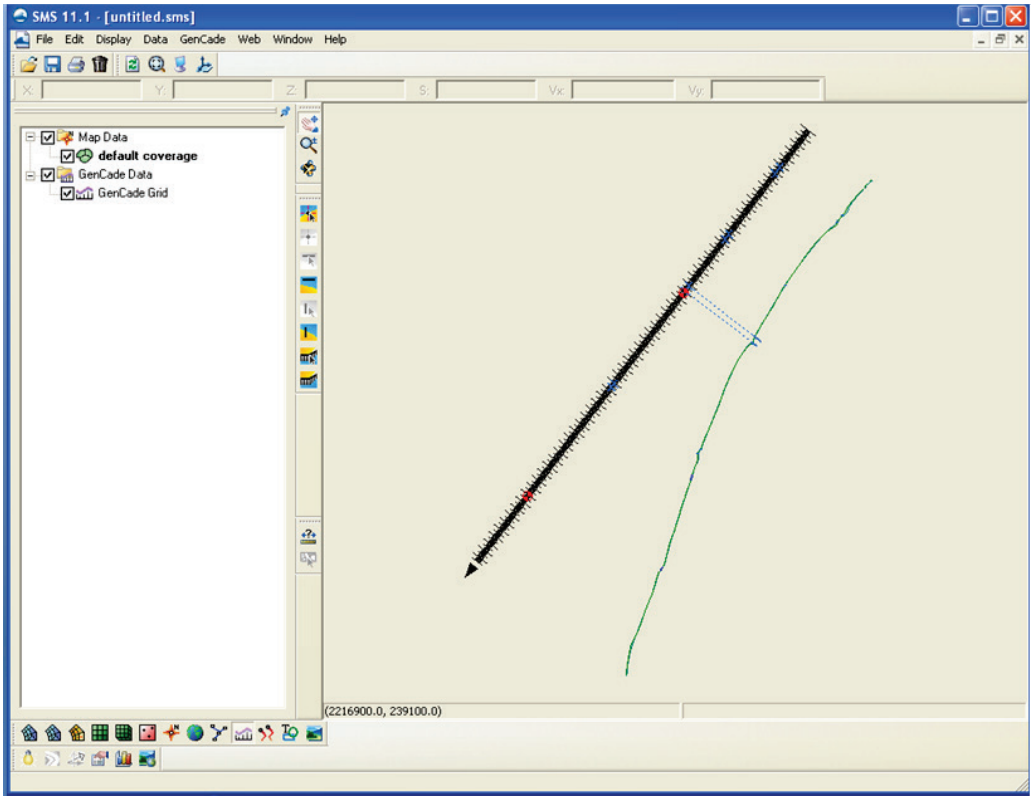


Figure 53. Only the GenCade grid is viewable with the *.gen file.



Since the *.gen file does not contain any information about the projection, the SMS will not know what projection to use when opened. The SMS will use the default projection which can be found under *Edit->Projection*. Usually, the default local projection will be meters.

The problem is encountered when the default local projection is a different projection than what was used to create the grid. Although the *.gen file does not save the projection from the *.sms file, it does include a section which defines the units as meters or feet. If the project was created in feet, the SMS will display a pop-up message stating the display projection does not match the data from GenCade when using the default projection of meters. If the user does not save the *.gen file in the SMS when the display project does not match the data from GenCade, the simulation will be unaffected by the projection confusion. However, the user may want to save the *.gen to a new location or save it again in order to have the correct path information in the file. Once the *.gen file is saved, the default local projection will override the defined units in the control file. For example, in a case where the default local projection is in feet and the defined units in the control file are meters, if the *.gen file is saved, the control file units will change to feet. If the user runs the simulation with the incorrect units,

all of the results from GenCade will be incorrect. To avoid this problem, modify the projection by going to *Display->Projection* and enter the correct local or geographic projection before opening the existing *.gen file. Although this seems like a very simple mistake, it can waste time if the user does not understand how projections and units are defined in GenCade.

4 Recommendations for GenCade Applications

In addition to a large list of input requirements to run GenCade, there are also several recommendations that should be followed and topics that should be reviewed to simplify the experience setting up and running GenCade. Although the recommendations in this chapter are not mandatory, they should help the user understand what types of parameters are reasonable for a GenCade simulation.

4.1 Work flow for a GenCade project

4.1.1 Introduction

While every application of GenCade will have many unique aspects, the fundamental work-flow steps that a modeler goes through to obtain final results are similar for many applications and follow a logical sequence. This discussion is intended for the novice modeler who may be using GenCade for the first time, as experienced modelers will have already developed an understanding of the work-flow process. It gives a brief overview of the sequence of standard steps involved in a typical project between its initialization and successful completion. This discussion is only intended as suggested guidance which the modeler should modify as circumstances dictate.

No assumptions are made about the nature of the study other than that GenCade will be used extensively to make predictions of beach behavior and that the study is large enough and detailed enough to require considerable man-hours. The term *modeler* is used to mean the person possessing the appropriate technical skills who sets up and runs GenCade and interprets the results, and who, in fact, may be an individual or a small team working closely together.

Before discussing the sequence of steps, a few items are mentioned that should receive the modeler's active attention throughout the life of the project.

4.1.1.1 Site familiarity

One of the first things that a modeler should do at the start of a project is to become familiar with the study site. This involves a process of understanding why the beach at the study site behaves as it does. This process should continue throughout the project lifetime, with the modeler continuing to develop a more complete understanding of the nature and unique characteristics of the site. This will greatly assist in making wise choices about initial model input parameters and in continuously checking GenCade results for reasonableness and consistency. As part of this process, a site visit, as early in the life of the project as practical, can be invaluable. Reviewing literature and data and discussing the site with experts are other activities that can provide further understanding of the site.

4.1.1.2 Final report

For most studies, some type of final technical report, which discusses the details of the methodology and the results, will be generated. While the writing of much of this report clearly must wait until the model runs and data analysis have been completed, it is efficient to begin working on some pieces of the methodology section throughout the project. Very early in the project it is useful to envision the layout of this report and to develop a straw man outline. It is easier to generate certain figures and text at the end of each portion in the study when the concepts used, conclusions reached, and appropriate data files are fresh in the mind, rather than postponing this effort until the end.

For example, the search for historical shoreline data and their use as model input occurs early in the study, so the section of the final report that discusses them can be completed early. Topics could include the following:

- number and dates of the shorelines
- how each was generated (aerial photo, 4-runner with GPS, beach profiles, lidar, etc.)
- what each represents (vegetation line, wet/dry line, zero elevation line, etc.)
- the reason each was collected (post-storm, scheduled measurement, one-time measurement of opportunity, etc.)
- the source of each

- reasons that some may have been excluded from the analysis (incomplete coverage, suspect anomalous points, suspect calibration/datum conversion, missing metadata, etc.)
- which were selected for use as initial and final shorelines in model calibration, model validation, and production runs, and which were used to generate a regional contour
- a discussion of the trends in shoreline evolution and shoreline change rates as shown by the sequence of these lines.

Even if the modeler chooses not to write certain parts of the report early in the project, it is a good idea to keep all of the literature and data together for easy access. A Word document or spreadsheet should list important details from each source such as estimated bypass rate, observed erosion or accretion rates, transport direction and rate, and inlet migration.

This makes it simpler to find a specific article or dataset. There should also be an inventory of all engineering activities during a simulation period. For example, a section in the document concerning beach fill should include columns for dates, location, volume or width of the placement, and references for each piece of information. Another section of the document could include inlets with dredging information and shoal volumes.

4.1.1.3 Customer care

In almost all circumstances, a project that involves GenCade modeling will be funded by a sponsor who is interested in specific information about beach behavior. As such, modelers should consider themselves as part of a team. The sponsor and the other team members should be regularly kept abreast of the modeling progress, the difficulties encountered, and the current expected completion date. Both regularly scheduled meetings and informal discussions should be part of the comfortable two-way communication process. As technical experts, modelers need to be able to communicate not only the modeling results, but also an interpretation of their meaning and how these should be applied. They also need to not only be aware of, but to appreciate the specific needs of the other team members and attempt to provide answers in the most effective form.

4.1.2 Project initiation

This process is initialized by someone identifying that beach behavior information is needed at a specific site. From the modeler's perspective, it

should be recognized that the project has time and financial constraints. The modeler needs to require that appropriate time and funding are available to conduct each of the following steps, understanding that large projects may require running GenCade many times for model setup, calibration, and production runs. The modeler needs to develop a detailed plan for the methodology to be used (including assessing if GenCade is the right model for the job) to address the study questions. If some of the study questions cannot be addressed by the methodology, or only partially addressed, this information needs to be conveyed to the sponsor.

4.1.3 Collection of input data

This portion of the project begins when the set of study questions has been agreed upon, a modeler or modeling team has been identified, and resources allocated. GenCade requires extensive specific information about a study site as input data in order to appropriately model the beach behavior. A more extensive set is required for the modeler to develop an understanding of the site and to be able to choose the most appropriate sub-sets for data input. At a minimum, the types of data needs include the historical aerial photographs and bathymetric charts, shorelines and beach profiles, wave and tidal information including tidal datum conversion relationships, inlet tidal prism and shoal volume data, engineering activities, and any prior technical studies conducted at the site or adjacent areas. Other important information can include data on historical storms; estimates of longshore transport rates; sediment grain size data; human management activities such as dredging, beach fills, or jetty construction; and previously calculated sediment budgets.

The quality and quantity of these data can vary tremendously from project to project. Furthermore, there is no standardized procedure for locating all of these data. Federal (USACE, USGS, FEMA, NOAA), state, and university archives should be queried. A general internet search should be conducted. Informal contacts with knowledgeable individuals may provide the best leads. Some types of data, such as sediment samples to determine median grain size, may be obtained during a site visit.

4.1.4 Model setup

This portion of the project will frequently overlap somewhat with the previous data-collection portion. As part of the model-setup process, initial choices for key model parameters such as model grid length, cell

size, grid orientation (offshore azimuth), length of study period, model time-step, and boundary conditions need to be made. Adjustments of these values will likely be made during the setup process, but judicious first choices will reduce the iteration process. The goal at this time is to get a simplistic, barebones version of the study site up and running error free. At a minimum, this will require wave data, shoreline data, and the key parameters just listed.

Once the initial model is running, additional features can be added (hard structures, inlets, etc.) a few at a time and the model rechecked. This procedure will continue until the model has all the needed complexity to represent the prototype. Conducting the setup in this way will help the modeler pinpoint the source of modeling issues as they arise.

The process of setting up a medium- to large-scale GenCade modeling project is complex enough that it is unreasonable to expect that any two modelers, working independently, would ever come up with a full suite of identical parameter choices. However, it is reasonable to expect there would be strong similarities on key points.

As dozens of model runs will likely be made during the project lifetime, it is useful at this point for the modeler to develop a file management plan. This should include an organized file- and directory-naming convention along with a protocol for determining when model runs can overwrite previous runs and when model-run names should be updated with incremental-version names so that the prior runs are not overwritten. These files should be organized in such a manner that a colleague could access the directory and find a specific alternative. It is also possible that the modeler may need to return to the study years later. If the directory is well organized, it should not take much time for the modeler to find the final alternatives and view the results.

4.1.5 Calibration, validation, and sensitivity testing

Additional GenCade documentation is planned that will provide more detailed guidance on these topics.

Model calibration and validation can be based upon shoreline positions or upon longshore sediment transport rates; however, calibration and validation are usually based upon shoreline positions as these are more widely available in the historical record. Also, if historical transport rates

are available, they were likely calculated from historical shoreline positions.

The process of calibration involves the selection of two measured shoreline position data sets collected at known dates. The earlier one is used as the model initial shoreline. The model is run for the time interval between the dates of the measured shorelines, and the model-computed shoreline position is compared with the later (final) measured shoreline. Care should be taken that the model only contains the features (groins, inlets, etc.) that existed between the two measured shoreline dates. Then, model parameters are adjusted in an attempt to obtain better agreement between the model output and the final measured shoreline. Adjustments may include model refinements such as the use of variable grid cell spacing and a regional contour. This procedure continues until the agreement between the model shoreline output and the final measured shoreline is considered satisfactory, which can be quantified through a statistical analysis.

Once calibration is complete, model validation consists of running the model with the final calibration parameters held constant for other time periods using other sets of shoreline pairs and reporting the results. These results provide an indication of the model's predictive capabilities during production runs. As such, the modeler must resist the temptation to present only the most favorable validation comparisons.

The minimum number of shorelines required for calibration and validation is three, with typically the middle shoreline (in sequential order) being used twice, once as an initial shoreline and once as a final shoreline. However, numerous pairs of shorelines (collected at the same season in different years; see the discussion on model assumptions) will provide a substantially better calibration/validation exercise.

Beside validation, another way that the modeler can show the range of potential results is through a sensitivity analysis. For GenCade applications, sensitivity testing is frequently done through an examination of the variability in the input wave data. WIS wave data (which is hindcasted from weather data) are available for all U.S. coastal areas. One methodology is to divide a 20 yr WIS hindcast into year-long blocks, drive GenCade with each block, and rank the model results obtained from a relatively stable, natural location along the shoreline. Typically the approach is to identify the years that satisfy the following conditions:

- the net transport is closest to the 20 yr average
- the greatest gross transport
- the least gross transport
- the greatest leftward gross transport
- the greatest rightward gross transport.

Results can indicate the range of results to be expected in the prototype in the future, without significant engineering activities.

4.1.6 Production runs

This phase of the study begins when the modeler completes the calibration/validation/sensitivity analysis and has defined an initial specific set of alternatives to address the study questions. The number of GenCade runs in this portion of the study can be numerous depending upon several variables, including the nature of the questions to be addressed, the number of alternatives to examine, and the number of times that refinements are applied to the alternatives (based upon interim model results).

It is simple to make changes to the model for production runs. A modeler will develop a no-action case in the conceptual model and then convert to the 1D grid to run the simulation. Usually, examining variants will only involve making a change to a single parameter. Changes can be done quickly in the conceptual model. Once the user converts to the GenCade model, the modeler should save the alternative in a well-defined directory. The entire process of creating a new alternative should take no more than a few minutes as long as all of the features of the no-action case are represented in the initial conceptual model. It is generally not recommended to execute these production runs outside of the SMS; however, there are two cases where it might be beneficial. First, if the machine has multiple processors, the user can run multiple simulations at once with the command prompt. Second, a batch file allows the user to run many simulations in sequence. When conducting a sensitivity analysis, the user might choose to use the command prompt or develop a batch file. While executing the production runs, it is important to keep the files organized and to keep track of which cases have been simulated. It is also important to not only be focused on completing the large number of runs, but at the same time to be continuously evaluating the model output for reasonableness and consistency.

4.1.7 Analysis and interpretation of results

Many projects will require additional analysis of the GenCade model output. The modeler can view shoreline change, transport rates, and changes in the volumes of the morphological features of the inlet and create simple plots in the SMS. If the user wants to produce charts or calculate statistics, it is simple to copy the necessary data into a spreadsheet. MATLAB and FORTRAN are not required to analyze and interpret the results, although some users may feel more comfortable working in these environments. This task may follow the completion of the production runs, or it may be going on simultaneously, particularly if the results of the analysis have the feedback potential to modify the details of the subsequent alternatives to be tested. All output files of this analysis should also be continuously examined to evaluate the reasonableness of the results and also to draw conclusions about the study.

4.1.8 Final report

The last portion of the study is usually the writing of the final report. This may be made easier if the modeler has followed the advice in Section 4.1.1.2. In the report, it may be appropriate to include an appendix that features a full list of the final model parameters. While most readers will have little interest in these details, the modeler, or another modeler, may find them invaluable if there is any reason to return to the project or conduct a similar project at some later time.

4.2 Standards for cell spacing

4.2.1 Cell spacing for constant resolution

The user specifies cell spacing based on how much detail is necessary to accurately represent the physical environment and activities that occur during the simulation. GenCade was developed from GENESIS and Cascade, both of which have different requirements for cell spacing. GENESIS, a design-level model, needs a smaller cell size than Cascade in order to resolve the structures in the simulation. The generic recommendation for the smallest cell spacing for GENESIS is approximately 25 ft. However, the cell spacing is also dependent on other recommendations like the number of cells representing a breakwater (at least eight). On the other hand, Cascade is a regional-scale model, so local effects are not as important. In Cascade, a cell spacing of approximately 1500 ft is considered the standard.

Grid cell spacing for GenCade should be selected through a balance of four conditions. These conditions include the desired resolution, the accuracy of the measured shoreline positions and other data, the expected reliability of the prediction, and the time needed to execute the simulation. GenCade is solved with the explicit-solution scheme, so smaller cell spacing requires a shorter time-step to meet the conditions of numerical stability. The model takes longer to run when a shorter time-step is used compared to a longer one. The general recommendation for the smallest cell size to use in GenCade is 25–30 ft. Pages 15–18 of Report 1 (Frey et al. 2012a) provide other details about the recommended resolution in GenCade.

4.2.2 Variable cell spacing

Another option in GenCade is variable cell spacing, which allows for increased resolution in specific areas of the grid while larger cell spacing is used in areas that do not need refined spacing. More details about how to set up and run a GenCade simulation with variable cell resolution are described in Report 1 (Frey et al. 2012a); however, additional information about cell spacing defaults and recommendations is explained here.

In GenCade, variable cell spacing is initiated by using the *Use refine points* option. The user defines the *Maximum cell size* and the *Maximum bias*. The *Maximum cell size* is the largest cell size in the grid. The *Maximum bias* refers to how much each adjacent cell increases in length. GenCade uses a default *Maximum bias* of 1.1 (Figure 54). For example, if the user defines the smallest cell size as 30 ft, then the adjacent cell would be 33 ft if the default of 1.1 is used. This means each cell increases by 10%.

Although the default *Maximum bias* is 1.1, previous documentation has not provided much guidance on how using other values will affect the simulation results. This section provides two examples that illustrate what happens when using different maximum biases with different maximum cell sizes.

The first example is a very simple case with a single inlet and groin. The total length of the grid is 50,000 ft. This is an idealized case with a straight shoreline and constant waves with a height of approximately 1.6 ft, period of 6 seconds (sec), and wave direction of 10° (shore-normal). The purpose of this 5 yr idealized case is to determine whether different cell spacings affect the quality of the simulation results. The cell spacing for the middle 10,000 ft of the grid is constant at 25 ft (Figure 55). Both the inlet and the groin are located within the constant cell-spacing area. Then the cell spacing increases based on the user's input for maximum bias.

Figure 54. Default setting for variable grid cell spacing.

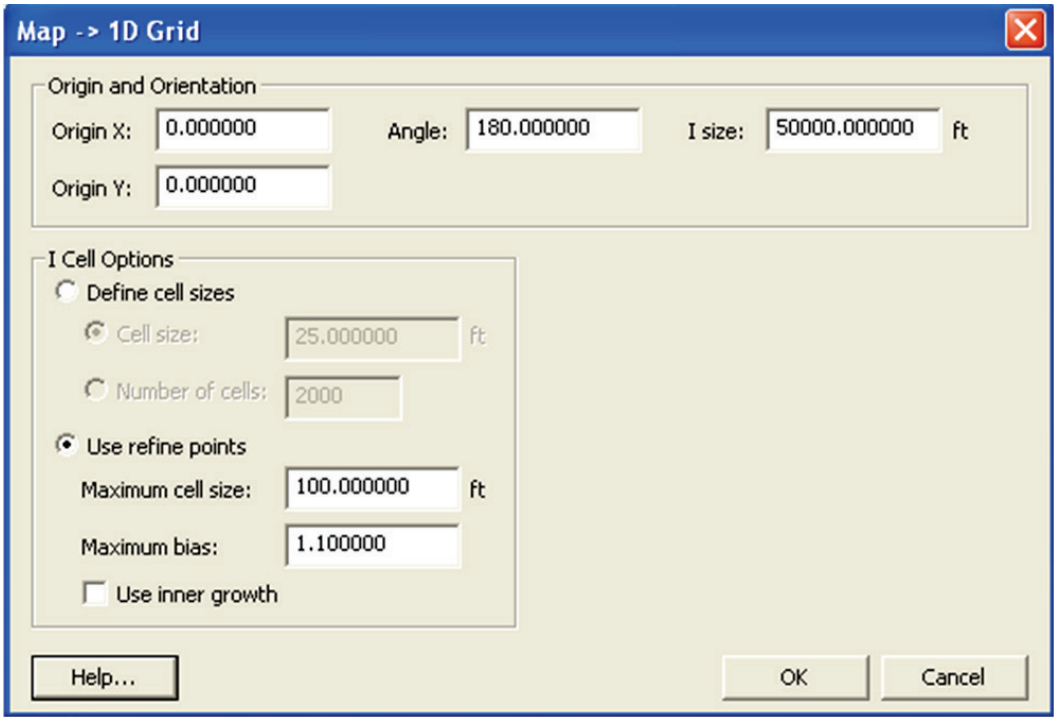
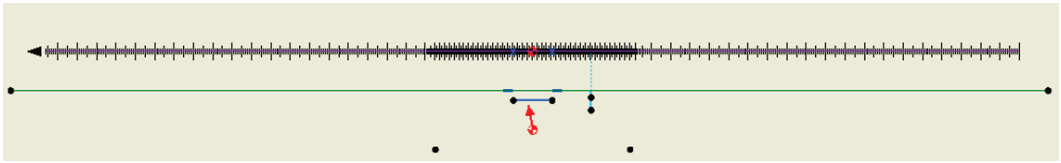


Figure 55. Setup for idealized variable cell-spacing case (Example 1).



Several variations of this case were conducted to determine the effects of variable resolution as shown in Table 2. First, the case was run with a constant cell spacing of 25 ft along the entire grid. All of the rest of the cases had variable cell resolution enabled. In these cases, the spacing in the center section of the grid was constant at 25 ft, but the largest cell size was increased to 100, 250, or 500 ft. The maximum bias was also adjusted. The first set of scenarios had a maximum cell size of 100 ft. For these cases, maximum biases of 1.1, 1.2, 1.5, 2.0, 3.0, and 4.0 were tested. Then the second set used a maximum cell size of 250 ft. Maximum biases of 1.1, 1.2, 1.5, 2.0, 5.0, and 10.0 were used. Finally, the last set of cases had a maximum cell size of 500 ft. The maximum bias for these cases was adjusted from 1.1, 1.2, 1.5, and 20.0.

Before any of the results were compared, the amount of time necessary to run each simulation was recorded. Table 2 lists the duration of each simulation. When a constant cell spacing of 25 ft over the entire grid was

used, the simulation took more than 6 minutes (min) (376 sec). Even the grid with a maximum cell size of 100 ft and the maximum bias of 1.1 (total of 816 cells) took less than 2 min to run (113 sec). With the same maximum bias of 1.1, the time to run the simulation decreases to 79 and 67 sec, when the maximum cell size is increased to 250 and 500 ft, respectively. Generally, as the maximum cell size and maximum bias increase, the time to run the simulation decreases. However, when the maximum bias is increased to 10 with a maximum cell size of 250 ft, this simulation takes a few seconds longer to run than cases with a smaller maximum bias. In this case, the cell size increases immediately from 25 to 250 ft, which is probably too much of an increase between adjacent cells, so the computational efficiency slows down.

Table 2. Default setting for variable cell spacing for Example 1.

Constant Cell Spacing of 25 ft: 376 sec					
Maximum Cell Size: 100 ft		Maximum Cell Size: 250 ft		Maximum Cell Size: 500 ft	
Maximum Bias	Time (sec)	Maximum Bias	Time (sec)	Maximum Bias	Time (sec)
1.1	113	1.1	79	1.1	67
1.2	113	1.2	74	1.2	66
1.5	113	1.5	74	1.5	65
2.0	112	2.0	73	20.0	61
3.0	112	5.0	73		
4.0	112	10.0	76		

The set of simulations with a maximum cell size of 100 ft was compared first. The simulation with a maximum bias of 1.1 had 816 cells where 286 of those cells were approximately 100 ft in size. Using a maximum bias of 1.2 decreased the number of cells to 808 with 292 cells of 100 ft in size. Both the maximum biases of 1.5 and 2.0 have 804 cells while maximum biases of 3.0 and 5.0 have 802 cells. Although the cases with maximum biases of 1.5 and 2.0 have the same number of cells, the spacing of those cells is different. Depending on the purpose of an application, it may be that a bias of 1.1 for this example would provide the necessary increase in simulation speed without a significant sacrifice in accuracy.

Figure 56 shows shoreline change for all of the cases with a maximum cell spacing of 100 ft. The vertical black line around 4 miles represents the groin while the black horizontal line between miles 4 and 5 represents the inlet. The groin at 4 miles is much longer than the length shown in Figure 56.

When shoreline change is shown over the length of the entire grid, it looks like each case is identical. Therefore, it is necessary to zoom in to the transition zones where the cell spacing increases to the maximum size.

Figure 57 focuses on the transition zone from 3 to 4 miles from the grid origin. Each simulation calculates a slightly different shoreline change at approximately 3.8 miles. The red line represents the case with constant spacing of 25 ft. Each of the variable grid cell resolution cases is compared to that case. As the maximum bias is increased, the shoreline change in the transition region differs the most from the constant spacing case. Although instability warnings did not appear during any of the simulations, as the maximum bias increases, the results in this zone seem to be less accurate. Depending on the purpose of an application, it may be that a bias of 1.1 for this example would provide the necessary increase in simulation speed without a significant sacrifice in accuracy.

Figure 56. Shoreline change for cases with maximum cell size of 100 ft for Example 1 (vertical black line at 4 miles is a groin; horizontal black line between 4.5 and 5 miles is the inlet).

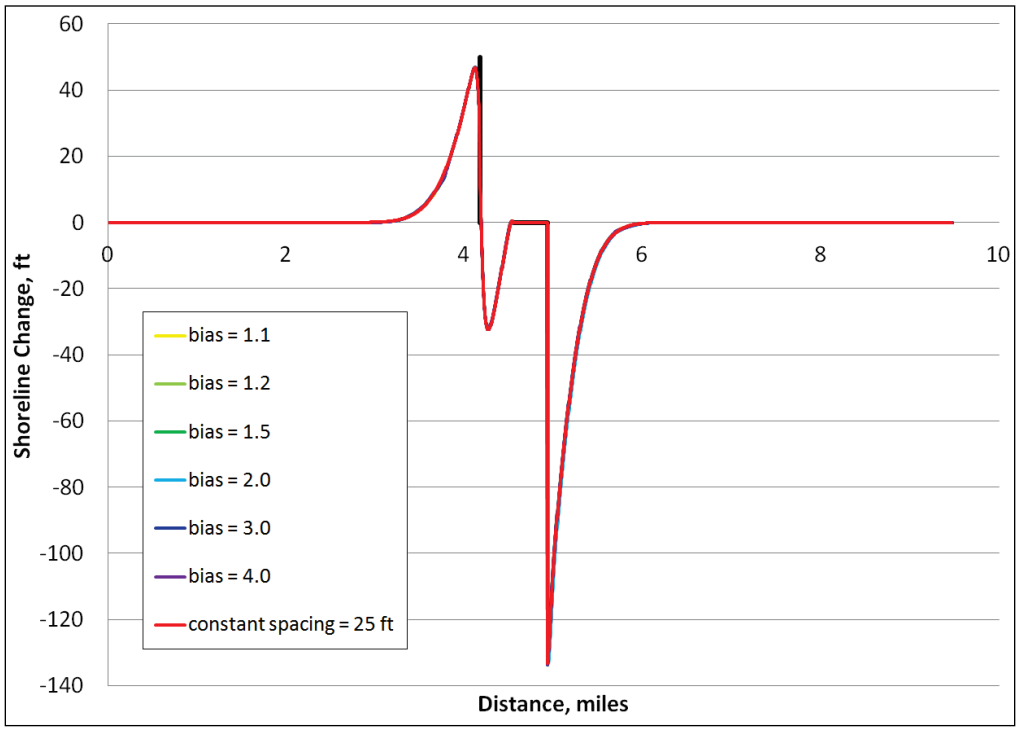
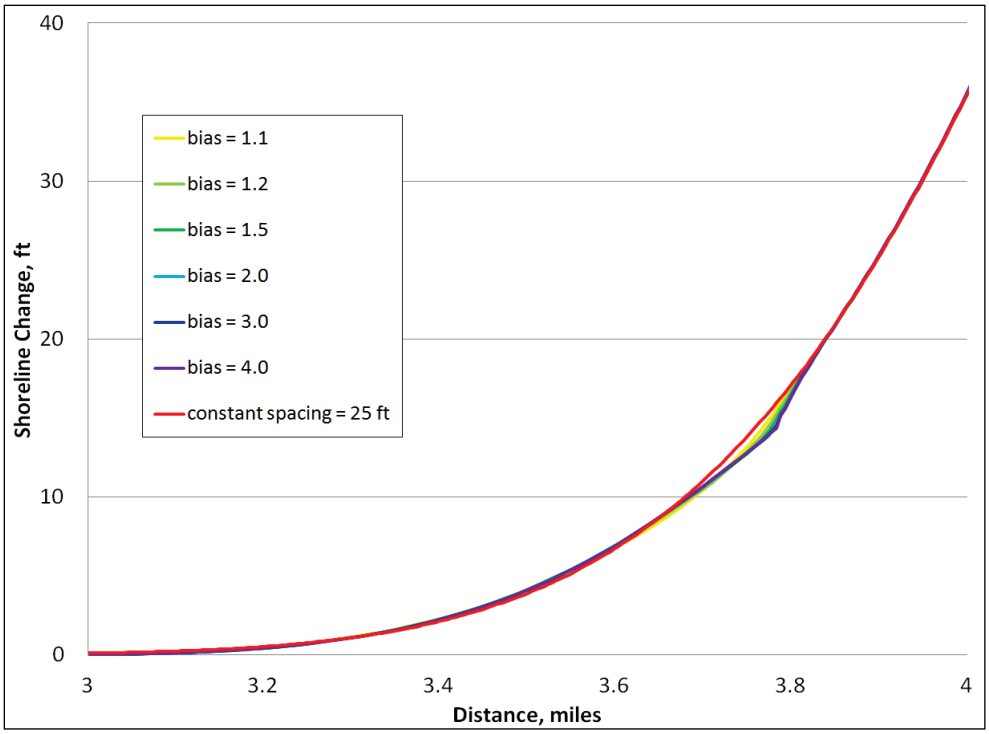


Figure 57. Zoomed-in view of simulations with maximum cell spacing of 100 ft for Example 1.



The same type of analysis was conducted for the cases with maximum cell spacing of 250 ft and 500 ft. The number of cells ranged from 562 to 592 with a maximum size of 250 ft and from 482 to 524 with a maximum cell spacing of 500 ft. Figure 58 displays a zoomed-in view of the transition zone for cases where the maximum cell spacing is 250 ft. Similar to the cases with a maximum cell spacing of 100 ft, the shoreline change results at approximately 3.8 miles tend to differ depending on the maximum bias. As the maximum bias increases, the shoreline change in the transition zone becomes less like the shoreline change for the case with a constant cell spacing of 25 ft. Figure 59 shows the shoreline change for the same region of the grid for cases with a maximum cell spacing of 500 ft. The same trend appears in this case where a greater maximum bias results in shoreline change that does not follow the shoreline change of the constant cell spacing case. In the case with a maximum bias of 20.0, the unusual shoreline change at approximately 3.8 miles seems exaggerated. The shoreline change along the grid does not follow a smooth curve for this case; it appears that the shoreline change jumps from approximately 10 to 15 ft in adjacent cells. All of the cases should follow the trend of the constant-spacing case, so these figures show that a maximum bias that is too large may produce inconsistent results even though the simulation does not experience any instability.

Figure 58. Zoomed-in view of simulations with maximum cell spacing of 250 ft for Example 1.

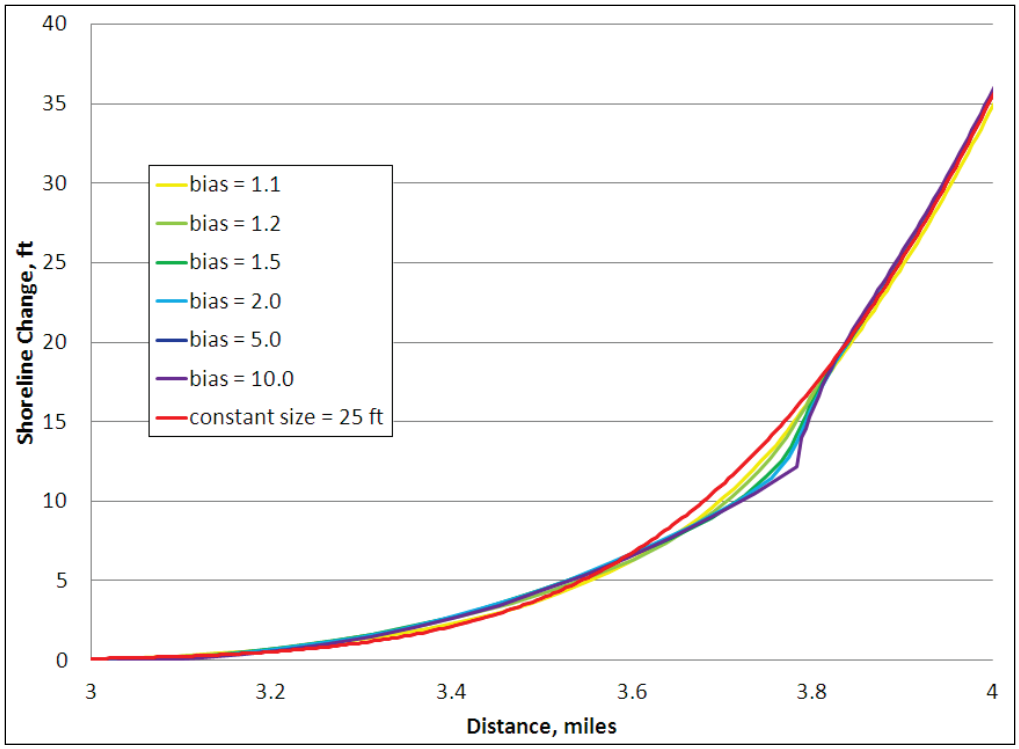
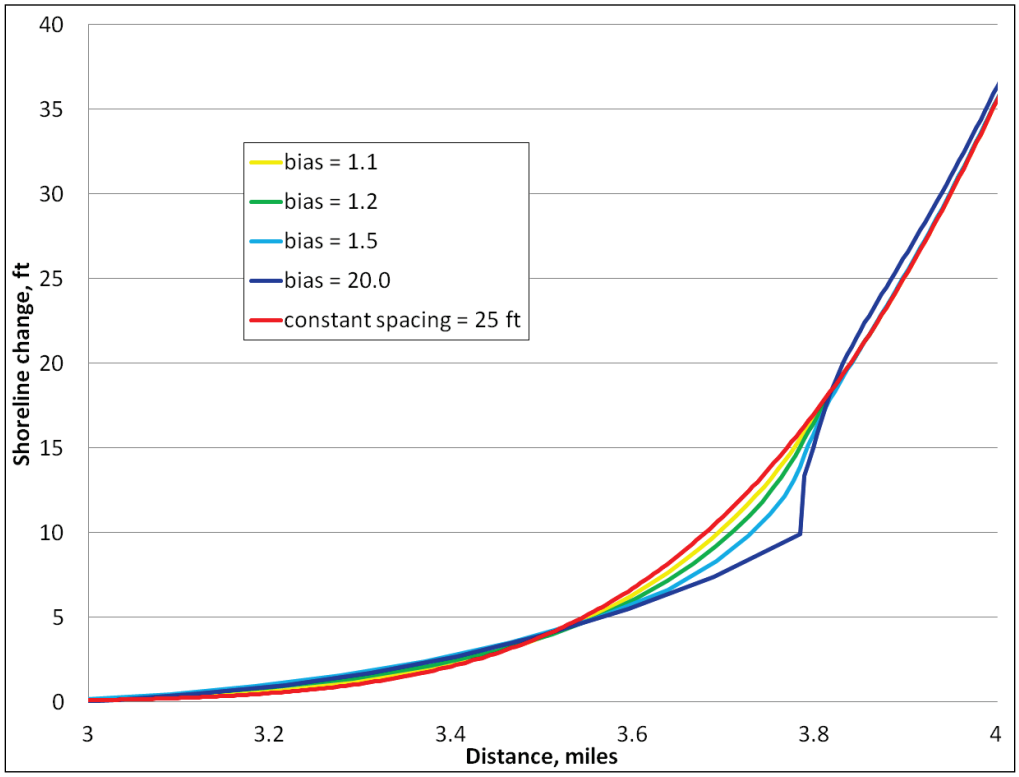


Figure 59. Zoomed in view of simulations with maximum cell spacing of 500 ft for Example 1.



Although these cases consisted of straight shorelines and idealized waves, as the maximum bias and maximum cell size were increased, the calculated shoreline change began to deviate from the case with constant cell spacing. Since these cases were idealized and still show differences in shoreline change with different bias and maximum cell spacing along the grid, it was necessary to analyze a case with real waves and a real shoreline to develop guidance for specifying maximum bias and the maximum cell size for a simulation.

Example 2 was based on a completed project. The original GenCade input data included an inlet and three groins. In order to simplify the simulation, the inlet was removed. The shoreline near the inlet was smoothed, and one WIS wave gauge was used. All of the simulations were run for 5 yr. Similar to the idealized case, a grid was developed with a constant cell spacing of 10 m. Meters were used instead of feet because the original project was set up and run in meters; however, the figures associated with these cases have been converted to USCS units. Then variable grid cell resolution was used where the largest cell spacing in the grid was 330 ft, 820 ft, or 1640 ft. There are two reasons that larger cell spacing was used for these cases. First, the grid was longer, so the larger cell spacing was used to speed up the simulation time. Second, the larger cell spacing was used to determine if there are any restrictions on the largest cell spacing in a grid compared to the smallest one. Descriptions of each of the simulations and the amount of time to run each are shown in Table 3. The case with constant spacing of 33 ft had 3000 cells and took more than 83 min to run. By using a maximum cell spacing of 330 ft and the default maximum bias of 1.1, the time to run the simulation dropped to just over 8 min (488 sec). Although the cases with variable resolution may not have identical results to a case with small, constant cell spacing, decreasing the time by more than an hour is certainly considerable for production runs. For these cases, the maximum bias ranged from 1.01 to 50.0. In the case with a maximum bias of 1.01 and a maximum cell size of 330 ft, the cell size gradually increased from 33 ft to 330 ft over more than 5.6 miles along the grid. The largest maximum bias (10.0, 25.0, and 50.0) for each maximum cell size (330 ft, 820 ft, 1640 ft) resulted in cells increasing from the minimum to the maximum without any intermediate cell sizes. For the case with a maximum cell size of 330 ft and a maximum bias of 10.0, each cell adjacent to the minimum cells was 330 ft. In these cases, there were no transition cells. Please note that the amount of time to run the simulation usually decreases as the maximum cell size and

maximum bias are increased. However, a very large increase in size between adjacent cells may actually slow down the simulation because of a reduction in computational efficiency. This is the reason the maximum bias of 50.0 took longer to run than the maximum bias of 3.0 with a maximum cell size of 1640 ft.

Table 3. Listing of and amount of time to run cases for Example 2.

Constant Cell Spacing of 10 m: 83 min, 7 sec					
Maximum Cell Size: 330 ft		Maximum Cell Size: 820 ft		Maximum Cell Size: 1640 ft	
Maximum Bias	Time (sec)	Maximum Bias	Time (sec)	Maximum Bias	Time (sec)
1.01	756	1.01	730	1.01	730
1.05	492	1.05	358	1.05	338
1.1	488	1.1	319	1.1	282
1.2	451	1.2	299	1.2	253
1.5	448	1.5	286	1.5	241
3.0	443	3.0	292	3.0	235
10.0	440	25.0	286	50.0	248

Figure 60 shows shoreline change over the entire grid for the cases with a maximum cell spacing of 330 ft. The black lines represent the groins; however, the groins in the simulations were much longer than the 65 ft shown in the following figures. At no point does the shoreline advance seaward of the groins in any of the simulations. In these cases, the constant, minimum cell spacing of 33 ft extends about 0.3 mile past the first and third groin. The more idealized shape of the shoreline between approximately 11.2 to 14.9 miles is the region where the inlet was removed and the shoreline was smoothed. The calculated shoreline change for all of the scenarios is very similar far from the influence of the groins. However, the results near the groins are affected by the maximum bias specification.

Figure 61 shows the same cases as Figure 60 except it focuses on the distance between 7.5 to 14.3 miles. With a maximum bias of 1.01, the results are almost identical to the constant spacing of 33 ft. As the maximum bias increases, the results begin to deviate from the constant-spacing case. The light green represents the default maximum bias of 1.1. Although differences can be noted, the calculated shoreline change is within a meter or two at all locations on the grid after a 4 yr simulation. Considering that the cell spacing near the groins is 33 ft, a 3–6 ft difference in shoreline change is not that significant. However, as the maximum bias increases, the shoreline change for those cases begins to

Figure 60. Shoreline change for cases with maximum cell spacing of 330 ft for Example 2.

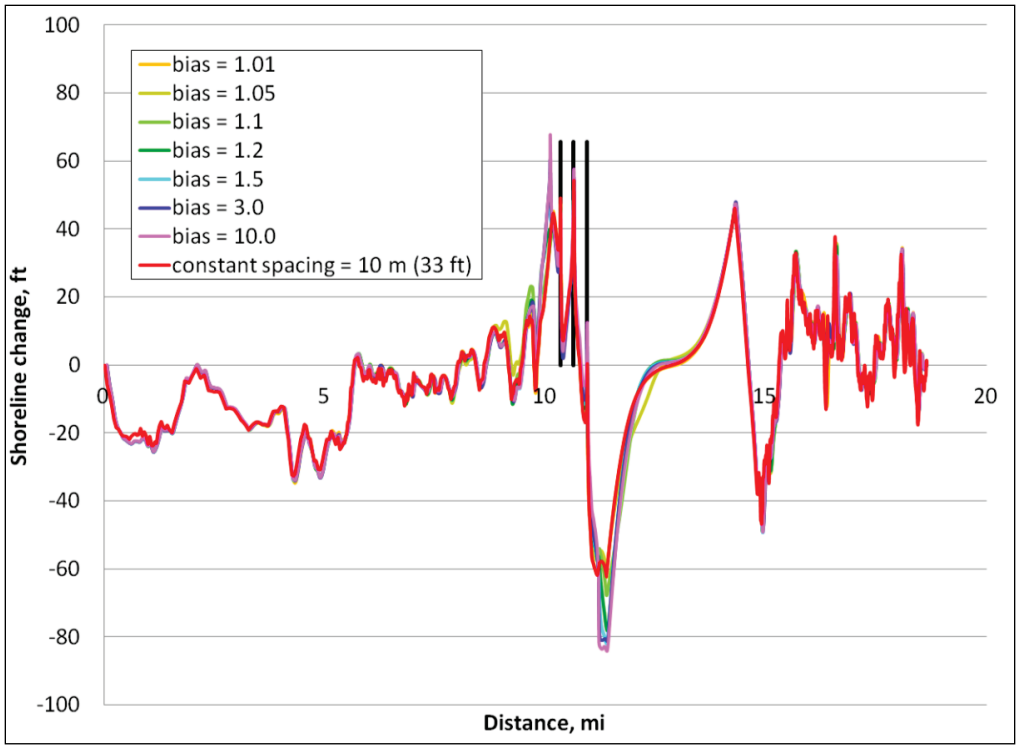
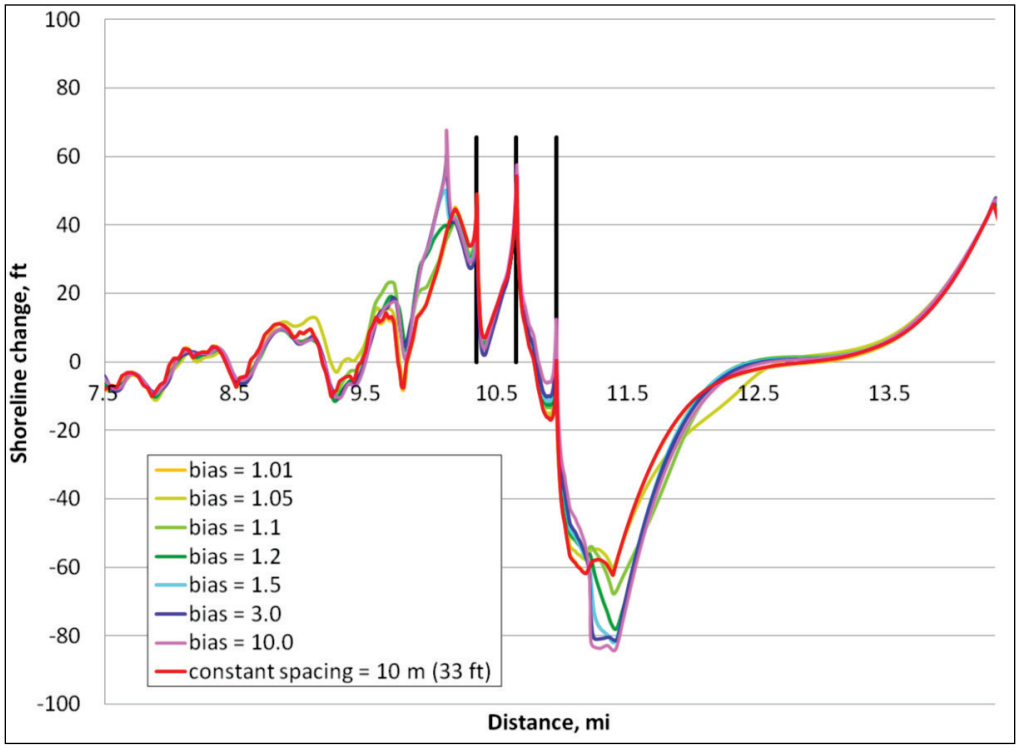


Figure 61. Zoomed in view of shoreline change for cases with maximum cell spacing of 330 ft for Example 2.



differ from the constant cell spacing. For the case with a maximum bias of 10.0, there is a noticeable spike at approximately 10 miles. This does not exist in the constant-spacing case or any of the lower-maximum bias cases. This spike should not exist, so a maximum bias of 10.0 is too large for this example and should not be used.

Shoreline change for cases with maximum biases of 1.01 to 25.0 and a maximum cell spacing of 820 ft is shown in Figure 62. The difference between the shoreline change for the constant-spacing case and the maximum-bias scenarios becomes much more noticeable than the cases with maximum cell spacing of 330 ft. With a maximum cell spacing of 820 ft, maximum biases of 1.01 and 1.05 have similar results to the constant cell spacing case. The same shoreline change trends appear with the maximum bias of 1.1. As the maximum bias increases to 1.2, the shoreline begins to look more *jagged* as if there are instabilities during the simulation that are causing unrealistic results. With a maximum bias of 1.5 or greater, a pronounced spike occurs just before the first groin. Also, each of these cases calculates more than 98 ft of erosion downdrift of the last groin. The constant spacing case calculates less than 66 ft of erosion. These differences in shoreline change are significant, so these maximum biases are too large for this example. It is important to consider that although the maximum biases are the same as the 33 ft cell-spacing cases, there is a difference in the transition cell spacing. Since the cell size is increasing to 820 ft instead of 330 ft, each cell will increase by the same rate, but it will take longer to grow to a cell size of 820 ft than 330 ft. For example, with a maximum bias of 1.2, it will take approximately 0.3 mile for the cells to grow from 33 to 330 ft. This occurs over a total of 14 cells. On the other hand, in order for the cells to increase to 820 ft, the distance of the transition zone is 0.8 miles, which is 19 cells. A greater difference between the minimum and maximum cell spacing may cause greater instability when using a larger maximum bias.

All of the scenarios with a maximum cell spacing of 1640 ft are shown in Figure 63. Shoreline change with a maximum bias of 1.01, 1.05, and 1.1 is very similar to the case with constant cell spacing. Greater maximum biases result in unusual shoreline change around the groins; for example, the case with a maximum bias of 50.0 calculates shoreline advance of greater than 165 ft when other cases calculate advance of less than 33 ft.

Figure 62. Zoomed-in view of shoreline change for cases with maximum cell spacing of 820 ft for Example 2.

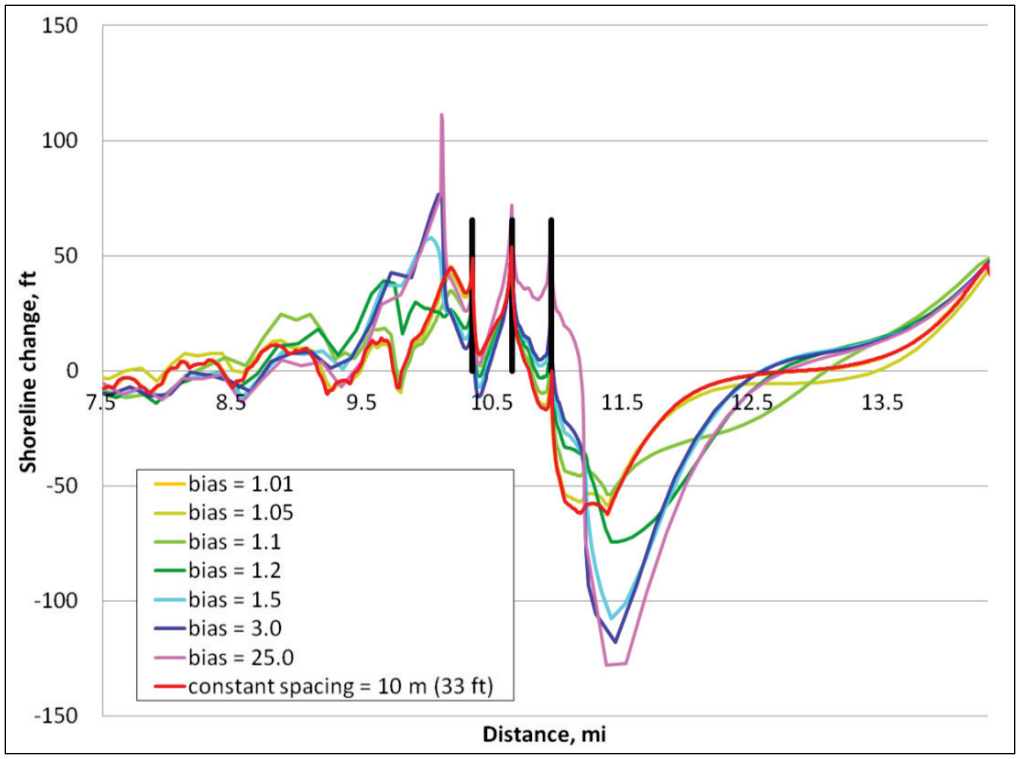
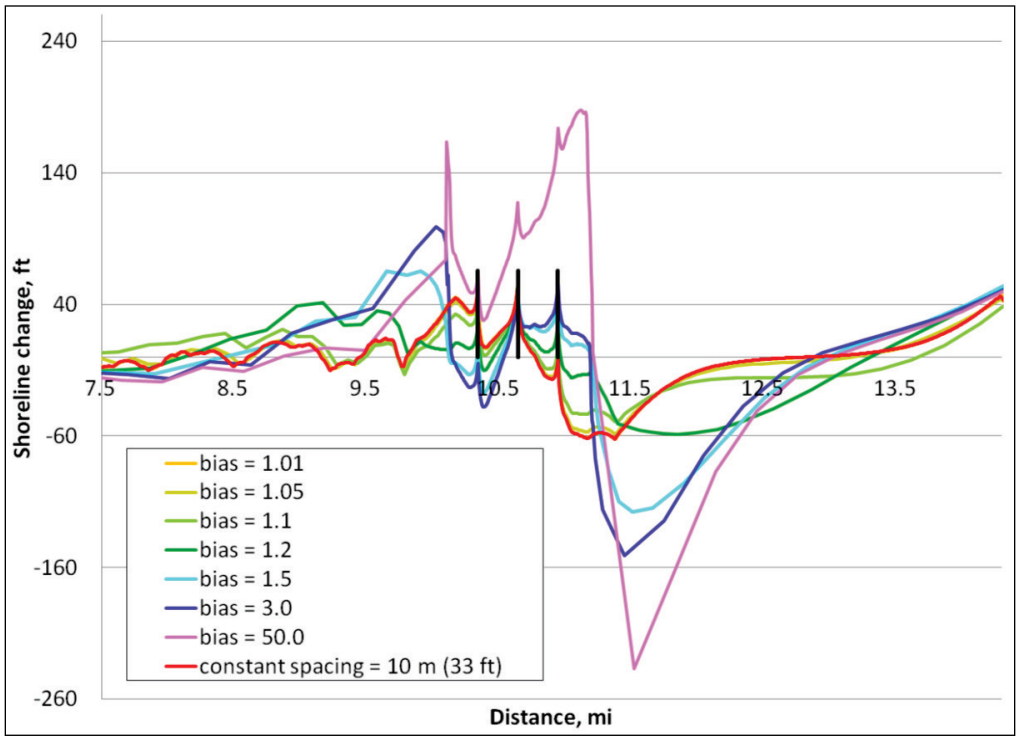
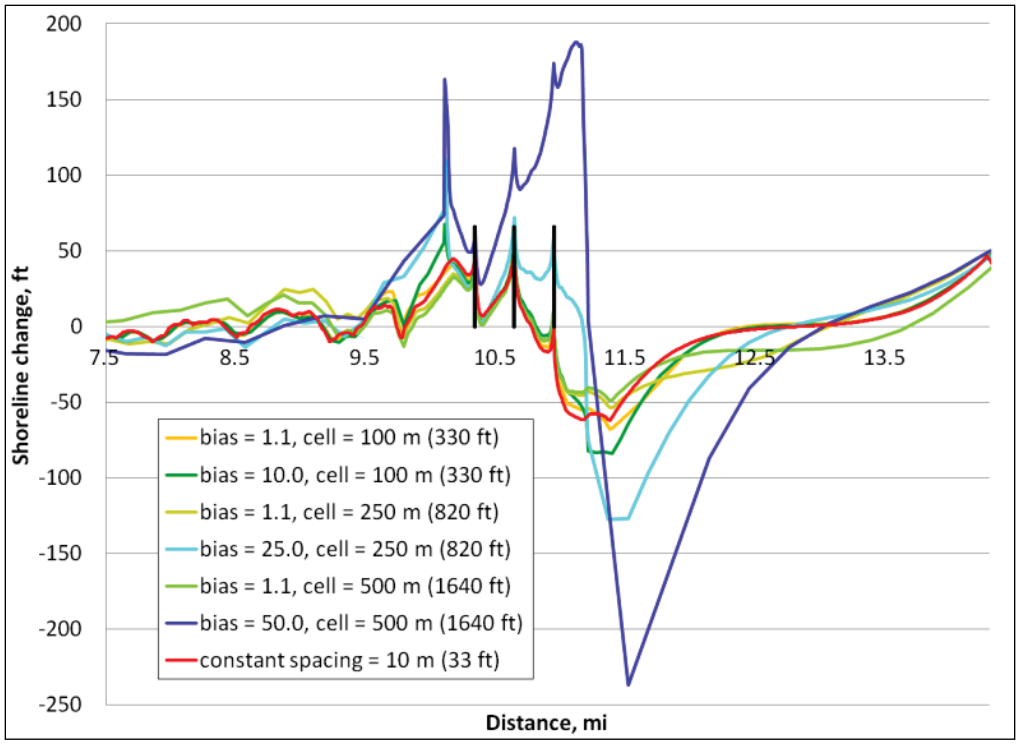


Figure 63. Zoomed-in view of shoreline change for cases with maximum cell spacing of 1640 ft for Example 2.



The three previous figures show that as the maximum bias increases, the calculated shoreline around the groins begins to differ from the constant cell spacing. Figure 64 compares the maximum biases for the different maximum cell sizes. The case with a maximum bias of 1.1 and a maximum cell size of 330 ft most closely follows the shoreline change results of the constant spacing case. Regardless of the maximum spacing along the grid, when the maximum bias is 1.1, the results are similar to the constant spacing case. The other case for each maximum cell spacing in the figure (bias of 10 and maximum spacing of 330 ft, bias of 25 and maximum spacing of 820 ft, bias of 50 and maximum spacing of 1640 ft) represents the simulation where the maximum cell size is directly adjacent to the 33 ft cells along the grid. Although the case with a maximum bias of 10.0 and a maximum cell spacing of 330 ft does result in slightly exaggerated shorelines, the shoreline change for this case is not nearly as *spiked* as the cases with maximum cell spacing of 820 ft and 1640 ft. If all else is equal, a greater maximum cell spacing will cause more instabilities with the shoreline results.

Figure 64. Comparison of shoreline change for different maximum bias and maximum cell sizes for Example 2.



It is recommended to use the default maximum bias of 1.1, which will increase each adjacent cell by 10%. This maximum bias will decrease the number of cells and decrease the time to run the simulation without adversely affecting the results. It is also recommended that the maximum cell size be no larger than 10 times the minimum cell size. In the example described in Table 3, the time to run the simulation decreases from 83 min with constant cell spacing of 33 ft to just over eight min with a maximum cell spacing of 330 ft and a maximum bias of 1.1. Increasing the maximum bias or the maximum cell size from the recommendations does not significantly decrease the simulation run time further.

If the user has an application in which these recommendations must be violated because of project needs (e.g., the user wants to use a maximum cell spacing more than 10 times greater than the minimum cell spacing or a maximum bias of greater than 1.1), there are a few things to keep in mind. First, when either the maximum cell spacing or maximum bias increases, the shoreline change in the transition zone and in the area with the smallest cell size will deviate more from a constant, small cell size. If the user does not follow the recommendations for variable grid cell resolution, exceeding the ratio of maximum to minimum cell size is the better option. If either of the recommendations is exceeded, the user should move the location of the transitions zones farther from the area of interest. Also, if either recommendation is exceeded, it is best to decrease the other variable to less than the recommendation. For example, if the maximum-to-minimum cell size ratio is 25 (minimum cell size = 33 ft, maximum cell size = 820 ft), then the maximum bias should be dropped to less than 1.1. On the other hand, if the maximum bias is greater than 1.1, the ratio between the maximum and minimum cell sizes should be less than 10. For example, if a maximum bias of 1.2 is used, then a maximum-to-minimum cell spacing ratio of 5 would be better than the general recommendation of 10. While the simulation will run regardless of what combination of maximum cell size and maximum bias is selected by the user, it is important to consider that while decreasing the simulation run time, the results calculated by GenCade could be compromised.

4.3 Angle between shoreline and *x*-axis

GenCade is a one-line model which means it is dependent on the grid to calculate shoreline change and longshore sand transport. It is up to the user to determine the orientation of the grid's *x*-axis with respect to the initial shoreline. Onslow Bay, North Carolina, one of the first projects

completed with GenCade, is a crescentic series of barrier islands. It is bounded by Cape Lookout and Cape Fear so that the shoreline orientation transitions from southwesterly facing on Shackleford Banks near Cape Lookout to nearly easterly facing near Cape Fear. One grid was used initially, but very large instabilities occurred near the grid boundaries. Additionally, the large angle between the shoreline and the *x*-axis caused structure distortion so that the structures were either elongated or shortened along the grid *x*-axis and were not necessarily in the correct location. Due to these problems, three overlapping grids were used to complete the project; however, the limits of angle between the shoreline and the *x*-axis were not investigated at the time.

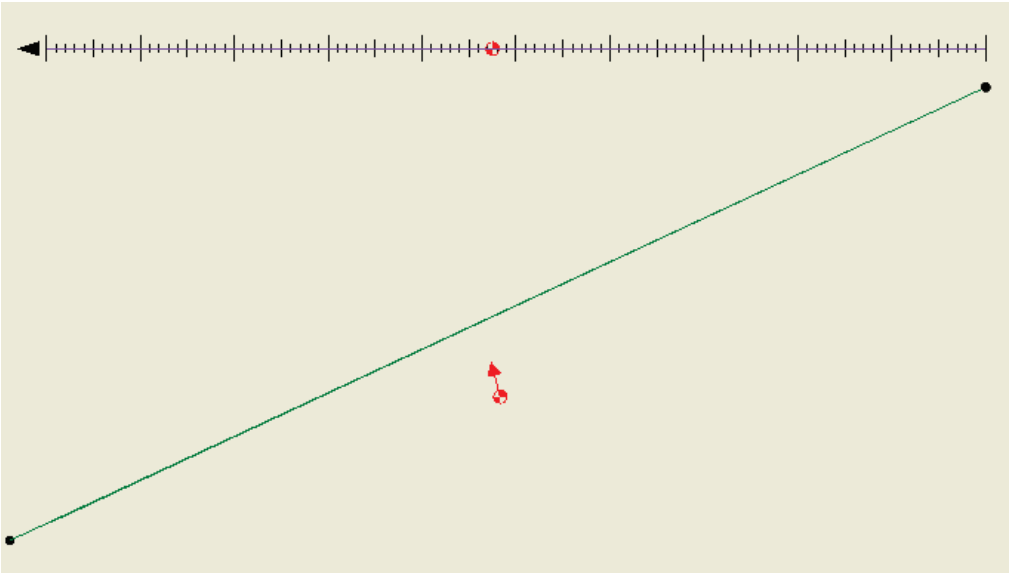
In order to provide more information on the limit of the angle between the shoreline and the *x*-axis, an idealized case was investigated. The purpose of the idealized case was to determine if there was a specific angle for which excessive error is introduced. The 10 yr, idealized case consists of a straight shoreline parallel to the GenCade *x*-axis and constant waves of approximately 1.6 ft at a grid *x*-axis-normal direction of 10° (Figure 65). This case does not have a regional contour. The GenCade *x*-axis is always *landward* of the shoreline, so the water is located to the south of the shoreline.

Figure 65. Straight shoreline and grid *x*-axis idealized case.

After the simulation was finished, the output files were analyzed. Since the initial shoreline is straight and there are no engineering activities to modify the shape of the shoreline, there is no shoreline change during the simulation. Longshore transport calculated for this case is constant along the grid. In this case, the longshore sand transport is 77,000 yd^3/yr to the right (to the west).

To test the angle, the shoreline in the initial case was rotated away from the *x*-axis. For example, Figure 66 shows the shoreline rotated 25° counterclockwise. The inputs for this case are identical to the initial case.

Figure 66. Straight shoreline rotated 25° from the grid *x*-axis.



GenCade can accept wave inputs in meteorological, oceanographic, Cartesian, or shore-normal orientation, but GenCade will automatically convert the waves to shore-normal. However, shore-normal is not the correct term since the shoreline does not have to follow a straight line like the GenCade *x*-axis. Therefore, it is correct to say that GenCade converts waves to grid *x*-axis-normal convention. This is an important concept to understand for this analysis. In the initial case, the constant wave direction is 10°. Figure 65 illustrates the wave direction with the red arrow located offshore. GenCade will not change the wave direction when the shoreline is rotated away from the *x*-axis because the wave direction is grid *x*-axis-normal, not shore-normal. However, when the shoreline orientation is adjusted, the wave angle relative to the shoreline will be different. For example, the shoreline in the first case was rotated 5° counterclockwise. When this happens, the initially specified waves of 10° grid *x*-axis-normal are no longer 10° shore-normal. Since the shoreline has been rotated, the wave angle to the shoreline is now 5°. This wave angle will not produce the same results as the first case (Table 4).

Several different shoreline angles were tested, and all of the results are shown in Table 4. Each case produces the same constant longshore sand transport of 77,000 yd^3/yr until the shoreline is rotated 41.725° away from the *x*-axis. At 41.72°, the results are identical to all of the other cases. Once the shoreline is rotated 41.725°, the calculated longshore transport increases to 78,000 yd^3/yr. While this difference is small, it shows that the threshold has been reached. As the angle between the shoreline and the *x*-axis is

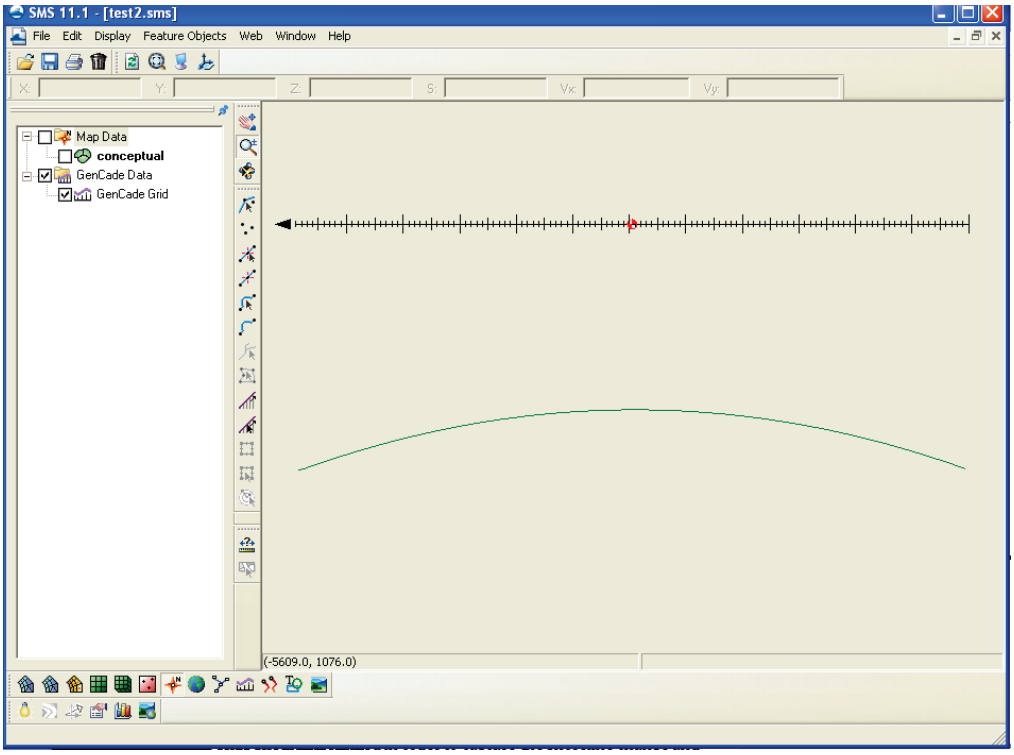
increased, the calculated longshore sand transport begins to decrease. Finally, the calculated longshore transport switches directions to the east. Since the longshore transport should be the same in all of the cases, it appears that a 41.725° angle between the shoreline and the *x*-axis is the threshold for reasonable results. If the user increases the angle between the shoreline and the *x*-axis to greater than this, the longshore transport is not calculated correctly.

Table 4. Summary of grid *x*-axis vs. shoreline angle analysis.

Shoreline angle relative to grid	Grid- x-axis-normal waves	Shore-normal waves	Longshore transport (1000 * yd^3/yr)
0°	10°	10°	77
5°	15°	10°	77
10°	20°	10°	77
15°	25°	10°	77
20°	30°	10°	77
25°	35°	10°	77
30°	40°	10°	77
35°	45°	10°	77
40°	50°	10°	77
41°	51°	10°	77
41.72°	51.72°	10°	77
41.725°	51.725°	10°	78
41.75°	51.75°	10°	76
42°	52°	10°	66
45°	55°	10°	–77
50°	60°	10°	–303

The same analysis was conducted with a concave shoreline. In the first case, the grid *x*-axis has an azimuth of 270° (shoreline is south of the GenCade grid) and the concave shoreline is oriented to the south (Figure 67). Then the GenCade *x*-axis was rotated to increase the angle between the shoreline and the *x*-axis for each subsequent case. The calculated longshore sand transport was about 79,800 yd^3/yr when the angle between the *x*-axis and the concave shoreline was between 0° and 35°. As the angle increased further, the longshore transport calculated by the model began to stray from the accepted 79,800 yd^3/yr.

Figure 67. GenCade *x*-axis and concave shoreline.



Since the shorelines are idealized in these cases, it is likely that the angle between the shoreline and *x*-axis can be larger than in cases with real waves and actual shorelines. Therefore, it is recommended that the user does not set up a GenCade simulation where the angle between the GenCade *x*-axis and the shoreline exceeds 25°. While the simulation will run without errors, GenCade may have difficulties calculating the output when the angle exceeds 25°. If the user would like to conduct a GenCade project with a shoreline similar to the curvature of Onslow Bay, multiple grids that overlap should be created in order to capture the shoreline change and longshore transport in all areas of the grid. Please note that the shoreline should be parallel to the GenCade *x*-axis if possible. The example shown in Figure 66 is very exaggerated to show that there is a specific angle between the shoreline and the *x*-axis where the model will not calculate transport correctly. If the shoreline is a straight line, it should be oriented parallel to the *x*-axis. The selection of the GenCade grid orientation is a very important decision during the model setup since it affects the calculated transport at every grid cell at every time-step. The main reason this happens is because longshore transport is driven by waves. Only waves between +90° and –90° grid *x*-axis-normal are used in the model. When the orientation of the GenCade *x*-axis is different from the shoreline orientation, this means that some of the waves that are

between +90° to –90° relative to the shoreline are not included in the model since these are not the same waves that are +90° to –90° relative to the *x*-axis. Therefore, the user should orient the grid *x*-axis parallel to the shoreline as much as possible. If the shoreline is a slightly concave shape, the grid *x*-axis should be aligned parallel with the center portion of the shoreline as to minimize deviations at the extremities. The exception to this would be if one area closer to either end of the GenCade grid is of particular interest for the study. Since results will be the most accurate when shoreline is oriented within ± 25° of the GenCade *x*-axis, it would be acceptable to align the *x*-axis with the area of interest or to use multiple grids such that the area of interest is parallel to the *x*-axis.

4.4 Stability parameter

The stability parameter is discussed in pages 21–23 of Frey et al. (2012a), and the reader may wish to review that text before or in addition to reading the following discussion. This section of the report is divided into three sub-sections. The first sub-section discusses the ways that the model alerts the modeler to stability issues associated with a GenCade run. The second sub-section discusses the options that the modeler has to address these issues. The third sub-section presents background information that provides the modeler with a more complete understanding of how and why issues of model stability occur.

4.4.1 Stability parameter error messages

Model stability in GenCade is expressed by the inequality

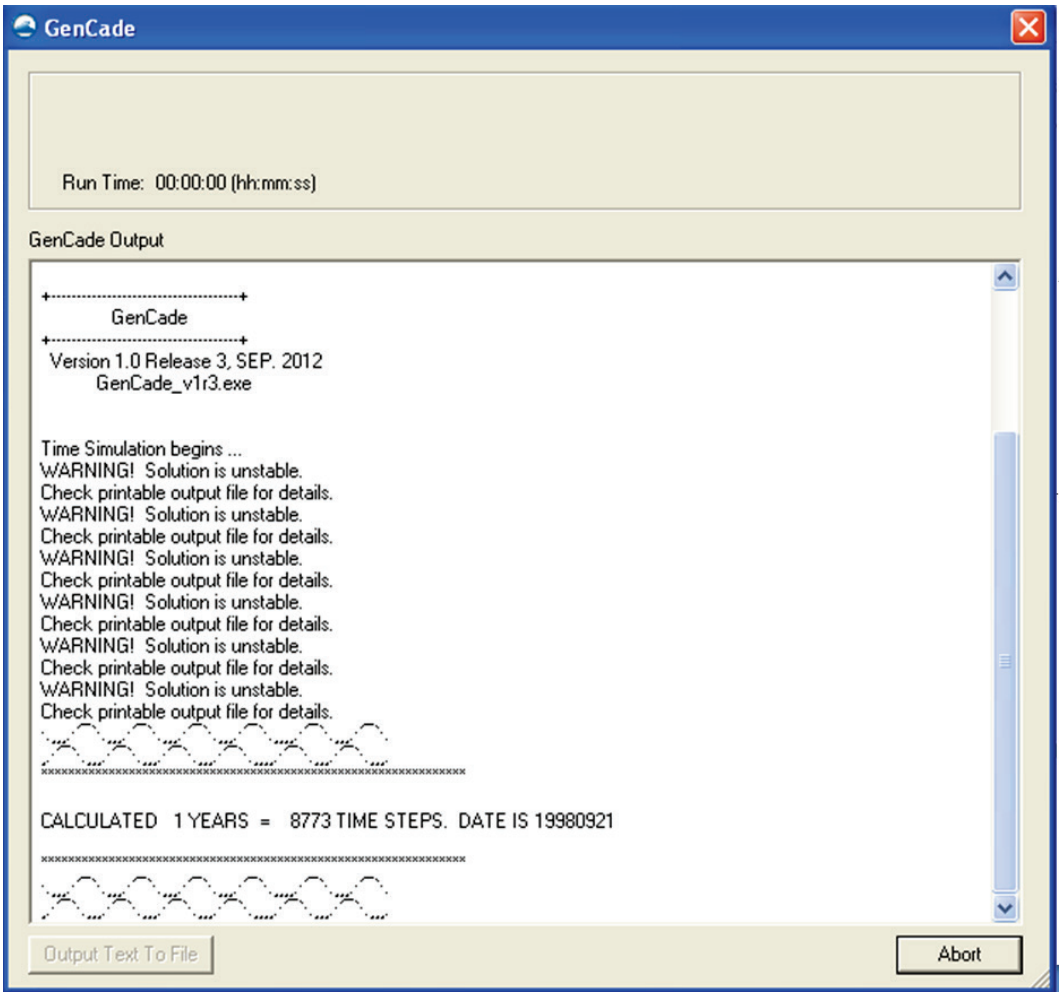
$$R_s \leq 0.5 \tag{1}$$

where the dimensionless term R_s is known as the model stability parameter or the Courant-Friedrichs-Lewy number, which is frequently shortened to the Courant number. GenCade calculates the stability parameter for each cell at each time-step. When this inequality is satisfied (i.e., small R_s), the model is normally stable. However, when the stability parameter first exceeds 0.5, the solution will start to become unstable.

GenCade provides two warnings to the user when this occurs. The first notice is located in the GenCade output window during the simulation. Instead of notifying the user when each year of the simulation is finished, a message stating “WARNING! Solution is unstable. Check printable

output file for details" will pop up for each time-step where the stability parameter is greater than 0.5. Figure 68 shows several warnings in the first year of a simulation. In some cases, warnings may occur at only a few time-steps in the simulation while in other cases they may happen at nearly every time-step. If there are only a few warnings, it is likely the notifications are related to the specific wave inputs at those times. When there are instabilities at nearly every time-step, which could be in the hundreds or thousands, the problem is likely related to the time-step versus the cell size.

Figure 68. Example of GenCade model simulation with six stability warnings.



GenCade's second notification of stability parameter violations is added to the *.prt file. An example of the text in the *.prt file is shown in Figure 69. This section lists the value of the stability parameter the first time it exceeds 0.5. It also gives the first date when the instability occurred, along with the wave height (hz), the wave angle (zzdeg), and the wave period (t).

This warning in the *.prt file is located directly before the shoreline position for the year in which the instability occurred. The case that produced the warning shown in Figure 69 was run from 1997 to 2004. Instability first occurred in August 1998, which was during the second year of the simulation. Therefore, this warning is located directly before shoreline position after 2 yr. The user can also search for STABILITY PARAMETER in the *.prt file using the find tool in the text editor.

Figure 69. Stability parameter warning in the *.prt file.

```
 WARNING!  CALCULATION SCHEME UNSTABLE.
 STABILITY PARAMETER =  0.5281727
 PLEASE CONSULT YOUR MANUAL.
date is    19980826  wave date is    19980826 hours is   1200
hz is   4.000000     zzdeg is  -2.931732     t is   14.29000
```

4.4.2 Solutions for stability parameter issues

GenCade calculates the stability parameter for each grid cell at each time-step using the following equation:

$$R_s = \frac{(\varepsilon_1 + \varepsilon_2)\Delta t}{(\Delta x)^2} \quad (2)$$

where values of $R_s \leq 0.5$ indicate a stable solution.

The following discussion separates the right-hand side of Equation 2 into three parts. Δx is the alongshore length of the grid cell, Δt is the model time-step, and the quantity ($\varepsilon_1+\varepsilon_2$) is referred to as the model diffusivity. The following sub-sections discuss alternative ways to modify these values. These methods can be used separately or together to reduce the value of R_s with the overall goal of having Equation 1 satisfied at all grid cells for all time-steps.

4.4.2.1 Increase the size of the grid cells (Δx)

When the model is first set up, the size of the GenCade grid cells must be specified (see Section 4.2 for further discussion on cell size selection). The cell size specifies the shoreline resolution. At first glance, it may seem reasonable for the modeler to want all the detailed information possible, so the modeler may choose to have the grid cells spaced very close together.

Most of the time stability issues will arise when a model is first run. At that time GenCade may report a huge number of stability parameter violations. This indicates a mismatch between the model cell size and the model time-step. One way to address this issue is to increase the grid cell spacing. This may be acceptable because for most locations on most beaches, dramatic shoreline changes do not occur over short spatial distances. If this type of stability issue is occurring, the modeler should determine the largest possible grid cell spacing that will still produce satisfactory answers to the project questions and not exceed that value.

If increasing the current grid spacing will still provide an acceptable level of shoreline detail, this is usually the best and easiest way to reduce R_s. Since the cell length term is squared in Equation 2, it is seen that a small increase in the grid cell spacing may provide a dramatic improvement in model stability. As an added benefit, having fewer cells means fewer calculations to make, so the model has a faster total runtime.

During model setup, the modeler may recognize that detailed shoreline information is needed at specific locations on the grid, such as in the shadow of a detached breakwater or adjacent to a groin. Unlike most beach locations, here shoreline position is expected to change over short distance scales. If, however, the modeler does not need the small-scale grid spacing over the whole grid, the modeler may choose to employ a variable grid with the smallest cell sizes in the areas of most interest. When the variable grid is first used, new stability issues may arise. If they do and somewhat larger cell sizes on the variable grid are acceptable, this may solve the problem. However, increasing the cell size is not likely to be an acceptable solution, as the modeler just decreased the cell size at the location to address a specific need. It is likely that the only acceptable solution for this type of problem is to decrease the time-step.

4.4.2.2 Decrease the time-step (Δt)

Sufficiently decreasing the time-step is always a potential solution to solving a stability issue. However, this solution introduces the concern of increasing the model runtime, possibly dramatically. Because the cell length is squared in Equation 2, if a cell length is decreased by a factor of 10, the model time-step must be decreased by a factor of 100 to achieve the same stability factor as obtained previously. There is almost a 1:1 relationship between the decrease in a model's time-step and the increase in its total runtime. On occasion, a model may need to be run many times to examine many

alternatives or parameter permutations, and decreasing the model time-step can end up impacting the workflow and the entire project lifetime. However, many times the model runtime is brief enough and the number of runs is small enough that this issue is not a major concern.

Decreasing the time-step does have two positive benefits. First, this solution solves the stability issue cleanly in that it introduces no side effects that may degrade the model accuracy (assuming that the model time-step is not decreased to the point where it becomes of the same order as the wave period or less). This can be important if the only other available solutions do degrade the model accuracy. Second, it makes more information available about the beach behavior, but since the shoreline usually changes relatively slowly, this increased frequency of shoreline output information is usually of little use.

4.4.2.3 Decrease the diffusivity (ε_1+ε_2)

The two diffusivity terms in Equation 2 are defined as

$$\varepsilon_1 = \frac{2H_b^2 C_{gb} a_1}{\left(D_B + D_C\right)} \tag{3}$$

and

$$\varepsilon_2 = \frac{H_b^2 C_{gb} a_2 \sin\alpha_b}{\left(D_B + D_C\right)} \frac{\partial H_b}{\partial x} \tag{4}$$

where:

H_b = breaking wave height
C_{gb} = wave group velocity at breaking
a_1 and a_2 = dimensionless parameters defined by Frey et al. (2012a) (Equations 3 and 5, respectively, therein.)
α_b = breaking wave angle
(D_B+D_C) = vertical distance between the berm and depth of closure.

The parameters in these two terms are all geophysical values that characterize the study site as opposed to modeler-selectable quantities (like the time-step and cell length), thus they are not generally available for adjustment to help satisfy the stability criterion. Therefore, in most

cases, changing these values just to satisfy Equation 1 is not recommended as this will make the model less representative of the prototype, which in effect will degrade the results.

If the stability parameter is violated only during a large storm event, this is likely being caused by the large wave heights in the two diffusivity terms. It may be possible to swap out the particular wave record (typically a year-long segment) for a different one having equivalent statistics but lacking the large wave event. If the violation occurs for highly oblique waves near structures, this may be caused by large values of ($sin\ \alpha_b$) in the ε_2 diffusivity term. If so, it may be possible to address the issue by increasing the value of ISMOOTH, as discussed in Section 4.5.

4.4.2.4 Summary

- The usual solution for dealing with stability violations is to decrease the time-step and/or increase the cell size until stability is achieved.
- If large numbers of stability violations occur at many grid locations and for many time-steps, this will usually be evident when the model is first run and will continue occurring for every model run. This indicates a mismatch between the model time-step and cell length during model setup. First, try increasing the grid spacing. If adjusting the grid cell spacing to the largest reasonable size does not solve the issue, decrease the time-step.
- If stability issues occur when a variable grid is first used and they occur where the grid spacing is the smallest, decide if a larger cell size would still be acceptable at those locations. If not, decrease the time-step.
- If stability issues occur only during times of large storm events, occasional large waves are likely the problem. Try any of the following which are justifiable: increase the cell size; decrease the time-step; replace the wave time series with a different, but statistically equivalent, wave time series that does not include as-large storm events. As a last resort, consider modifying specific wave heights in the time-series or accepting the model results without changing the modeling conditions, with the understanding that either of these will decrease the solution accuracy.
- If stability issues occur at times and at locations where the waves approach the beach at large wave angles, consider all the solutions listed in the previous bulleted paragraph. Also, consider increasing ISMOOTH.

- If the stability parameter is exceeded only infrequently and only locally, the model will tend to smooth out the oscillatory stability perturbations during subsequent time-steps. While it is axiomatic that fewer (or no) violations of the stability limit will produce better agreement between the shoreline behavior in the model and prototype, there may be situations where the modeler is forced to consider that accepting a limited number of violations is the only viable alternative.

4.4.3 Understanding the stability parameter

Frey et al. (2012a) (Equation 1, therein) describe the fundamental relationship of a one-line model (i.e., how a gradient in the longshore transport rate changes the cross-shore position of the shoreline):

$$\frac{\partial y}{\partial t} + \frac{1}{\left(D_B + D_C\right)}\left(\frac{\partial Q}{\partial x} - q\right) = 0 \tag{5}$$

By inserting the transport relationship (Frey et al. 2012a (Equation 18, therein)) into Equation 5 and making two linearizing assumptions (i.e., that the breaking wave angle is small and that the gradient in the transport is small), Kraus and Harikai (1983) showed that Equation 5 can be approximated in the form of a 1D diffusion equation (Frey et al. 2012a (Equation 19, therein)):

$$\frac{\partial y}{\partial t} = \left(\varepsilon_1 + \varepsilon_2\right)\frac{\partial^2 y}{\partial x^2} \tag{6}$$

where ε_1 and ε_2 are diffusivity parameters defined in Equations 3 and 4 above.

They originate from the two terms in the transport relationship (Frey et al. 2012a (Equation 18, therein)). ε_1 comes from the CERC equation, and ε_2 from the longshore, wave-height gradient term. By examining the right-hand sides of Equations 3 and 4, it is seen that ε_1 and ε_2 have dimensions of diffusivity (length^2/time).

Equation 2 is obtained by expressing Equation 6 in its finite difference form. Equation 2 can be thought of as describing the way that information propagates (or diffuses) along the GenCade grid where time and distance are expressed in terms of time-steps and cell lengths. A fundamental

constraint of this type of model is that information cannot be allowed to propagate too far before the calculation values need to be updated. The limiting condition of Equation 1 can be thought a way of keeping the solution from propagating (diffusing) too far during a given time-step or as propagating (diffusing) for too long a time for a given cell length.

When a violation occurs, perturbations arise in the solution which alternate in sign between grid cells. If the violation continues for additional time-steps, the perturbations grow until they dwarf the shoreline signal and eventually may cause the program to crash. The calculated value of R_s is an indication of how unstable the system is (the larger the value, the more unstable) and how rapidly the instabilities will grow. Note, however, that the R_s value provided in the *.prt file is the value of the first violation occurring in a given year, not the maximum value.

If stability returns after a limited number of time-steps, the perturbations will start to damp out. However, please note that in this case, the model may provide what may appear to be a reasonable solution, but it will not be the same solution that would have occurred without the violations. The modeler should expect that any model results that follow a model stability violation will be less accurate than if the violation had not occurred. For a further discussion of the Courant number, see pages 82–84 of Hanson and Kraus (1989) or Courant et al. (1967).

4.5 ISMOOTH

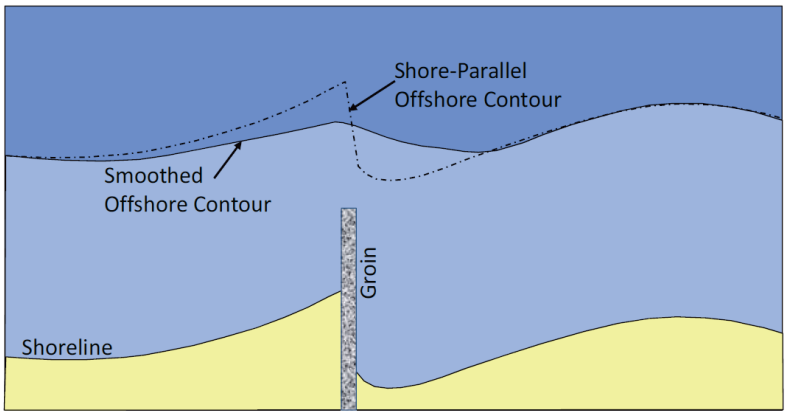
4.5.1 Number of cells in the offshore contour smoothing window (ISMOOTH)

An important GenCade calibration parameter is the ISMOOTH value. The ISMOOTH value represents the number of cells used in the smoothing window of the offshore contour. The smoothing algorithm used is a simple moving average performed in alternating direction. The ISMOOTH value is defined by going in the *GenCade Menu -> Model Control* under the *Seaward BC* tab. The model will accept a single value that will be applied to the entire grid. The default value is 11 cells. By definition, the ISMOOTH value must be an odd number. If an even number is entered in the *Model Control* window, one will automatically be subtracted from the ISMOOTH value before calculation.

4.5.2 Definition of ISMOOTH

The offshore contour provides the orientation of the bottom contour for the calculation of the wave transformation by the internal wave model. One of the basic assumptions of GenCade is that the offshore contour prior to smoothing moves parallel to the shoreline (profile moves parallel to itself). The shape of the representative offshore contour is recalculated continuously at each time-step using the shoreline position. Because the shoreline orientation can sometimes change abruptly, such as near a structure for example, GenCade uses a smoothed version of the offshore contour in performing the internal wave transformation (Figure 70). By smoothing the offshore contour, two potential issues are averted: (1) instabilities produced by having a large angle between the incoming wave direction and bottom contour and (2) the unrealistic transport produced by the large variation in offshore contour position.

Figure 70. Example of smoothed offshore contour.



The ISMOOTH value regulates the smoothness or the amount of detail of the offshore contour. An ISMOOTH value of 1 would result in an offshore contour that would be identical to the shoreline. When ISMOOTH is equal to *NX*, where *NX* is the number of cells in the grid, the resulting offshore contour is a straight contour line parallel to the *x*-axis. ISMOOTH is a parameter that may be adjusted in the calibration process.

4.5.3 Determination of optimal ISMOOTH value

The value of ISMOOTH should be set to be large enough so that local shoreline variations (e.g., adjacent to structures) are not reflected back on the shape of the offshore contour. Similarly to the regional contour, the offshore contour should only reflect the main features of the shoreline. A

first guess at this ISMOOTH value could be about 2–3 times the length of a detached breakwater (if present) or 2–3 times the distance between groins in a groin system. Therefore, if there are 15 cells between 2 groins, ISMOOTH should be at least 31. The precise value needs to be determined through sensitivity analysis such as the one shown in Figure 71.

In the example, a groin field was placed over a straight initial shoreline. The groins protrude 30 m (98 ft) seaward and are 250 m (820 ft) apart. The grid is made of 300 cells of 25 m (82 ft) in size. There are 10 cells between the groins. The simulation was run for 5 yr with a constant wave forcing of H_s = 0.75 m; T_p = 8 sec; Dir = 30°. The simulation was reproduced four times with different ISMOOTH values. At the end of the simulation the final shoreline was plotted (in red) along with the corresponding offshore contour (in blue). The offshore contour can be viewed in SMS by dragging the *.off file into the workspace or by opening the *.off in the SMS by selecting *File->Open*. Figure 71a) has a defined ISMOOTH value of five cells which is smaller than the recommendation of twice the number of cells between groins and resulted in unrealistic final shorelines. The shorelines show accretion beyond the groin tip that is induced by the large variation in the offshore contour. This feedback between the offshore contour and shoreline will eventually continue to exaggerate the shoreline change and lead to instabilities. Figure 71b) and c) show the result obtained with ISMOOTH = 21, or twice the number of cells between the groins, and ISMOOTH = 41, or four times the spacing. The offshore contour reflects the impact of the entire groin system but not the individual structures, which is the desired scenario. Figure 71d) shows the results obtained with a large ISMOOTH value (101 cells). The impact of the groin system is not reflected on the offshore contour which means ISMOOTH is too large. The correct ISMOOTH value would be between 21 and 41 and would have to be calibrated, *along with the K2 parameter*, against field data.

When the shoreline is relatively flat and there are no structures present, the effects of ISMOOTH on the calculated shoreline are reduced, but calibration is still needed. Figure 72 shows an example of a GenCade project that does not have hard structures beside the groin for gated boundary condition on the far left. The shoreline is slightly curved but generally smooth. The only shoreline protrusions that are sometimes present are near the inlet where the attachment bars connect to the shoreline.

Figure 71. Test case of a groin field under constant wave forcing: a) ISMOOTH = 5; b) ISMOOTH = 21; c) ISMOOTH = 41; d) ISMOOTH = 101.

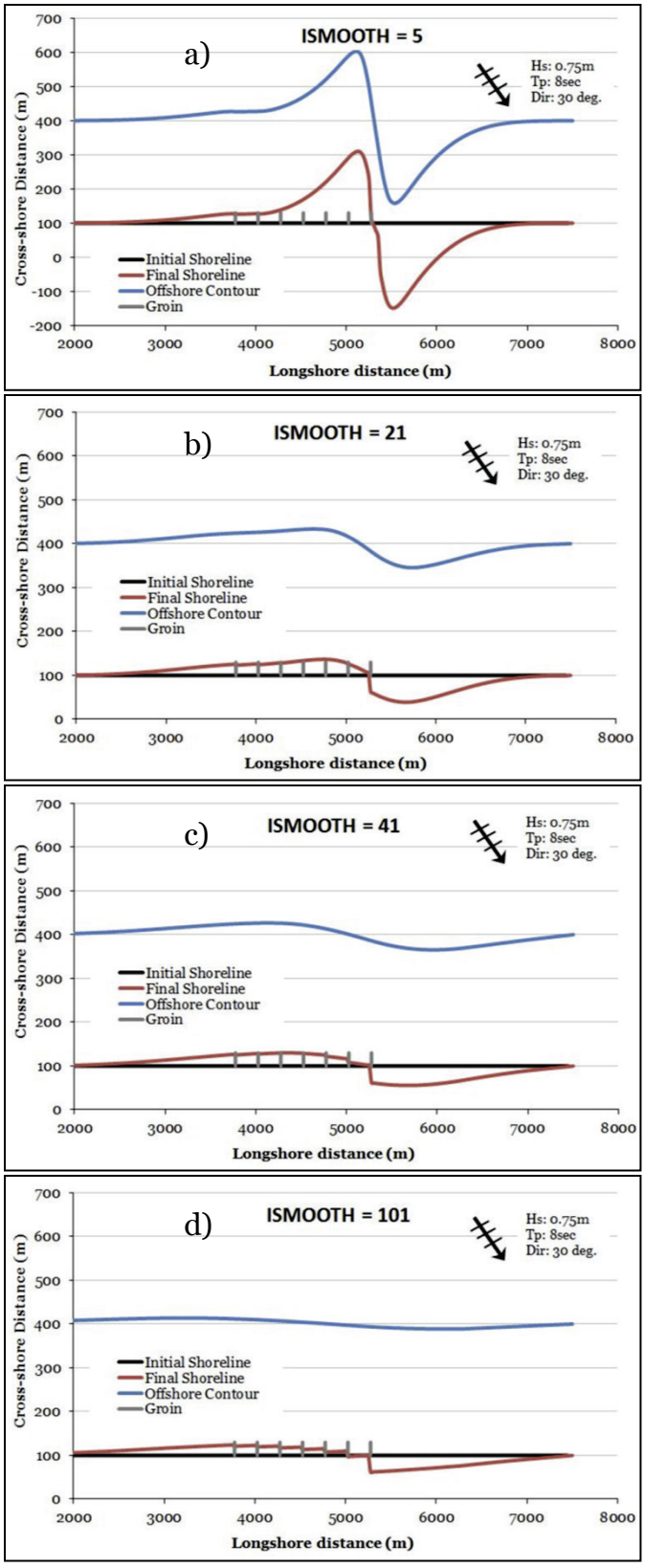
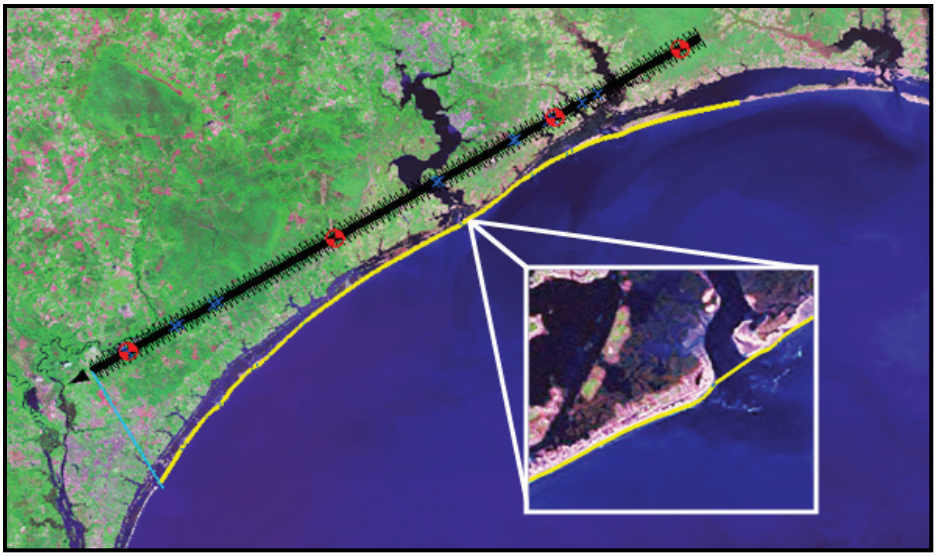
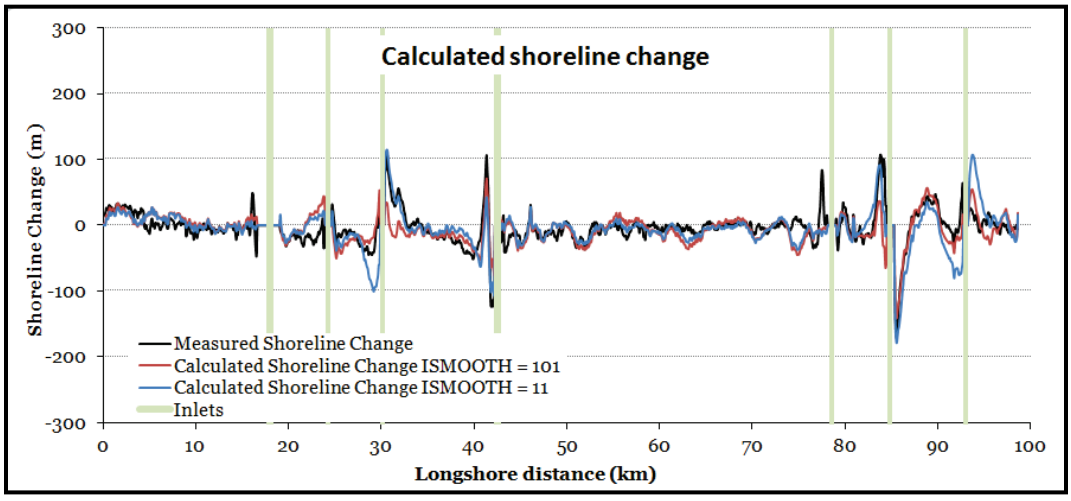


Figure 72. GenCade project without structures: the ~62.1-mile-long grid in black; the initial shoreline in yellow. The insert shows shoreline protrusion near an inlet.



The grid is 62.1 miles long, and the cells are 300ft wide. The simulations were run for a period of 7 yr using 4 wave gauges with 2 different ISMOOTH values: 11 and 101. The wave forcing was extracted from a 20 yr hindcast model. Figure 73 shows the shoreline change calculated for each simulation compared with the measured shoreline change. Between inlets, the calculated shoreline change is similar for the two simulations. However, near the inlets where protrusions of the initial shoreline were present, the shoreline change calculated with ISMOOTH = 11 (in blue) is larger than the one calculated with ISMOOTH = 101. For this particular application, a large ISMOOTH value was found to produce better agreement with observed data.

Figure 73. Measured shoreline change (in black) and shoreline change calculated with ISMOOTH = 11 (in blue); ISMOOTH = 101 (in red).



4.5.4 Other considerations

Sometimes the area to model is large and includes sections with smooth shorelines and others with a groin field. Since only one ISMOOTH value can be used for the entire grid, it is impossible to select a value that would satisfy all aspects of the domain. It is up to the user to determine which area of the grid is the most sensitive to the ISMOOTH value and use that area for calibration.

Variation in grid spacing will affect the smoothing level of the offshore contour. In the present GenCade version (V1), the smoothing algorithm only considers the number of cells specified in the smoothing window without taking into account the width of the cells included. Therefore, the smoothing will be less in the area where the grid size is smaller and larger in the area with the grid size is wider.

In addition, the ISMOOTH parameter can be a tool to improve the stability of the model. If the solution of a GenCade run is still unstable after using the methods provided in Section 4.4, the user may try increasing the ISMOOTH value, especially if the project includes many structures. However, time-step reduction should be the primary tactic for reducing or eliminating instabilities.

4.6 Regional contour

Pages 35–37 of Frey et al. (2012a) provide a good introductory discussion of the regional contour, which the reader may wish to review before continuing with this text.

4.6.1 What is a regional contour?

The regional contour is one of the many adjustment tools within GenCade that allows the model to more realistically represent the behavior of the prototype. Many shorelines are not straight and maintain typically arcuate shapes that are stable for hundreds of years. The use of a regional contour allows the modeler to specify the underlying shoreline shape that the model will evolve towards, rather than having the model evolve toward a straight line. The regional contour should not be thought of as a shoreline, even though it is frequently derived from one. Rather, it should be thought of as the fundamental planform shape of the coastline. It is the result of all the large-scale, alongshore forcing-function inhomogeneities and

underlying geology that are not accounted for in GenCade and that, in combination, cause the real-world shoreline to attain a non-straight, long-term equilibrium planform shape.

During a model run, if a regional contour is used, GenCade applies it at each grid cell to convert the shoreline into an *effective shoreline* which is the difference between the local regional contour orientation and the local shoreline orientation. The wave angle in the transport relationship is then calculated as the difference between the breaking wave angle and this effective shoreline angle. The effect of the regional contour is removed from the effective shoreline to create a final shoreline before it is reported to the modeler. This procedure is discussed in more detail in Larson et al. (2003) and Larson et al. (2006).

The regional contour is the shape that GenCade's output shoreline would approach if there were no shoreline obstacles (e.g., structures, inlets, sources/sinks), if all cells experienced the same wave conditions, if the lateral boundary conditions were pinned, and if the model were operated for a sufficiently long period of time. If no regional contour is specified, the model operates as though a default regional contour, which is a straight line between the two end point positions, has been applied.

This is seen in Figure 74. Each panel in this figure shows the results of a 25 yr GenCade simulation with H_s = 0.75 m, T_p = 8 sec, Dir = 15°. Each of these panels shows the same initial concave (green) shoreline that ranges between 200 and 1200 ft seaward of the GenCade grid line. (The offshore direction in each is *up*.) In Figure 74, the left-hand panels show GenCade results with no regional contour applied, while the corresponding right-hand panels show the same results when a regional contour (shown as a dashed black line) is applied. Note that there is approximately a 20:1 vertical exaggeration in the cross-shore to alongshore aspect ratios of these panels.

Figure 74A shows the changes in a simple curved shoreline with no structures when a regional contour is not used. The shoreline rapidly evolves toward a straight line. Figure 74B shows the modeling results for the same setup except that the shoreline has been used as a regional contour. In this case, the angle between the *effective* shoreline and the breaking wave angle is constant along the grid. So the amount of sediment transported into each cell is the same as the amount transported out, which means the shoreline is in equilibrium, and thus stationary. In Figure 74B, the initial, the 1, 2, 5, and 10 yr, shorelines are all underneath the red 25 yr shoreline.

Figure 74. Idealized GenCade results for a smooth concave shoreline for a 25 yr model run: A) without a regional contour and B) with a regional contour; C) with two groins without a regional contour and D) with two groins and with a regional contour. The regional contour is shown in dashed black.

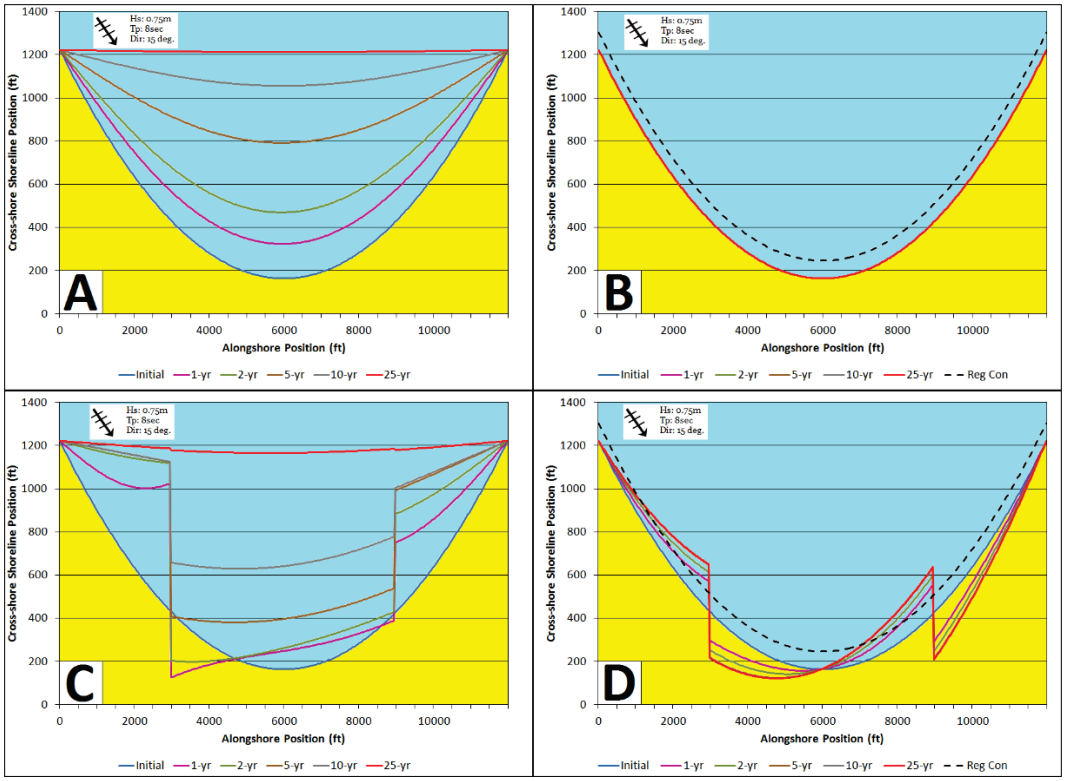


Figure 74C and Figure 74D have the same setup as Figure 74A and Figure 74B, respectively, except that a pair of groins has been constructed on the shoreline at year zero in Figure 74C and Figure 74D. Figure 74C again shows an overall rapid movement toward a straight shoreline; however, in this case, the complicating impacts of the groins are easily seen superimposed on the overall straightening. In Figure 74D, the shoreline would still be in equilibrium if not for the shoreline response of the groins.

4.6.2 When should a regional contour be used?

An appropriate regional contour should be used whenever its inclusion leads to a better calibration and ultimately provides better answers to the study questions.

Figure 75 is a picture of the shoreline around Ponce de Leon Inlet south of Daytona Beach in northeast Florida. This figure extends for approximately 19 miles in the north-south direction. The shoreline along this section of the Florida coast is approximately straight for long distances. The closest

perturbations are Matanzas Inlet, approximately 45 miles to the north of Ponce de Leon Inlet, and Cape Canaveral, approximately 40 miles to the south. For some applications, it would be completely appropriate to model this section of shoreline without using a regional contour.

Figure 75. Shoreline around Ponce de Leon Inlet near Daytona Beach on the northeast coast of Florida.

However, close inspection shows that the shoreline curves seaward for about 2.5 miles on both sides of Ponce de Leon Inlet. The maximum change in the shoreline azimuth adjacent to both sides of the inlet is approximately 10° to 12°, and the shorelines adjacent to both sides of the inlet protrude approximately 0.65 miles seaward of the straight shoreline. This inlet has existed for at least hundreds of years, as the oldest Spanish maps of the region from the 1600s indicate its presence. Long-established, stable, isolated inlets are known to slowly prograde their adjacent shorelines seaward and remain stable despite the potential for realignment from the shoreline straightening effects of the regional wave climate. If the purposes of a study were to address shoreline questions in the immediate vicinity of Ponce de Leon Inlet, it is reasonable to assume that the inclusion of a regional contour in the GenCade model would improve both the calibration and the quality of the results.

For study site shorelines with a more pronounced curvature, the benefits of including a regional contour should be obvious (see the example project discussed in Section 4.6.5). Additional potential benefits can include the

use of fewer grids to represent segments of a complex study site containing varied shoreline orientations. This saves research time as the time needed to create the regional contours is usually substantially less than the time needed for several additional model applications. Fewer grids provide the added benefit of fewer grid boundaries with the resultant discontinuities in transport rates.

4.6.3 How is the shape of a regional contour generated?

There are a few procedural points to be recognized when a modeler is setting up a regional contour. First, a regional contour must be specified as a cross-shore position at each cell on the GenCade grid, in the same way that a shoreline is specified. Second, the overall cross-shore position of the regional contour is immaterial. That is, the addition of any constant offset to each point on the regional contour will not change the contour's effect. For example, shifting the entire dashed blue line in Figure 74B and Figure 74D by any constant amount landward or seaward will not affect the model output as long as all the points are seaward of the grid. What is important for the regional contour is its curvature. Additionally, the modeler should recognize that there is no one *correct* way to generate a regional contour. As with other aspects of setting up a GenCade model, no two modelers, working independently, would likely produce exactly the same regional contour, but significant similarities should be expected. The following procedure is intended as a suggested guideline.

4.6.3.1 Initial shoreline entry into GenCade

The first step is to locate all available historical shorelines that cover the study area. Since depth contours that extend alongshore to span the study area can be used interchangeably with shorelines to generate a regional contour, references to shorelines in this discussion are generally meant to also include bathymetric contour lines. These underwater contours can be at any depth but usually are not deeper than the seaward edge of the surf-zone. In the same way that some shorelines are less desirable for use in generating a regional contour, such as those that include manmade shoreline perturbations such as groins, surfzone contours with these same types of small scale features (e.g., groins, detached breakwaters, exposed rock outcrops) should be avoided, if possible. In some cases, a good source of a regional contour may be an old historical shoreline that may show the regional shape prior to opening or stabilization of inlets. Many times,

though, these historical pre-engineered states do not exist in the data record.

A regional contour will frequently be derived from a single shoreline, but even for this case, it is important to make a well-considered selection. The process of assembling shorelines and entering them into SMS is usually conducted in conjunction with or as an extension to entering shorelines for use as initial and final model shorelines. However, it is not appropriate to use either the initial or final observed shoreline as the regional contour.

Shorelines that cover the project area may be available as previously-processed ASCII (x,y) point files or as Environmental Systems Research Institute (ESRI) shape files. These will most likely be datasets derived from other primary sources. It is important that these datasets include the appropriate metadata (e.g., date of the data collection; how the data were converted to a shoreline and by whom; whether the shoreline represents a MSL contour, a wet/dry line, a wrack line, a vegetation line). It may likely also be useful or necessary for the modeler to derive shorelines from various types of sources, including coastal maps, aerial/satellite imagery, surveyed shorelines, sets of beach profiles, and lidar data or bathymetric data. However derived, it is important to obtain shorelines from as many different dates as possible, including historical shorelines extending back in time as far as high quality data exist. These data will normally be entered into the SMS where useful tools are available to assist the modeler in deriving and manipulating shorelines (see Frey et al. (2012a) for more details on this topic).

4.6.3.2 Shoreline evolution and identification of the curvature features in the regional contour

Once in SMS, the modeler should overlay all shorelines and contours to make sure that all are in the same coordinate system and then evaluate the available lines. The modeler should strive to identify the large-scale underlying patterns and shapes that are common to the different shorelines and persistent in time. Small-scale but persistent shoreline perturbations are usually unimportant as GenCade modeling will likely be able to address these (e.g., the shoreline changes adjacent to both sides of a groin). The modeler should identify lines that have anomalous shapes and try to identify the causes (e.g., a post-storm shoreline, a shoreline from a different season than the rest) which would justify their exclusion. Following a full examination of the shorelines, some modelers find it

helpful to make a freehand sketch (from memory) representing their expectations of the shape of the regional contour along the entire grid. This is usually helpful in guiding the modeler through the next steps of this process.

4.6.3.3 Initial regional contour generation

At this point, the modeler must select a single shoreline or a group of lines based upon how well each represents the fundamental planform shape. The shorelines must cover the length of the GenCade grid. In order to maintain the large-scale patterns in the lines without the small scale irregularity, different types of techniques for filtering or pattern extraction may be employed, including moving-average methods or any type of low-pass filter. The simplest procedure would be to select a shoreline that features the fundamental planform shape and use the smoothing function present in the SMS. Finding the right smoothing or averaging function is a process of trial and error. The mechanics of this step are described in Section 4.6.3.5.

Averaging several shorelines together may produce a better regional contour, but this requires extra steps. The averaging is normally done outside of SMS, so the shorelines must first be exported, then averaged. The averaging may be a simple average or a weighted average, where the *better* shorelines are included multiple times in the averaging. In order for the combined shoreline to fall on top of the aerial-photo shoreline in the SMS (this is not mandatory, but useful), the modeler may need to shift the entire line landward or seaward by a constant amount, which is particularly true if the combined line contains surfzone contours. The line must be moved landward or seaward with respect to the grid x-axis so that the shoreline position of each grid cell is moved a constant distance nearer or further away from the grid x-axis. Various types of smoothing can then be applied to the combined line before or after it is re-imported into the SMS.

4.6.3.4 Final inspection and allowable final adjustments

The user should then carefully inspect the regional contour by overlaying it on aerial or satellite imagery together with the initial shoreline. The regional contour should reflect the general permanent large-scale curvature in the shoreline but not the small-scale or ephemeral irregularities. The shoreline change will be particularly large when the angle between the contour and the initial shoreline is large, which tends to happen near the mouths of

inlets. To address this issue, the first step is to make sure the initial shoreline does not dip into the inlet mouth but rather goes straight across the inlet (Frey et al. 2012a (p. 116, therein)). If the smoothing function has removed some of the smaller permanent features such as the inlet bulge shown in the Ponce de Leon Inlet example (Figure 75), the user can either adjust the existing regional contour at that location or recreate the regional contour with less smoothing. Making those modifications will reduce the angle between the contour and the shoreline. Sometimes in areas where the shoreline changes abruptly in orientation (see example in Section 4.5.4), the bulk smoothing operation might produce unrealistic shoreline shapes. In certain isolated cases, the user may be required to manually adjust certain cells on the contour so that it follows the permanent shoreline shape. This manual manipulation of the regional contour is discouraged and should only be done sparingly and for a limited number of cells.

Once a satisfactory candidate regional contour is chosen, very few other adjustments to the regional contour are permissible. It is not appropriate to make arbitrary freehand adjustments to the regional contour in an attempt to obtain better agreement during model calibration. Because the regional contour will drive the model shoreline results toward the shape of the contour, and the modeler has the ability to specify the regional contour shape, this tool provides the modeler with a great deal of power. Through misuse of the regional contour, it would be easy to force the model to produce nearly any desired output. Therefore, strict limits are placed on its adjustment. The regional contour should be fundamentally derived from the information contained in measured shorelines.

Once an acceptable regional contour has been derived and has been applied during model calibration, only two types of additional manipulations are allowed. The first is to decide to not use the regional contour at all. The second is to only make adjustments to the contour that make it more closely approach a straight line (i.e., that decrease the curvature). That is, the difference in offshore distance between any two adjacent cells may be decreased but not increased. Note that a change in the offshore distance of cell $i+1$ to make it more closely agree with cell i may also cause the difference between cell $i+1$ and cell $i+2$ to increase. In that case, cell $i+2$ must also be adjusted, and this ripple effect adjustment requirement may continue to some distance along the grid.

4.6.3.5 GenCade specific procedure guidance

It is difficult to provide explicit GenCade guidance for the generation of a regional contour because both the study sites and the forms of the available data can vary so widely. However, in this section, an attempt is made to provide step-by-step GenCade instructions for some of the specific procedures just described.

1. Import data into the SMS: Each shoreline should be imported in a separate coverage. To produce a *New coverage*, right-click on *Map Data*. When the data are dragged into the workspace, it will be placed in the coverage that is active. If the data are in the same coordinate system as the workspace (set under the *Display* menu), they should overlay correctly over the imagery or other data already input. Otherwise, right-click on the *coverage* and specify the projection that the data are in under *Projection (floating)*.
2. Acceptable formats: Almost any format can be entered in the SMS as long as the metadata is known (projection, datum, and units). If the SMS recognizes the data format, it will automatically be formatted in the workspace. If the format is unknown, the *Import Data Wizard* window will appear and guide the user through the process.
    a. *.cst file: The shoreline format for GenCade is the *.cst file which is an ASCII file containing a list of *x-y* coordinates representing the shoreline. The *.cst file differs from an *x-y* scatter set since the order in which the *x-y* points appear in the file is important (Frey et al. (2012a) (pp. 112-114, therein)). The *.cst file can be dragged into the workspace without further modifications.
    b. Polyline shapefile: After the polyline shapefile is selected, it is necessary to go to *Mapping->Shapes->Feature Objects* to convert the shapefile into the proper format for GenCade. The arcs need to be connected after converting to *Feature Objects,* which is described in page 114 of Frey et al. (2012a).
    c. CAD file: After the CAD file (*.dwg or *.dxf) is opened in the SMS, the layers that are not relevant should be turned off. It is necessary to right-click on the CAD drawing layer and select *Convert->CAD->Map*. When the new Map coverage appears, right-click and change to a GenCade map coverage. Finally, the relevant features can be selected and assigned as GenCade attributes.

d. Scatter set: A depth contour or shoreline can be extracted from a beach survey (series of cross-shore elevation measurements) or bathymetric survey scatter set. Drag the data into a coverage or use the SMS import wizard to create a scatter set. If the data are in a shapefile, the points must be selected and converted to *Feature Objects* from the *Mapping* menu and then again to a *scatter* from the *Feature Objects* menu making sure the column containing the elevation is correctly identified. When the data are in a scatter set, extract the desired depth contour by going to *Data-> Scatter Contour -> Feature*.

3. Pre-processed shoreline: To be read by GenCade, the shoreline (either initial or as a regional contour) must be a single continuous arc. The shoreline must be created in such way that it does not wrap around itself and only one shoreline position is possible at each point on the 1D grid. Inlet mouths must be closed and smoothed. Any necessary modifications can be made with the S*elect feature Arc/Vertex/Point* tool. Frey et al. (2012a) provides more details to produce a shoreline.
4. Produce regional contour: Select the shoreline to be used as a base for the regional contour.
    a. Smoothing function: It is first necessary to duplicate the original shoreline into a new coverage. Right-click on the coverage containing the shoreline and select *Duplicate*. This operation is necessary since there is no undo button in the SMS, and the original shoreline will be overwritten if the user makes any modifications to it. To smooth the shoreline, right-click on the shoreline using the *Select Feature Arc* tool and select the *Smooth Arc(s)* menu. Adjusting the *Number of neighbors* and *Self Weight* will produce different levels of smoothness. Unwanted coverages can be deleted by right-clicking the coverage and selecting *Delete*.
    b. Export to ASCII file: Convert the coverage to a scatter set: *Feature Objects -> Map -> Scatter*. Make sure the *Arc end points and vertex elevations* radio button is selected. Select the points of the scatter set just created and go into the menu *File -> Save As…* and select *.txt file from the *Save as type:* drop-down menu then identify the columns as *x*-*y*-elevation.
5. Inspect contour: If the regional contour needs to be modified for the reason mentioned in Section 4.6.3.4, the *Select Feature Vertex* tool should be used to move an individual vertex.

6. Define coverage and attribute: Once the contour is ready to be used in GenCade, define the *coverage* as GenCade (under *Type* when right-clicking on the *coverage*). Then define the attribute of the contour arc as *Regional Contour* by right-clicking on the shoreline with the *Select Feature Arc* tool.
7. Save map files: At this point, the user should have two coverages: one with the initial shoreline and one with the regional contour. It is recommended to save the individual coverage as a *.map file for easy access later if needed. Highlight the coverage to save and go under *File->Save Map*. Map files can then be loaded by dragging them into a SMS workspace. The user can also save the entire workspace (*.sms).

4.6.4 Example

The Onslow Bay project described as follows proved to be a difficult area for GenCade modeling mainly because of the pronounced curvature of the shoreline. It provides a good example of the successful benefits of a regional contour.

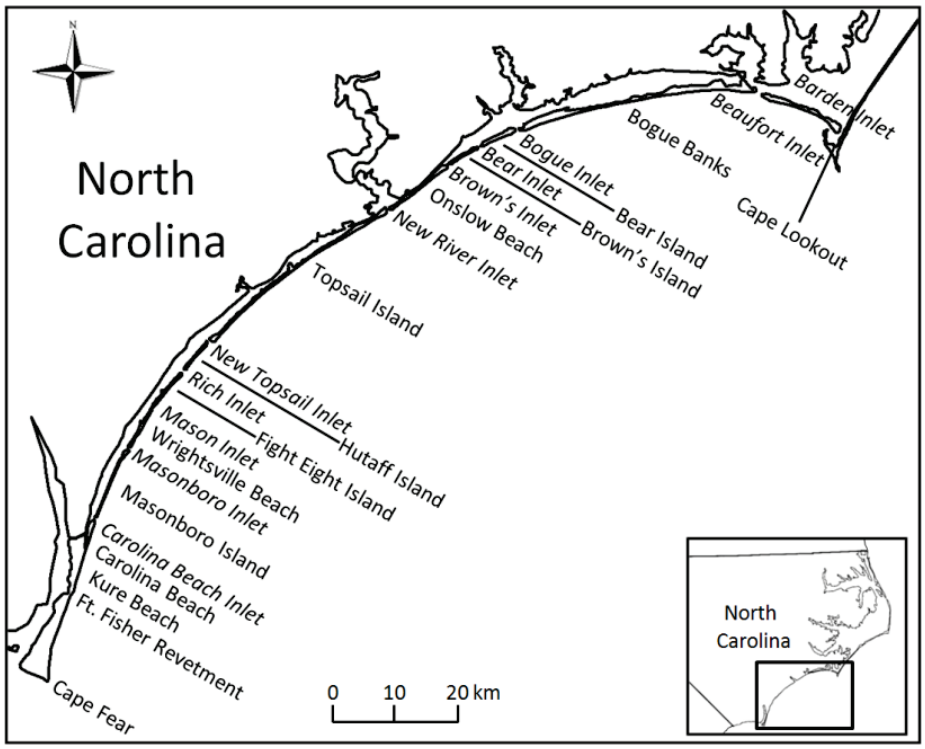
4.6.4.1 Background

Onslow Bay is a crescentic series of barrier islands covering approximately 185 km (115 miles) of beaches between Cape Lookout and Cape Fear in North Carolina (Figure 76). The narrow barrier islands forming the bay are separated by 11 inlets, most of which are unstructured, migrating, and classified as transitional, mixed-energy inlets (Cleary and Marden 2004). While some of the barrier islands are uninhabited, others are developed and have seen increased urbanization since the 1950s. On these islands, the combination of chronic erosion in many locations and the disruption of sediment pathways have threatened buildings and structures. To the north of Brown's Inlet, barrier islands are relatively stable, sand rich, and formerly regressive while sand-poor, eroding, and transgressive barriers are located to the south (Riggs et al. 1995; Cleary and Hosier 1987). This project was therefore undertaken to improve the understanding of the regional sediment transport magnitude and direction as well as the cumulative effect of the engineering activities on the shoreline.

The northern portion of Onslow Bay is partially sheltered from waves coming from the northeast (the predominant open-ocean wave direction) by Cape Lookout while the southern portion of the bay is sheltered from infrequent southwest swells by Cape Fear. The other prominent feature of

the shoreline is the seaward bulge in the New River Inlet area. The protrusion is due to the presence of a submarine headland in the shoreface (Riggs et al. 1996).

Figure 76. Onslow Bay, NC.



4.6.4.2 Selection of the regional contour base shoreline

The 1997 shoreline, used as the initial shoreline, was obtained from the U.S. Geological Survey (USGS) and consists of a mean high water (MHW) shoreline derived from a 1997 lidar survey. The 1997 shoreline required substantial pre-processing to combine various segments together, to make required modifications at inlet mouths, and to delete various unwanted bay shorelines (Figure 77 right).

To create the regional contour, shorelines from five different time periods were examined (1849–1873, 1925–1946, 1970–1988, 1997, and 2004) together with available aerial photographs. On a regional scale, all of the shorelines exhibited the same major features including the overall cresentic shoreline curvature between Cape Lookout and Cape Fear (approximately 90° change in azimuth orientation) and the protrusion at New River Inlet (Figure 77 left). The main differences between the shorelines occurred in the southern half of the study area and where the inlets are highly dynamic

(Figure 77 right). Over the time period covered by the shorelines, some inlets have migrated as much as 2 km (1.2 miles) (Mason Inlet), while others have opened or closed (Old Topsail; Carolina Beach). It was therefore decided to use the initial shoreline (1997) as a basis for the regional contour for two reasons. First, since all the shorelines showed the same major features, it was expected that any choice would provide at least reasonable results. Second, the migrating and closing inlets posed a potential problem associated with the use of the older shorelines. GenCade considers all inlets to be stable and permanent. It does not have the capability to account for inlet migration and closure at this time. Therefore, there was concern that the amount of smoothing necessary for some of the older shorelines to remove the traces of inlets that were no longer at the locations indicated would be excessive.

Figure 77. Historical shorelines at Onslow Bay (1849–1873, 1925–1946, 1925–1946, 1970–1988, 1997, 2004); left) regional view; right) showing migration of Rich Inlet and New Topsail Inlet (1849–1873 and 1997 over LandSat image from 2000).

4.6.4.3 Processing the regional contour

At the time the regional contour was produced, the smoothing capabilities in SMS were not implemented in the interface. The processing of the regional contour was accomplished in MATLAB. The 1997 shoreline was exported into an ASCII file readable by MATLAB. Once imported, the shoreline was resampled to generate equally spaced points. Then a Zero-phase forward and reverse digital filter was used (command filtfilt) with a number of smoothing window sizes (10, 20, 40, 100). The resulting

shorelines were compared. It was found that using a 10-point window size for the smoothing function (approximately 3 miles) eliminated the small irregularity but preserved the permanent shoreline features. Larger window size tended to excessively flatten the shoreline curvature near the inlets (Figure 78). The contour was carefully inspected, and a few changes were made to either remove protrusions found near inlet attachment bars or to realign the shoreline near the Masonboro south jetty (Figure 79).

Figure 78. Smoothing of the 1997 shoreline near Beaufort Inlet using 10 (in yellow) and 100 (in red) points in the smoothing window.

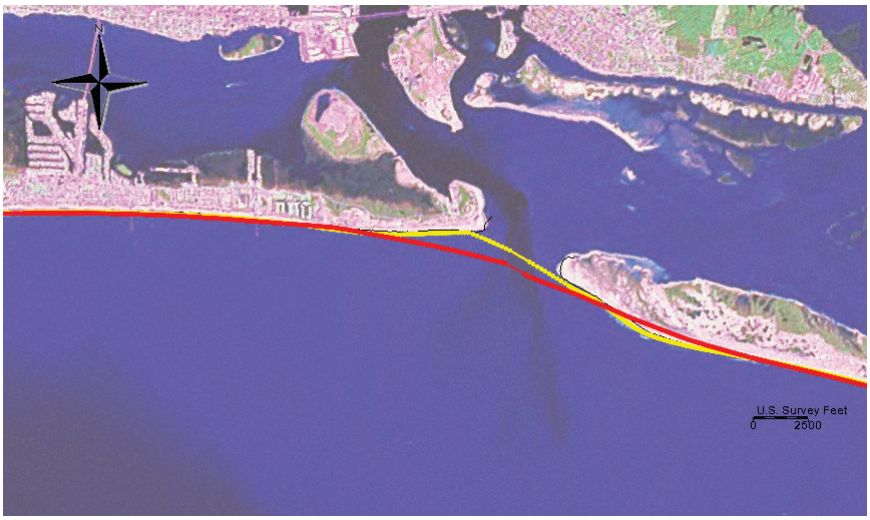
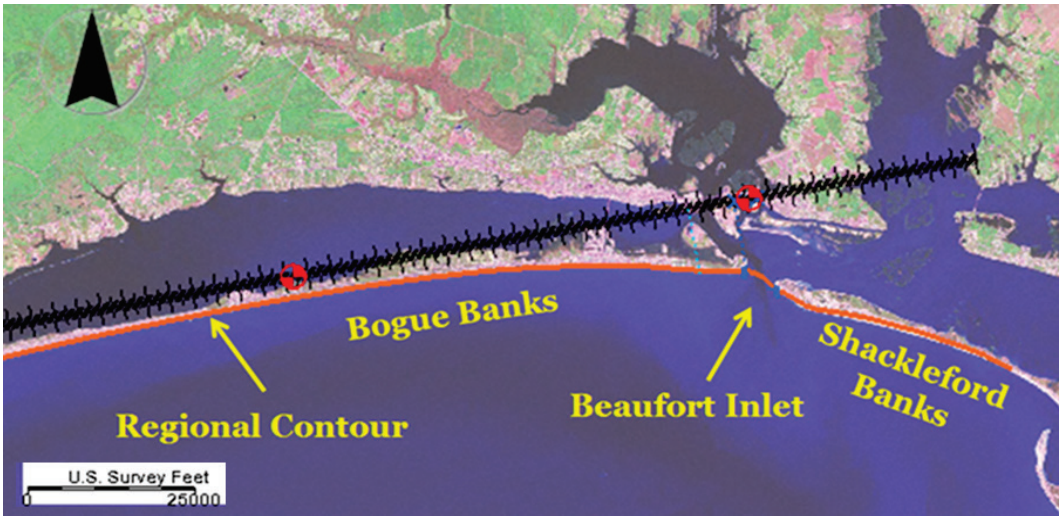


Figure 79. Final regional contour at Onslow Bay, NC.

4.6.4.4 *GenCade simulation with and without the regional contour at Beaufort Inlet*

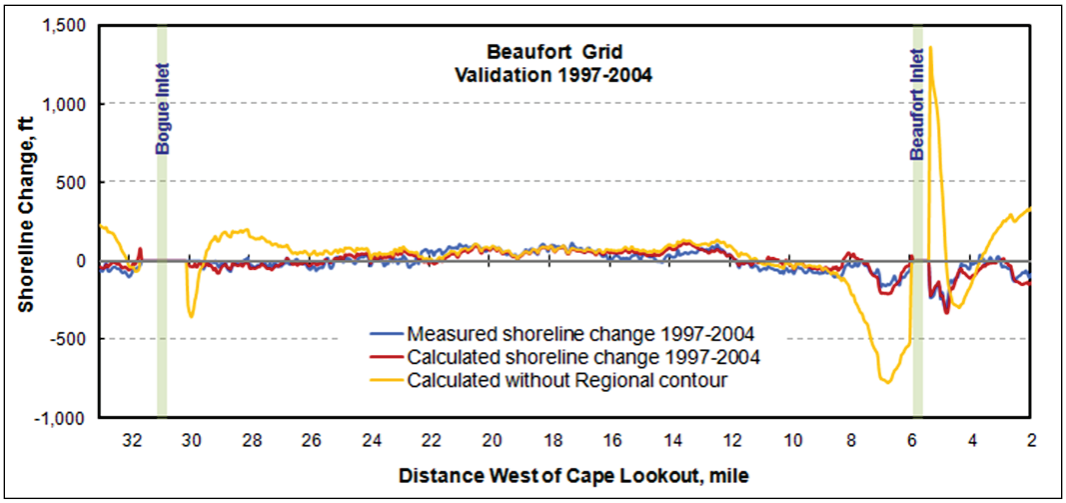
For study-site shorelines with pronounced curvature, the benefits of including a regional contour are obvious. Since the site is so large, the project was divided into three different segments having three different grid orientations. Beaufort Inlet, located in the northern portion of Onslow Bay (Figure 78; Figure 80), provides a good example of the usefulness of the regional contour. Beaufort Inlet is a federally maintained navigation channel and the main entrance to Morehead City Harbor. Almost 1 million yd^3 of material are annually dredged from Beaufort Inlet, and it is only stabilized by a small terminal groin built in the west side of the inlet. Average net transport on Bogue Banks (west side of Beaufort Inlet) is directed toward the inlet due to a local reversal, and transport on Shackleford Banks (east side of Beaufort Inlet) is also directed toward the inlet. This condition is created in part by the natural alignment of the barrier islands surrounding the inlet (Figure 80). It was essential that the model capture the shoreline shape to properly calculate the transport direction and magnitude.

Figure 80. Shoreline near Beaufort Inlet, showing regional contour (in red) and GenCade grid (in black).



A 7 yr simulation was conducted as part of the calibration process using the nearby WIS wave station as the main forcing (Frey et al. 2012b). The calibration results, shown in Figure 81, indicate a dramatically improved agreement when the regional contour is used. Without the regional contour, the shoreline change near Beaufort Inlet is unrealistically large (–800 to +1300 ft in 7 yr) (Figure 81). The same simulation with the regional contour turned on produced results similar to the observed shoreline change.

Figure 81. Calculated shoreline change with (red) and without (orange) the regional contour compared to the observed shoreline change (blue) for the same period.



4.7 Inlet Reservoir Model

4.7.1 Introduction

Stabilized and natural inlets can have substantial impacts on shoreline morphology for tens of miles from the inlet, particularly on the downdrift side (Bodge 1993; Fenster and Dolan 1996). In addition, natural and man-made inlet changes (e.g., inlet breaching and closure, channel realignment, jetty construction and modification, channel dredging, shoal mining) can have profound impacts on inlet bypassing and adjacent beaches. For both reasons, it is important to correctly represent inlets in the model. The GenCade model incorporates the Inlet Reservoir Model (IRM) (Kraus 2000; Larson et al. 2003 and 2006) to describe sediment storage and transfer at inlets. The method is described in detail in Frey et al. (2012a) and briefly summarized below.

The inlet is schematized into distinct geomorphic features: the shoal complex, the inlet channel, and the adjacent beaches. The shoal complex is further subdivided into six morphological units: the ebb shoal proper, the two bypassing bars, the two attachment bars, and the flood shoal. An initial sediment volume (V_x) and an equilibrium volume (V_{xq}), where the subscript x is a placeholder for subscripts a (attachment bars), b (bypass bars), e (ebb shoal), or f (flood shoal), are specified as inputs for each morphological unit. The IRM (Kraus 2000) assumes that the sediment passing through each unit is proportional to the ratio of the current volume to the equilibrium volume. If a shoal's volume reaches equilibrium, all subsequent arriving sediment is transferred or bypassed to the downdrift shoal in the chain as shown schematically in Figure 82.

Figure 82. Schematic of the interaction between the morphological elements at an inlet.

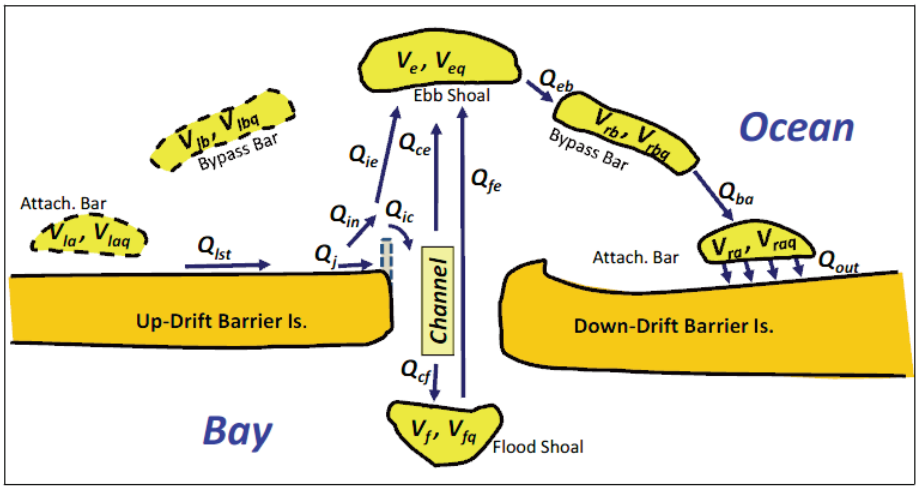


Figure 82 illustrates the complex sediment pathway modeled in GenCade. Sediment is transported toward the inlet along the updrift barrier island at a rate of Q_{lst}. Then, if a jetty is present, a portion of this sediment is trapped (Q_j) by the jetty, and the rest is transported into the inlet (Q_{in}). At this point, a portion of the sand goes to the ebb shoal (Q_{ie}) and the rest into the channel (Q_{ic}). The sediment transported into the channel (Q_{ic}) will supply sediment to the ebb shoal (Q_{ce}) and flood shoal (Q_{cf}) in proportion to their relative volumes. The channel only acts as a transfer point and does not store sand. Once the flood shoal reaches its equilibrium volume, the flood shoal stops growing, and all sand entering the inlet is directly transferred to the ebb shoal. From the ebb shoal, the material is transferred to the bypassing bar (Q_{eb}) and then further downdrift to the attachment bar (Q_{ba}). The bypassing rate from a unit to another is determined by ratio between the calculated volume at each time-step and the equilibrium volume. As the calculated volumes approach equilibrium volumes, more sediment is transferred to downdrift morphological units.

If the inlet system is at equilibrium (i.e., all morphologic elements are at full equilibrium capacity), the inlet system bypasses all the sediment out of the downdrift attachment bar (Q_{out}), which supplies downdrift beaches. If the inlet system is not at equilibrium, only a portion of the incoming transport rate (Q_{in}) will leave the inlet system as Q_{out} and be transported farther along the beach. Ninety percent of Q_{out} is distributed to grid cells identified as the downdrift attachment bar location (using a triangle distribution with the midpoint cell receiving the bulk of the sediment) and 10% of Q_{out} is distributed to grid cell immediately adjacent to the

downdrift side of the inlet. The time series of calculated volumes and bypassing rates for each morphological element can be viewed in the *.irv file. When the transport reverses direction and Q_{lst} is coming from the right side of Figure 82, then the right bypassing and attachment bars become inactive, and sand is transported to the ebb shoal proper and to the left bypassing and attachment bars.

In order to represent an inlet that does not have *any* impact on adjacent beaches, the inlet needs to fulfill *all* three conditions:

- no jetties on either side of the channel
- all morphological units completely full where the initial volume of the morphological elements is equal to the equilibrium volume
- Q_{out} on either side is released only to the first cell adjacent to the inlet.

Meeting these criteria ensures that 100% of the sediment entering the inlet system is bypassed out of the inlet system and distributed to the first grid cell downdrift of the inlet.

4.7.2 Analytical model

This section describes the basic way that GenCade passes sediment through an inlet. To simplify the mathematics, this discussion assumes that there are no inlet jetties, that the flood shoal is at equilibrium, and that the alongshore transport rate for material arriving at the inlet is constant in magnitude and direction. Referring to Figure 82, these assumptions allow the flood shoal and the left-hand bypassing and attachment bars to be ignored and the input to the ebb shoal to be constant (i.e., $Q_{lst} = Q_{in} = Q_{ie}$ = constant).

The IRM is so named because of the analogy with a series of stacked, leaky buckets (reservoirs) that receive water from the bucket above and pass water to the bucket below. The rate that each passes water to the next bucket in line is proportional to how full it is. Each bucket in the chain approaches fullness (equilibrium) asymptotically. At the start of this process, if all the buckets start out empty, none other than the uppermost one (which is fed at a constant rate) starts to fill rapidly, because initially each only passes a small percentage of the water it receives. Therefore, if all the buckets are of equal size, each approaches equilibrium at a slower rate than the one above. However, a complicating factor is that a small bucket

only needs a small amount of water to approach fullness and can end up doing so more rapidly than a large bucket that is above it in the chain.

The following discussion is based upon the IRM presentation in Kraus (2000). The fundamental relationship of the IRM is that the closer a shoal's volume is to its equilibrium value, the greater the fraction of arriving material that is passed to the next downstream shoal in the chain:

$$\frac{Q_{ox}(t)}{Q_{ix}(t)} = \frac{V_x(t)}{V_{xq}} \tag{7}$$

For volumes (V), the subscript x is a placeholder for subscripts a (attachment bar), b (bypass bar), or e (ebb shoal), and the subscript q represents an equilibrium volume. For volume transport rates (Q), the subscripts o and i represent transport out of and into a shoal, respectively. Alternately, Q_{eb}, Q_{ba}, and Q_{out} represent the transport rate from ebb to bypassing, from bypassing to attachment, and from attachment to the downdrift beach, respectively. Thus, for example, by definition: $Q_{oe} = Q_{eb} = Q_{ib}$.

The continuity equation (conservation of mass), which states that the difference in the rate of material entering and leaving a shoal is equivalent to the rate of change of the volume of the shoal, combined with Equation 7 yield the 1st order differential equation that governs the sediment behavior at each shoal:

$$\frac{dV_x(t)}{dt} = Q_{ix}\left(1 - \frac{V_x(t)}{V_{xq}}\right) \tag{8}$$

For a zero initial shoal volume, the normalized solution of Equation 8 describing shoal growth is

$$V_x(t) \Big/ V_{xq} = 1 - \exp[-\theta_x(t)] \tag{9}$$

where the form of the exponent (θ_x) is different at each shoal.

For the ebb shoal, θ_x is

$$\theta_e(t) = \frac{t}{T_{ebb}} \tag{10}$$

where T_{ebb} is the characteristic timescale for the ebb shoal:

$$T_{ebb} = \frac{V_{eq}}{Q_{in}} \tag{11}$$

T_{ebb} can be thought of as the amount of time that it would take the ebb shoal to grow from zero volume to equilibrium if no material left the ebb shoal, and it represents the fundamental timescale of the system. Note, however, that the volume of a shoal approaches equilibrium asymptotically, as, by Equation 7, the closer a shoal gets to equilibrium, the more material it bypasses. Thus, by Equations 9–11, for a zero initial shoal volume, the ebb shoal will be half full at 0.7 T_{ebb} and 95% full at 3.0 T_{ebb}.

Ebb-shoal equilibrium volumes are typically much larger than yearly longshore transport rates for most east-coast U.S. inlets. As an example, Kraus (2000) applied this model to Ocean City Inlet. He used 4×10^6 yd^3 for the ebb-shoal equilibrium volume and 2×10^5 yd^3/yr for the longshore transport rate, which are values derived from published field data. Thus, for this example, T_{ebb} = 20 yr. For Ocean City Inlet, which opened in August of 1933, a half-full ebb-shoal time of 14 yr (year 1947) and a 95% full time of 60 yr (year 1997) are in reasonable agreement with measured values.

For the bypassing and the attachment bars, the value of the exponent in Equation 9, θ_x, is more complex because sediment does not arrive at a constant rate (unless the upstream shoal is at equilibrium), and the ratio of equilibrium shoal sizes must also be considered. The expression for the bypassing bar exponent is

$$\theta_b(t) = \frac{\left[\frac{t}{T_{ebb}} - \frac{V_e(t)}{V_{eq}}\right]}{\frac{V_{bq}}{V_{eq}}} \tag{12}$$

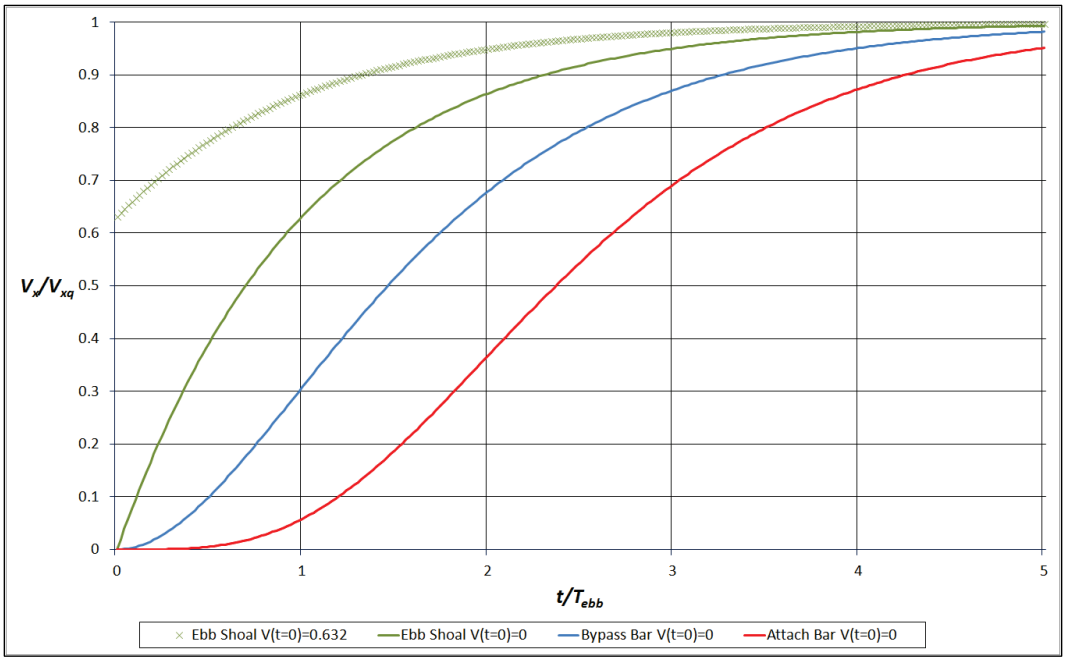
and for the attachment bar exponent, it is

$$\theta_a(t) = \frac{\left[\frac{t}{T_{ebb}} - \frac{V_e(t)}{V_{eq}} - \frac{V_b(t)}{V_{bq}}\left(\frac{V_{bq}}{V_{eq}}\right)\right]}{\left[\frac{V_{bq}}{V_{eq}} \times \frac{V_{aq}}{V_{bq}}\right]} \tag{13}$$

Figure 83 shows the normalized ebb-shoal volume curve in green. The zero initial volume curve is the solid green line. This curve shows the expected asymptotic approach to equilibrium. If the initial volume of the ebb shoal is not zero, but rather $V_e(t=0)$, then the ebb-shoal solution to Equation 8 is

$$\frac{V_e(t)}{V_{eq}} = 1 + \left(\frac{V_e(t=0)}{V_{eq}} - 1 \right) \exp\left(-t / T_{ebb} \right) \tag{14}$$

Figure 83. Normalized shoal volume growth curves for all shoals having the same equilibrium volume.



The hashed green line shows an ebb-shoal volume curve with a non-zero initial value, in this case, 0.632 V_{eq}. It is seen that starting at a non-zero initial volume is equivalent to shifting the horizontal time axis. For this example, the two green curves are horizontally displaced by [1*(t/T_{ebb})].

Figure 83 also shows the volume curves for the bypassing and attachment bars (in blue and red, respectively) for the simplified case of all shoal volumes being equal. It is seen that the growth of these bars lags behind that of the ebb shoal. Particularly in the early stages, most of the material delivered to the ebb shoal is retained on that shoal, so little is passed to the bypassing bar which retains most of that; only a tiny fraction is initially passed to the attachment bar.

The shape of these two curves is also more complex than for the ebb shoal, reflecting the lack of sediment in their early stages. While the ebb-shoal growth curve is always convex upwards, both the bypassing and attachment-bar growth curves are initially concave upwards. The inflection points where these curves become convex upwards is at (t/T_{Ebb}) = 2 for the bypassing shoal and 3 for the attachment shoal. The *lazy S* shape of these curves is reflected in the shoal growth rates seen at Ocean City Inlet (Kraus 2000).

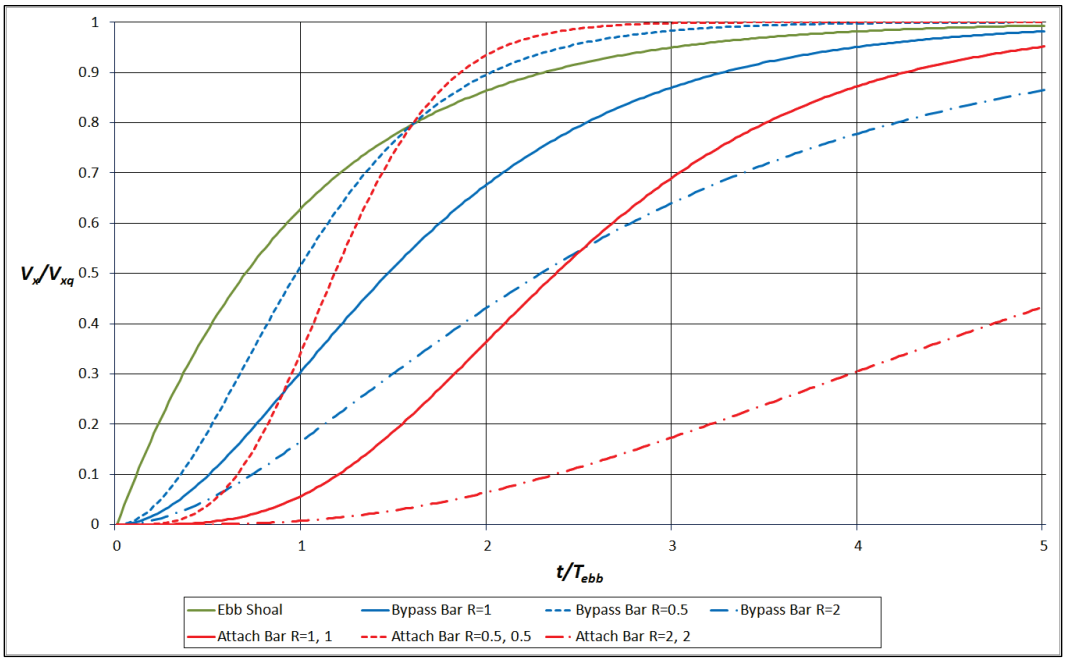
Other inlets with similar forcing, geologic setting, and tidal prism may have a T_{ebb} = 20 yr as was found at Ocean City Inlet. For this condition, Figure 83 shows shoal behavior over a 100 yr interval. Over this timespan, the lines on Figure 83 are clearly seen to be asymptotic growth curves. However, please note that GenCade is usually run for time periods shorter than this, and it is rare to have high-quality shoal volume data for this type of timespan. When investigating shoal growth over much shorter periods of time, these curve segments approach straight lines, and this type of linear approximation may be useful in certain circumstances.

Figure 84 repeats the three solid-color curves from Figure 83 but also shows additional curves to examine the effect of the different shoals having differing equilibrium volumes. In the legend, *R* is the ratio of the shoal volume at time *t* to the equilibrium volume. The three blue curves are for the bypassing bar. The solid blue curve is for a bypassing bar whose equilibrium volume is equal to the equilibrium volume of the ebb shoal and shows the lag in growth as discussed above. The short-dash blue curve represents a bypassing bar whose equilibrium volume is half that of the ebb shoal. This curve also starts off growing slowly, but because there is less volume to fill, it can later accelerate its growth and approach equilibrium faster than the ebb shoal. The dash-and-dot blue curve represents a bypassing shoal with twice the volume of the ebb shoal. This curve starts off growing slowly but continues growing slowly at its later stages because of the large volume that is needed to reach equilibrium.

The three red curves are for the attachment bar. This shoal's filling rate is affected by the relative volumes of all three shoals. The short-dashed red curve represents an attachment bar whose equilibrium volume is half that of the bypassing bar, and the equilibrium bypassing bar volume is half that of the ebb shoal. This bar's growth starts off slowly but ends up approaching equilibrium more rapidly than all the other curves because it only needs to

achieve a tiny equilibrium volume. At the other extreme, the dot-and-dash red curve is for an attachment bar whose equilibrium volume is twice that of the bypassing bar, and the bypassing shoal's equilibrium volume is twice that of the ebb shoal. Because of its massive size, this shoal fills very slowly.

Figure 84. Normalized shoal volume curves, showing the effect of differing equilibrium shoal volumes.



Sediment that is bypassed from the attachment bar is added to the downdrift beach. This relationship is shown by Equation 15:

$$Q_{out} = \frac{V_e(t)}{V_{eq}} \times \frac{V_b(t)}{V_{bq}} \times \frac{V_a(t)}{V_{aq}} * Q_{lst} \tag{15}$$

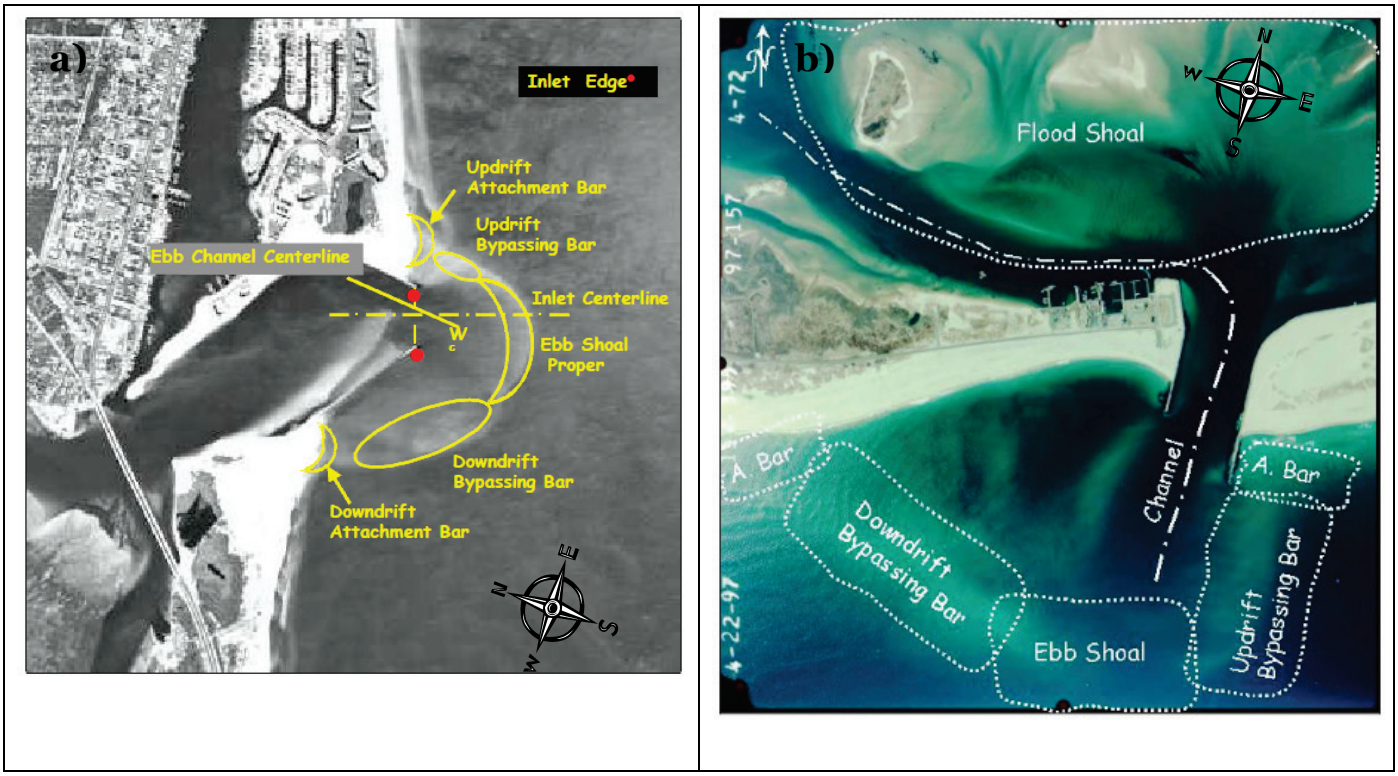
If all shoals are filled to equilibrium, the transport rates on both sides of the inlet for any given time-step are equal, as expected. By knowing the transport rates at both sides of an inlet, this equation may be useful to the modeler in checking initial and equilibrium volumes when setting up GenCade.

4.7.3 Initial volumes and equilibrium volumes

Because user-specified initial volumes and equilibrium volumes dictate the bypassing rate at the inlet, it is important to accurately estimate these volumes. The historical volume of the ebb-shoal complex (including bars)

is sometimes available from literature and can be used as the initial volume. To determine the volume of the different morphologic units, some assumptions must be made regarding their relative size. Historical aerial photographs or bathymetric surveys can be employed to determine the proportions of the morphologic elements. Figure 85 (adapted from Carr and Kraus (2001); Kraus (2002)) identifies the boundaries of the different morphologic elements for East Pass on the Florida panhandle near Destin and Shinnecock Inlet, on the south shore of Long Island, between Westhampton and Southampton, New York, respectively.

Figure 85. Inlet entrance morphology: a) East Pass, FL, 1990. Distance (W_c) between the tips of the jetties is ~ 960 ft. figure from Carr and Kraus (2001); b) Shinnecock Inlet, NY, 1997. The jettied inlet channel is ~790 ft wide. Figure from Kraus (2002).



If the volume is not known, methods exist to determine the volume of the ebb-shoal complex based on bathymetric surveys. Stauble (1998) describes three techniques that may be employed to calculate the inlet ebb-shoal volume. A commonly used technique, originally developed by Dean and Walton (1975), consists of calculating the volume of sand above a *no-inlet* bathymetry constructed by interpolating adjacent contours. The subjectivity associated the identification of the boundaries of the shoals may lead to error of ±10% and sometimes more according to Walton and Adams (1976).

The equilibrium volume is usually more difficult to estimate. Shoal volume estimates from historical bathymetric surveys (pre-modification) can sometimes be used if it is assumed that the inlet was at equilibrium. Inlets can be considered as being near equilibrium if the cross-sectional area of the inlet throat has remained constant for a long period of time (decades to centuries).

Walton and Adams (1976) describe how the inlet capacity to store sand is related to the inlet tidal prism. While their technique can help establish equilibrium volumes, these equilibrium volumes can change if the inlet cross-section is altered either naturally or mechanically by dredging or stabilizing structures. Walton and Adams (1976) were the first to relate the tidal prism to the ebb-shoal volume. Their results were derived from field data at 44 United States inlets. Walton and Adams' definition of the ebb shoal approximately corresponds to the sum of the IRM volumes of the ebb shoal and bypass bars. Their relationship is summarized by Equation 16, with the coefficients provided in Table 5:

$$V = aA^b \tag{16}$$

where:

V = volume of sand stored in the ebb shoal, cubic yards
A = inlet cross-sectional area, square feet
a, b = correlation coefficients related to the energy of offshore waves near the inlet.

Table 5. Coefficients for the Walton and Adams formula.

Wave energy level	a	b
Highly exposed coasts	33.1	1.28
Moderately exposed coasts	40.7	1.23
Mildly exposed coasts	45.7	1.28

The wave energy level is determined by calculating H^2T^2 from nearshore (15–20 ft) wave gages, where H is the average wave height in feet, and T is the average wave period in seconds. Highly exposed coasts have $H^2T^2 >$ 300 and mildly exposed coasts have $H^2T^2 <$ 30. Powell et al. (2006) have also developed a similar relationship based on data from 57 Florida inlets. They derived different coefficients for the Atlantic and Gulf coast inlets but

state that globally for the Florida coast, generally, ebb-delta equilibrium volume is one-fifth of the spring tidal prism.

Determining the flood-shoal volume can be more of a challenge since good quality bathymetric surveys of the bay are often non-existent or incomplete. When possible, the same method used to determine the ebb shoal can also be used for the flood shoal. Similarly to Walton and Adams (1976), Carr de Betts and Mehta (2001) and Powell et al. (2006) found a weak correlation between the tidal prism and the flood shoal while studying Florida inlets. Powell et al. (2006) found that for inlets on the Gulf coast of Florida

$$V_f = C_f \times 10^3 P^{0.37} \tag{17}$$

where:

V_f = flood-shoal volume (cubic yards or cubic meters)
C_f = coefficient for the flood-shoal volume (8.231 when in cubic yards; 6.95 when in cubic meters)
P = spring tidal prism (cubic meters).

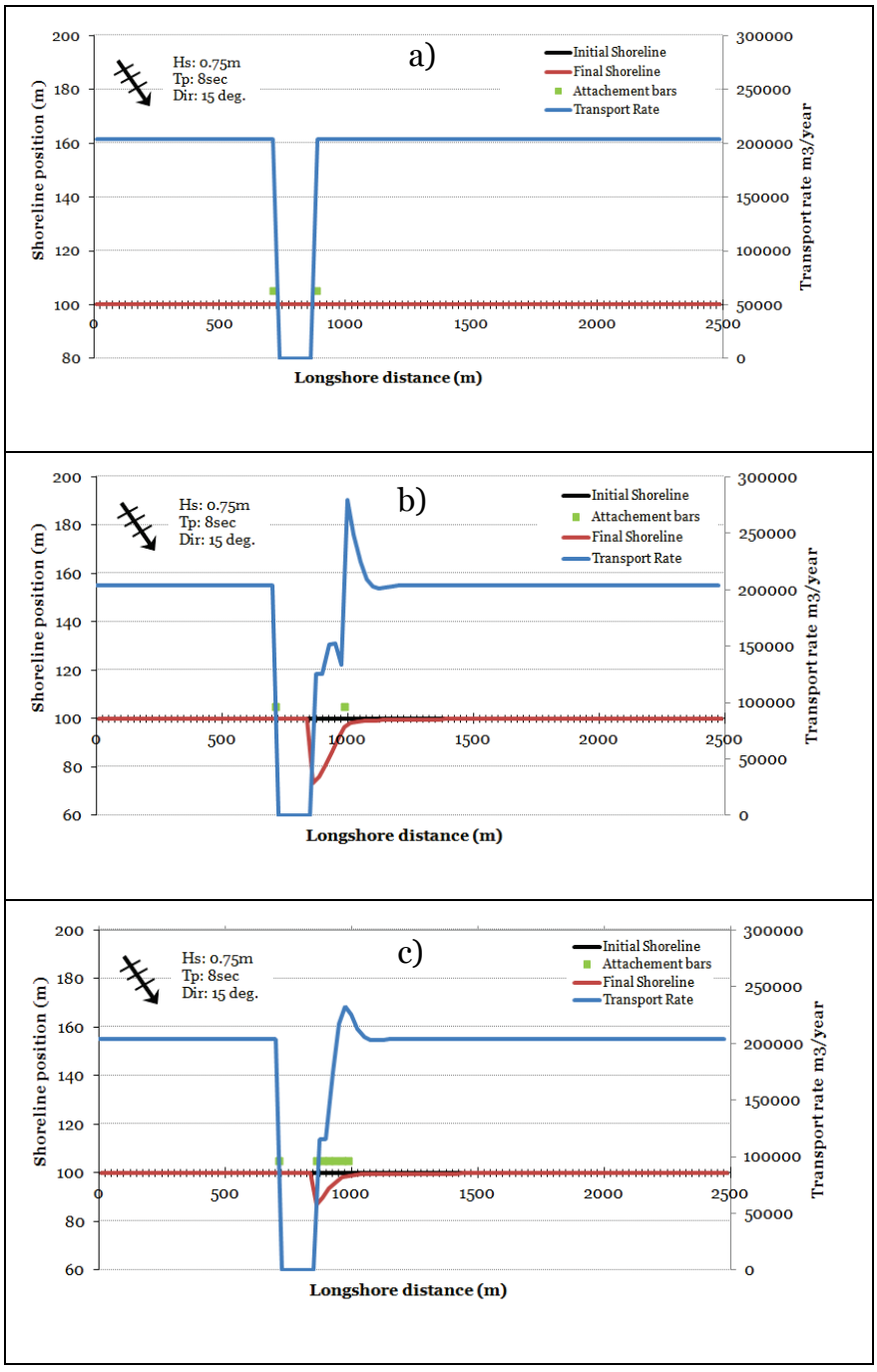
For an inlet on the Atlantic Coast, the flood-shoal volumes do not show any correlation with the tidal prism presumably because, at many entrances, the depths have been altered by dredging.

4.7.4 Attachment bars

In GenCade, it is possible to specify the width (number of GenCade cells) and the location (cell number) of the attachment bars. These parameters will affect how the sand is transferred to and distributed along the shoreline. The default value is set to the cell downdrift of the inlet. If a cell position other than the first cell downdrift is specified, 90% of the bypassed sand is distributed to that cell, and 10% is bypassed to the cell immediately downdrift of the inlet. If more than one cell is selected, the transported volume will be divided among the cells. The center cell of the attachment bar will receive the largest volume, and the volume will linearly decrease to neighboring cells on both sides.

Figure 86 shows the effect of changing the width and the location of the attachment bars. In this example, the GenCade grid contains 100 cells of 82 ft in width. The unstructured inlet is five cells wide 410 ft, and all

Figure 86. Impact of the location and width of the attachment bar on the final calculated shoreline (in red) and the transport rate at the beginning of the simulation (in blue). The initial shoreline position is shown in black. a) Attachment bar is one cell wide and next to the inlet; b) attachment bar is one cell wide and located six cells downdrift of the inlet; c) attachment bar is five cells wide and located next to the inlet.



shoals are at equilibrium to maximize bypassing. The 5 yr simulation was executed under constant wave forcing of H_s = 0.75 m, T_p= 8 sec, and wave angle = +15 ° relative to grid normal. The final calculated shoreline (in red)

is shown along with the average transport rate 3 days after the beginning of the simulation (initial shoreline shown in black). The figure shows the transport rate calculated early in the simulation before significant shoreline change has occurred.

Figure 86a shows the results obtained when the bypassing bar (in green) is set to the one cell adjacent to the inlet (the default in GenCade). Because all the inlet shoals are at equilibrium, 100% bypassing occurs, and $Q_{in} = Q_{out}$. The transport rate in the attachment bar is equal to the rate of the cells updrift of the inlet and also to the cells downdrift of the attachment bar. Since the transport rate remains constant, there is no shoreline change. This example satisfies all three above-mentioned conditions, and thus the inlet has no impact on the shoreline.

In Figure 86b, the attachment bar was moved to the 6th cell to the right of the inlet boundary. The first cell downdrift of the inlet only received 10% of the bypassed sand from its updrift cell (the cell adjacent to the inlet on the updrift side), which is (approximately) 90% less than the wave-driven transport out of that cell, so erosion occurs at this cell. At the same time, the attachment bar cell (6th from the inlet) has wave-driven transport into the cell, plus the input of 90% of the inlet-bypassed material. Since this is greater than the wave-driven transport out of this cell, accretion occurs at this location. Minor fluctuations in the transport rate (the blue line in Figure 86b) occur because changes in the shoreline orientation change the breaking wave angle. For this case, erosion is evident between the inlet and the attachment bar on the downdrift side of the inlet, but because all material is bypassed, there is little inlet impact downdrift of the attachment bar.

Figure 86c shows a case where the downdrift attachment bar is located next to the inlet but is five cells in width. The bypassing rate is distributed among the attachment bar cells. Because the rate is distributed non-uniformly, there is shoreline change. The shoreline change is less pronounced than in Figure 86b because the transport rate variation is less drastic.

The location of the attachment bar can be identified from aerial photographs in many cases. The bar will create a protrusion in the shoreline such as the one visible in the aerial photographs of Figure 85. Depending on the chosen cell size, the attachment bars at East Pass (Figure 85a) could be

represented by a single cell adjacent to the inlet. At Shinnecock Inlet (Figure 85b), the bar is clearly a certain distance downdrift of the inlet. Placing the attachment bar a few cells past the inlet will also help recreate the tendency of observed erosion downdrift of the jetty.

4.7.5 Bypassing coefficient

In the inlet dialogue box (in the GenCade menu), there are two boxes labeled *Left Bypass Coef* and *Right Bypass Coef*. These boxes will be grayed out in the absence of a jetty, since they only apply when a jetty is present at an inlet. These bypass coefficients are related to the virtual shoreline, as described in the gated boundary condition discussion in Frey et al. (2012a). The shoreline position relative to the seaward tip of the jetty is required to calculate bypassing around the structure. The shoreline position must be known on both sides of the jetty. Since there is no shoreline position in the inlet, the user needs to specify a bypass coefficient that will control the bypassing around this structure. The bypass coefficient *BC* is defined in Equation 18 as

$$BC = \left(Y_{gro} - Y_{vir}\right)/\left(Y_{gro} - Y_{nxt}\right) \tag{18}$$

where: (the cross-shore distance values are identified in Figure 87)

Y_{gro} = length of the jetty
Y_{vir} = position of the virtual shoreline inside the inlet channel
Y_{nxt} = shoreline position next to the structure.

Figure 87. Schematic of the bypass coefficient.

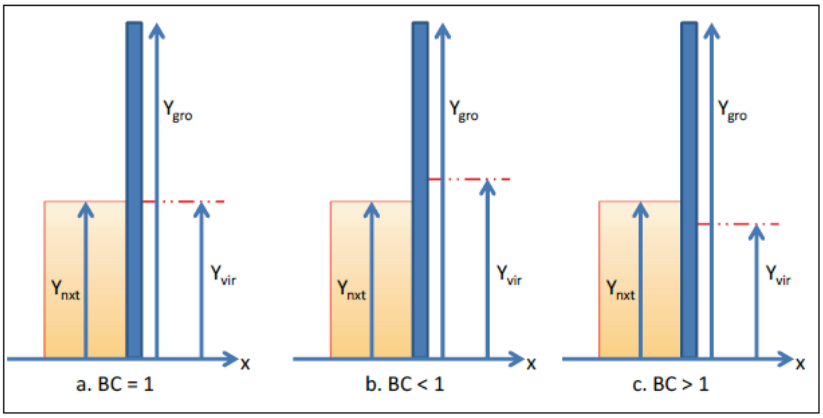
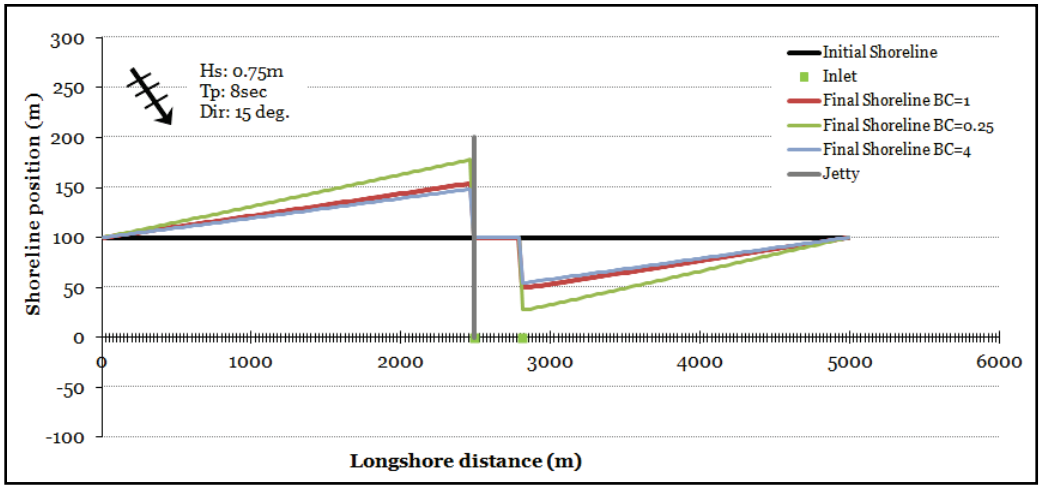


Figure 88 examines the effect of the bypass coefficient on the accumulation of sediment against the jetty. The grid contains 200 cells of 25 m (82 ft) in

width. The unstructured inlet is 12 cells wide 300 m (984 ft), and all shoals are at equilibrium to maximize bypassing. A 656 ft-long jetty was placed on the updrift side of the inlet. The 5 yr simulation was made under a constant wave forcing of H_s = 0.75 m, T_p = 8 sec, and wave angle = +15 ° relative to grid normal. The final shoreline is plotted for bypassing coefficient of 1 (in red), 0.25 (in green), and 4 (in blue).

Figure 88. The effect of the bypassing coefficient near an inlet.



The red line represents the result obtained with the bypass coefficient set to the default value of 1, which means that the virtual shoreline inside the inlet is at the same *Y* position as the shoreline next to the jetty. In contrast, the green line shows the final shoreline when the bypass coefficient was set to 0.25, which means that the virtual shoreline in the inlet is seaward of the shoreline next to the jetty. With a bypass coefficient of less than one, less sand is allowed into the inlet, and more sand is trapped by the jetty. The blue line shows the final shoreline when the bypass coefficient is set to 4. The virtual shoreline is landward of the shoreline on the other side of the jetty and will allow more sand into the inlet. This is evident in the figure since less sand is flanking the jetty.

Therefore, as mentioned by Frey et al. (2012a), a constructive strategy could be to start with the default value 1 and then increase or decrease the *bypass coefficient* depending on whether the prototype shows more or less accumulation against the structure. The *bypass coefficient* is one of the variables which may be adjusted to help the modeler represent structured inlet processes.

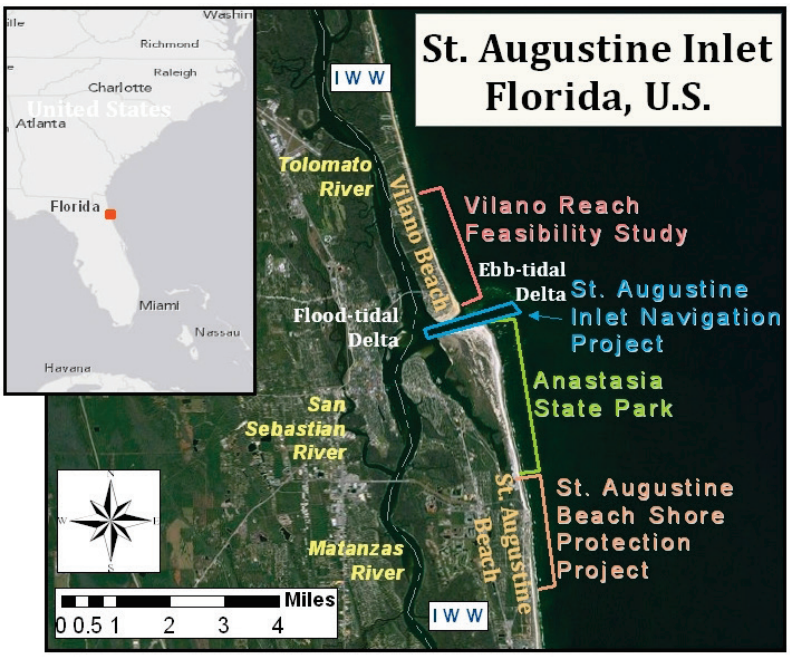
4.7.6 Example

A recent shoal-mining optimization study that was performed at St. Augustine Inlet on the east coast of Florida (Beck and Legault 2012) provides a good example of the applicability of the Inlet Reservoir Model.

4.7.6.1 Background

The study evaluates the feasibility of combining the maintenance navigation channel dredging operation of St. Augustine Inlet and the potential shoal mining activities with associated beach nourishments for present and future shore-protection projects at St. Augustine Beach and Vilano Beach, respectively (Figure 89). By combining those three projects, the USACE, Jacksonville District, could potentially save an estimated $2 million in mobilization and demobilization of the equipment for each beach-placement activity.

Figure 89. St. Johns County, FL, and the USACE projects: Vilano Beach Feasibility Study; St. Augustine Beach Shore Protection Project; St. Augustine Inlet Navigation Project.



Although the benefits of combining the three projects are evident, determining a sustainable sand volume and time interval for the dredging and beach-placement operation require careful analysis with respect to a dynamic sediment budget. If too large a quantity is removed from the inlet shoals and placed on the adjacent beaches, the shoal may become unstable

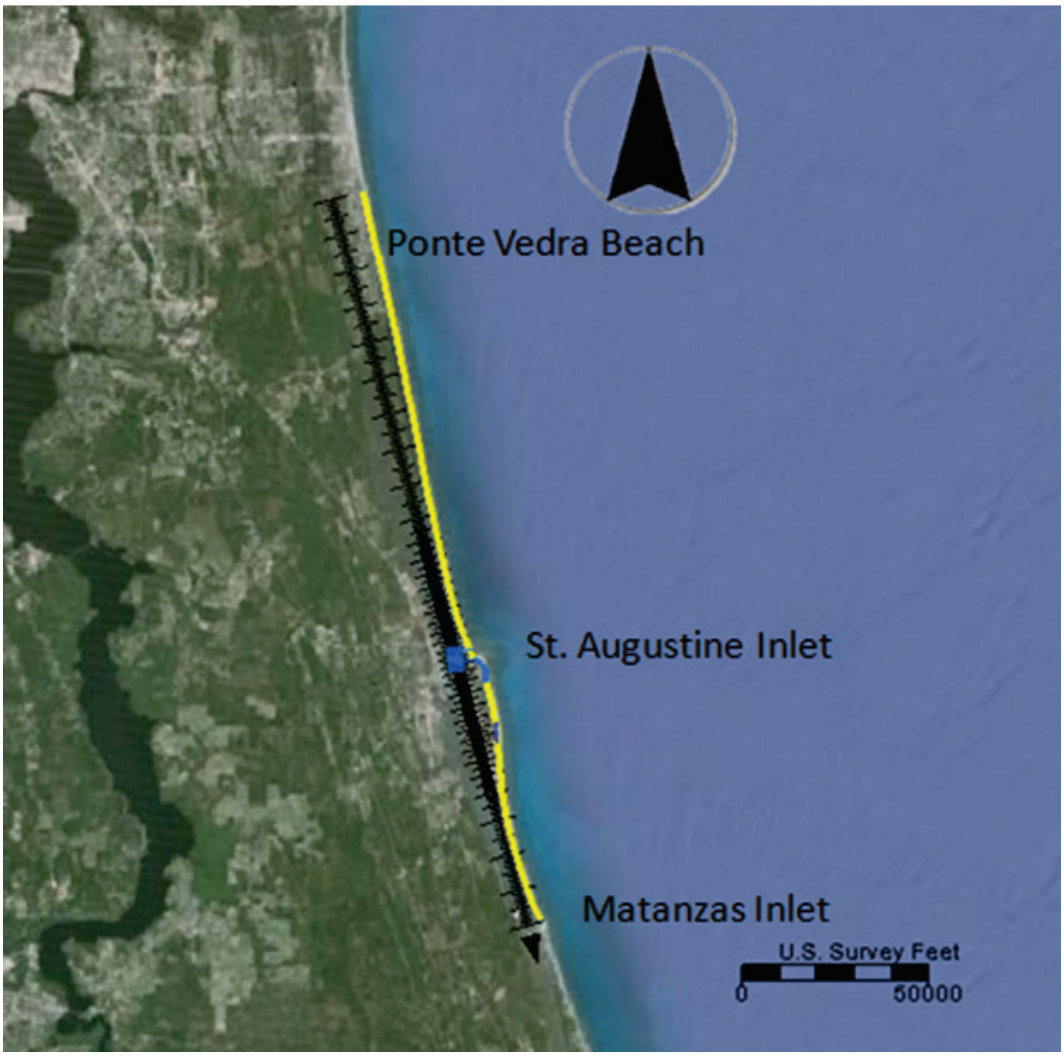
and could collapse. The inlet would drastically reduce bypassing to the adjacent beaches and thus increase beach erosion and compromise shore-protection projects (i.e., beach fills). If too small a quantity is removed, the benefit of mobilization and demobilization of the dredging and placement equipment is not fully realized, and adjacent beaches would not be as protected. Another potential problematic case would be the placement of sand on beaches at locations too close to the inlet where the nourishment is quickly transported into the navigation channel, thereby increasing future maintenance costs. If the sand is placed too far from the inlet, the costs incurred during the placement process are unnecessarily increased.

The specific objectives of the investigation were to (1) determine the sustainable maximum ebb-shoal dredged volume and interval which would not cause significant long-term effects on ebb-shoal recovery and (2) determine the beach nourishment volume and interval required to maintain the two present and planned shore-protection projects (St. Augustine Beach and Vilano Beach, respectively) and to minimize costs and potential rehandling of dredged sand. A regional GenCade model was set up to help address those questions.

4.7.6.2 GenCade setup and calibration

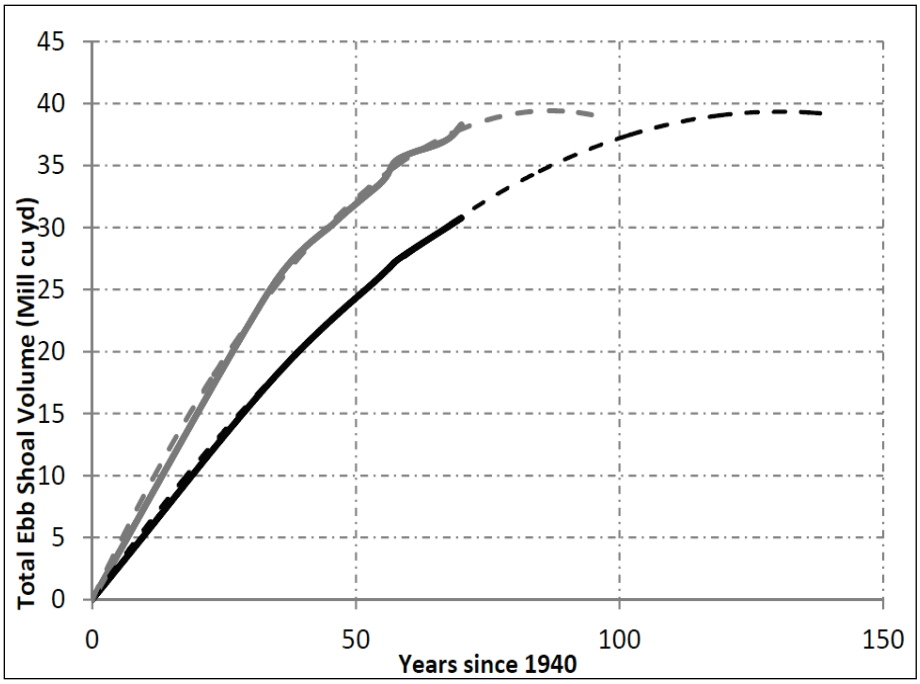
The GenCade project study area covered 40 miles of St. Johns County, Florida, from Ponte Vedra Beach to the north to Matanzas Inlet to the south (Figure 90). The grid consisted of 360 cells varying in width from 1,000 ft at the north and south extremities progressively decreasing in width to 200 ft near St. Augustine Inlet. The two terminal groins present on both sides of the inlet were entered in the model (as jetties) as well as a seawall along St. Augustine Beach. The regional contour was developed from a smoothed version of the –4 ft MSL depth contour. Wave forcing was obtained from one wave station (Station 63417) from the Wave Information Study (WIS). Calibration was primarily made using a detailed beach volumetric change dataset from 1986 to 1999 (Legault et al. 2012). The calculated shoreline change and magnitude of sediment transport were also considered. Known beach fills and nearshore placement of sand were included in the model.

Figure 90. GenCade grid in black for the St. Augustine inlet optimization study with the initial shoreline in yellow.



The equilibrium volume of the inlet shoal features, estimated with the Walton and Adams (1976) formula for moderate wave exposure, was found to be approximately 40 million yd^3. This value was corroborated with reported ebb-shoal volume growth and calculated extrapolation. Figure 91 shows the measured growth and the extrapolation calculated based on a best-fit exponential equation. Total volume for the ebb-tidal delta was calculated for 1986 as approximately 30.5 million yd^3 (above the 30 ft depth contour) using the method described in Dean and Walton (1975). Because all dredging occurs in the ebb-shoal-proper portion of the inlet ebb-tidal delta, all of the sand volume was kept in one morphologic feature (ebb shoal) within the IRM. The flood-shoal equilibrium value of 2.0 million yd^3 was taken from Carr de Betts and Mehta (2001). The initial flood-shoal value of 1.7 million yd^3 was measured from a 1992 survey map.

Figure 91. Reported ebb-shoal volumes in the solid lines. Extrapolated volumes shown in the dashed line. Measurement using the 26 ft (black) and 30 ft (gray) depth contours.



The attachment bar locations were determined by examining existing aerial and satellite imagery and bathymetric survey. Potential bypassing to Vilano Beach, updrift of the inlet, did not appear to be significant in that there was no notable shoreline or morphologic features to indicate active deposition to the beach (Figure 92). Therefore, the inlet-left attachment bar was set to the first cell north of the inlet. On the downdrift side of the inlet, a large seaward protrusion was visible marking the active bypassing zone. The attachment bar was set to extend from the jetty to a distance of 6,500 ft (26 cells) downdrift of the inlet. Figure 92 shows the location of the attachment bars adjacent to St. Augustine Inlet.

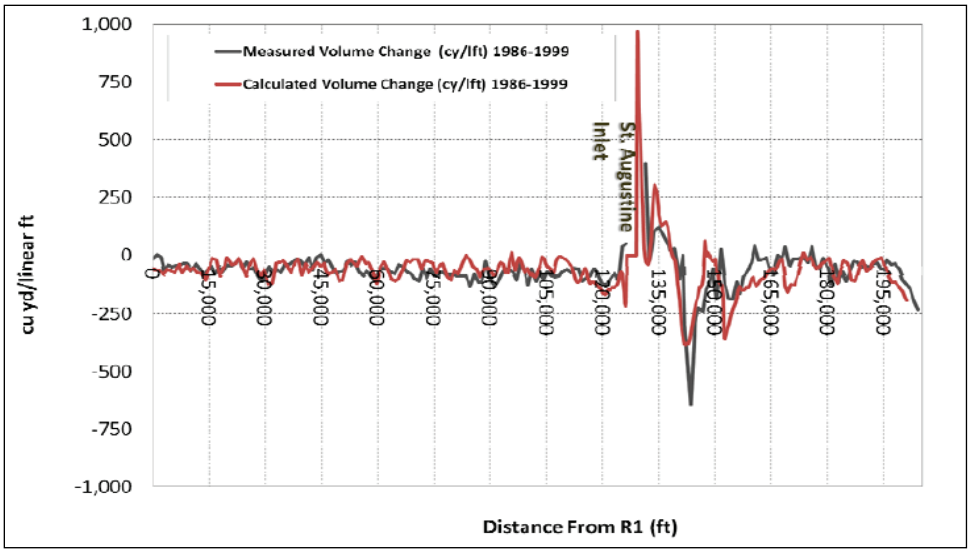
The two terminal groins present on both sides of the inlet were identified as jetties in GenCade. Since the north jetty was typically buried and not functional, the permeability was set to 0.8 (80%). The south jetty defines the boundary between the channel and the barrier terminus and was set to a permeability of 0.3.

Figure 92. GenCade grid near St. Augustine Inlet. The 1986 initial shoreline is in yellow, regional contour in orange, and attachment bars in blue.

In addition to groin permeability, the bypassing coefficients of the inlet jetties were calibrated to represent the capacity of the adjacent shoreline volume to transport sand into the inlet reservoir system. The shoreline protrusion on the downdrift side of the inlet indicated a large bypassing signal on the northern end at Anastasia Island, as is typical of a mixed-energy, drumstick-barrier island. To account for the accretion of the headland, the bypassing coefficient of the north jetty was set to 0.5 to allow more bypassing into the inlet, and the downdrift jetty bypassing coefficient was set to 70 to intercept the sand occasionally transported northward. As a result, the final calculated ebb-shoal volume for the calibration test had a difference of –36% from the measured volume.

Figure 93 shows the comparison between the measured and calculated profile volume change from the final calibration run.

Figure 93. Measured (black) vs. calculated (red) profile volume change for the calibration period of 1986–1999.

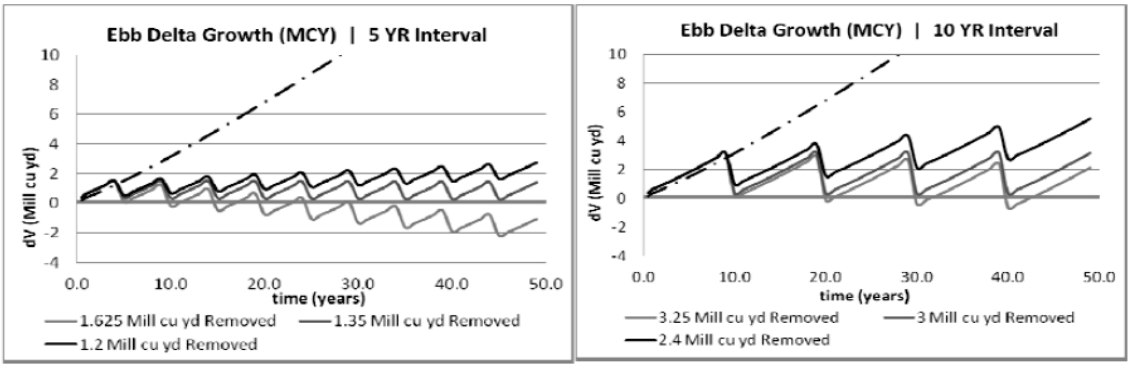


4.7.6.3 *Dredging intensity*

To determine the possible sustainable dredging rates to be used for viable alternatives, a simplified shoal-recovery model was set up. Based on previously measured recovery rates following large dredging events at St. Augustine Inlet, it was found that over a period of 10 yr, the average volumetric change rate of the ebb-tidal delta after a shoal-mining event would be ~300,000 yd^3/yr. This rate was then applied to a linear calculation of volumetric change of the ebb-tidal delta for 5 yr and 10 yr dredging interval scenarios (Figure 94).

It was found that dredging less than 1.35 million yd^3 every 5 yr would allow the ebb-tidal delta to increase or maintain its volume. For the 10 yr dredging scenario, the dredging must be less than 3 million yd^3 to maintain or increase initial volume.

Figure 94. Shoal recovery rate calculated for recurrent 5 yr (left) and 10 yr (right) mining scenarios.



4.7.6.4 Results and alternatives

Based on the result of the dredging intensity analysis, four dredging alternatives were investigated. Volume and dredging intervals are listed in Table 6. The alternatives were tested for a 50 yr forecast period starting with the 2010 inlet condition. The wave forcing consisted of the 20 yr wave hindcast (WIS) repeated 2.5 times.

Table 6. Dredging and placement scenarios.

Scenario	Dredged Volume	Dredging Interval	Volume Available for Beach Fills over the 50 yr Period
Alt A1	1.0 million yd^3	5 yr	10.0 million yd^3
Alt A2	1.35 million yd^3	5 yr	13.5 million yd^3
Alt A3	2.0 million yd^3	7 yr	14 million yd^3
Alt A4	3.0 million yd^3	10 yr	15 million yd^3

Results of the simulations indicated that only alternatives A2 and A3 lost volume over the 50 yr simulation, both less than 3%. A comparison of performance of the ebb-delta recovery of these alternatives is summarized in Table 7 and Figure 95. Alternative A1 resulted in significant growth of the ebb delta. Removing 2 million yd^3 (Alternative A3) on a 7 yr interval and 3 million yd^3 (Alternative A4) on a 10 yr interval resulted in a near static equilibrium volume of the ebb delta.

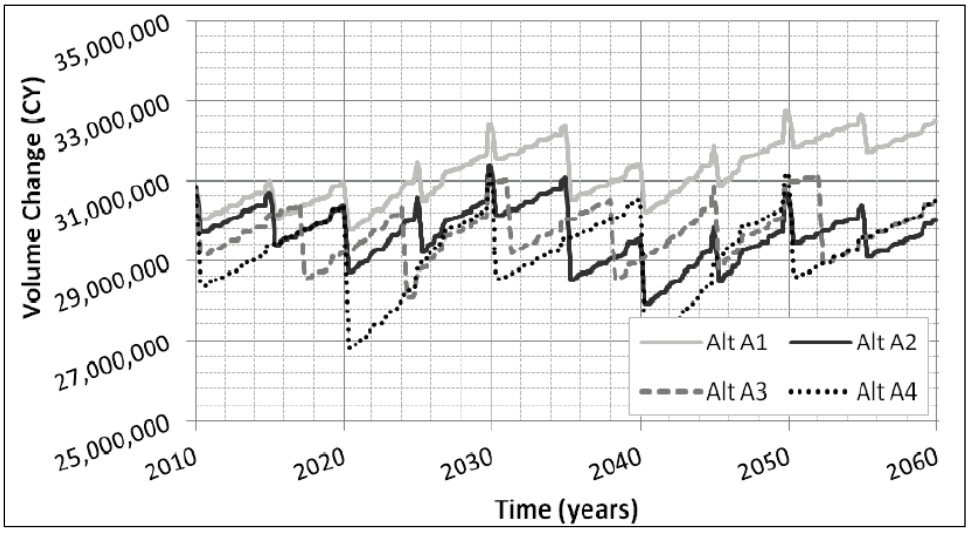
Two variations of alternatives A1 and A4 were considered to investigate the impact of beach fills on the final shoreline. Alternative B1 and B2 were derived from alternative A1 of dredging 1.0 million yd^3 every 5 yr and alternatives C1 and C2 were created using A4 or 3 million yd^3 dredged every 10 yr. The four alternatives present different volumes of sand placed over different reaches of St. Augustine Beach and Vilano Beach. It was found that the alternatives deriving from the 5 yr dredging plan (B1 and B2) would not supply enough material to prevent volume loss over the reaches. The preferred scenario was Alternative C1. Alternative C1 uses the maximum volume that can be removed for the 10 yr interval of 3.0 million yd^3. In this scenario, a volume density of 50 yd^3/linear (lin) ft is placed over Vilano Beach, with a resulting 125 yd^3/lin ft placed over the maximum reach of the St. Augustine Beach Shore Protection Project.

More information regarding calibration, alternatives, results, and discussion can be found in the original report by Beck and Legault (2012).

Table 7. Ebb-tidal delta volume after 50 yr simulation and the percent difference.

Scenario	Final Volume (yd^3)	% Difference
2010 condition	30,500,000	--
Alt A1	32,485,116	5.10%
Alt A2	30,019,068	–2.88%
Alt A3	30,473,748	–1.41%
Alt A4	31,942,946	3.34%

Figure 95. Ebb-tidal delta volume for alternatives A1, A2, A3, and A4.



5 Summary and Future Guidance

This report presents application guidance for the newly developed model, GenCade. This report is to be used as a companion to Frey et al. (2012a), the first GenCade report in the series which provided a user's guide and model theory. However, Frey et al. (2012a) did not detail specific parts of the model, the basic requirements to run GenCade, describe common setup mistakes, or provide site-specific example applications. This report, the second in the GenCade series, is intended to be a reference for GenCade users to learn from previous GenCade experiences and also be a resource for users in providing more detailed examples of GenCade applications.

This report described the basic assumptions, requirements to run the model, and recommendations that should be used when working on a GenCade application. In addition to a description of the basic assumptions, the report explained some of the assumptions at a study site and how the user should proceed when not all of the basic assumptions are met. Each of the input and output files for GenCade were described in the GenCade requirements section. A number of common setup mistakes were discussed and solutions to each were explained. A typical work flow for a GenCade project was introduced. Common questions such as cell spacing standards and the maximum angle between the shoreline and the grid were discussed. The stability parameter, ISMOOTH, the regional contour, and the Inlet Reservoir Model were described. Although each of these topics was discussed in the first GenCade report, this report provided additional details not previously covered in any GenCade documentation.

Additional reports in the GenCade series are planned. Report 3 will document wave input and use of the external wave model. Report 4 will discuss the calibration process for GenCade. A GenCade Quick Start Guide will be published as a technical note and also will be posted to the CIRP Wiki. The purpose of this Guide is to give a very brief background of the model so that new users can understand what the model does and can decide if it should be used for a certain project. The version of the Guide on the CIRP Wiki will be a living document where it can be updated. While the published version of the Guide will describe where to find additional

information, the CIRP Wiki version will have the latest links to the other documentation and reports in the GenCade series.

This technical report describes topics in GenCade Version 1. The GenCade team is developing new features and capabilities which will be available when GenCade Version 2 is released. The new developments should not adversely affect the interface or the process to create a new project. It is expected that most of the guidance herein should be relevant for the long-term although a few additional checks in the conceptual model are planned which should eliminate some of the error messages related to improper placement of structures.

References

Ahrens, J.P. 2001. *Wave transmission over and through rubble-mound breakwaters*. Draft Contract Report submitted to the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydaulics Laboratory (CHL), Vicksburg, MS.

Ari Güner, H. A., Y. Yüksel, and E. Ö. Çevik. 2013. Longshore sediment transport—field data and estimations using neural networks, numerical model, and empirical models. *Journal of Coastal Research* 29(2):311–324.

Bagnold, P. A. 1963. Mechanics of sediment transport. In *The Sea 3,* ed. M. N. Hill, 507–582. New York: Wiley-Interscience.

Beck, T. M., and K. R. Legault. 2012. *Optimization of ebb-shoal mining and beach nourishment at St. Johns County, St. Augustine Inlet, Florida*. ERDC/CHL TR-12-4: Report 3. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Birkemeier, W. A. 1985. Field data on seaward limit of profile change. *Journal of Waterway, Port, Coastal and Ocean Engineering* 111(3):598–602.

Bodge, K. R. 1993. Gross transport effects and sand management strategy at inlets. *Journal of Coastal Research*, Special Issue no. 18 Beach/Inlet Processes and Management: A Florida Perspective (Fall 1993):111–124.

Bodge, K. R., and N. C. Kraus. 1991. Critical examination of longshore transport rate magnitude. In *Proceedings of Coastal Sediments '91*, 139–155. Seattle, WA: ASCE.

Carr, E. E., and N. C. Kraus. 2001. *Morphologic asymmetries at entrances to tidal inlets*. CHETN-IV-33. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Carr de Betts, E. E., A. J. Mehta. 2001. An assessment of inlet flood deltas in Florida. In *Proceedings of the 4th Conference on Coastal Dynamics*, 252–262. Reston, VA: ASCE.

Cleary, W. J., and P. E. Hosier. 1987. Onslow Beach, NC: Morphology and Stratigraphy. In *Proceedings, Coastal Sediments '87*, 1745–1759. New Orleans, LA: ASCE.

Cleary, W. J., and T. P. Marden, eds. 2004. *Shifting shorelines: A pictorial atlas of North Carolina inlets*. Raleigh, NC: NC State University, North Carolina Sea Grant.

Coastal Engineering Research Center (CERC). 1973. *Shore protection manual*. Fort Belvoir, VA: U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Cooper, J. A. G., and O. H. Pilkey. 2007. Quantification and measurement of longshore sediment transport: An unattainable goal? In *Coastal and Shelf Sediment Transport,* ed. P. Balson and M. Collins, 37–43 . Geological Society of London, Special Publication 274.

Courant, R., K. Friedrich, H. Lewy. 1967. On the partial difference equations of mathematical physics. *IBM Journal of Research and Development* 11(2):215–234, MR 0213764, Zbl 0145.40402. (This is an English translation of the original 1928 publication in German. A freely downloadable copy can be found at http://www.stanford.edu/class/cme324/classics/courant-friedrichs-lewy.pdf.)

d'Angremond, K., J. van der Meer, and R. De Jong. 1996. Wave transmission at low-crested structures. In *Proceedings, 25th Coastal Engineering Conference*, 2418–2427. ASCE.

Dean, R. G., and T. L. Walton, Jr. 1975. Sediment transport processes in the vicinity of inlets with special reference to sand trapping. In *Estuarine Research*, Vol. II, ed. L. E. Cronin, 129–149. New York: Academic.

Dean, R. G., and R. A. Dalrymple. 2002. *Coastal processes with engineering applications*. United Kingdom: Cambridge University Press.

Fenster, M., and R. Dolan. 1996. Assessing the impact of tidal inlets on adjacent barrier island shorelines. *Journal of Coastal Research* 12(1):294–310.

Finkl, C. W. 2002. Long-term analysis of trends in shore protection: Based on papers appearing in the *Journal of Coastal Research*, 1984–2000. *Journal of Coastal Research* 18(2):211–224.

Fowler, J. E., J. D. Rosati, D. G. Hamilton, and J. M. Smith. 1995. *Development of a large-scale laboratory facility for longshore sediment transport research*. The CERCular, CERC-95-2. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Frey, A., K. Connell, H. Hanson, M. Larson, R. Thomas, S. Munger, and A. Zundel. 2012a. *GenCade version 1 model theory and user's guide.* ERDC/CHL TR-12-25. Vicksburg, MS: U.S Army Engineer Research and Development Center.

Frey, A., S. Munger, G. L. Williams, M. J. Wutkowski, and K. B. Conner. 2012b. *GenCade Application at Onslow Bay, North Carolina.* ERDC/CHL CHETN-IV-85. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Greer, M. N., and O. S. Madsen. 1978. Longshore sediment transport data: A review. In *Proceedings, 16th Coastal Engineering Conference,* 93(2):1563–1576. Hamburg, Germany: ASCE.

Haas, K. A., and D. M. Hanes. 2004. Process based modeling of total longshore sediment transport. *Journal of Coastal Research* 20(3):853–861.

Hallemeier, R. J. 1981. A profile zonation for seasonal sand beaches from wave climate. *Coastal Engineering* 4:253–277.

Hanson, H., and N. C. Kraus. 1989. *GENESIS: Generalized model for simulating shoreline change, Report 1: Technical Reference*. Technical Report CERC-89-19. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center.

Houston, J. R. 1995. *Beach-fill volume required to produce specified dry beach width*. Coastal Engineering Technical Note II-32. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Kaufman, W., and O. H. Pilkey. 1979. *The beaches are moving: The drowning of the American shoreline*. New York: Anchor-Doubleday.

King, D. B. 2006. Dependence of the CERC formula K coefficient on grain size. In *Proceedings of the 30th International Conference on Coastal Engineering,* ed. J. M. Smith, 3381–3390. San Diego, CA: ASCE.

King, D. B., and R. J. Seymour. 1989. State of the art in oscillatory flow sediment transport models. In *Nearshore Sediment Transport*, ed. R. J. Seymour. New York: Plenum Press.

Komar, P. D. 1969. The longshore sand transport on beaches. PhD Thesis, University of California, San Diego.

Komar, P. D. 1988. Environmental controls on littoral sand transport. In *Proceedings of the 21st International Conference on Coastal Engineering*, 1238–1252. New York: ASCE.

Komar, P. D., and D. L. Inman. 1970. Longshore sand transport on beaches. *Journal of Geophysical Research* 75:5514–5527.

Kraus, N. C. 1983. Applications of a shoreline prediction model. In *Proceedings of Coastal Structures '83*, 632–645. Arlington, VA: ASCE.

Kraus, N. C., and S. Harikai. 1983. Numerical model of the shoreline change at Oarai Beach. *Coastal Engineering* 7(1):1–28.

Kraus, N. C. 1988. Part IV: Prediction models of shoreline change, wave model (chapter 2). In *Nearshore dynamics and coastal processes: Theory, measurement, and predictive models*, ed. K. Horikawa, 324–328. Tokyo, Japan: University of Tokyo Press.

Kraus, N. C. 2000. Reservoir model of ebb-tidal shoal evolution and sand bypassing. *Journal of Waterway, Port, Coastal and Ocean Engineering* 126(6):305–313.

Kraus, N. C. 2002. *Reservoir model for calculating natural sand bypassing and change in volume of ebb-tidal shoals, Part 1: Description*. ERDC/CHL CHETN IV-39. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Larson, M., N. C. Kraus, and H. Hanson. 2003. Simulation of regional longshore sediment transport and coastal evolution – The Cascade model. In *Proceedings of the 28th Coastal Engineering Conference*, 2,612–2,624. ASCE.

Larson, M., N. C. Kraus, and K. J. Connell. 2006. *Cascade version 1: Theory and model formulation*. ERDC TN-SWWRP-06-7. Vicksburg, MS: U.S. Army Engineer Research and Development Center. https://swwrp.usace.army.mil/ .

Legault K. R., J. D. Rosati, T. M. Beck, J. Engle, and L. Hadley. 2012. *St. Johns County, St. Augustine Inlet, FL report 1: Historical analysis and sediment budget*. ERDC-TR-12-14. Vicksburg, MS: U.S. Army Research and Development Center.

Nielsen, P. 1988. Three simple models of wave sediment transport. *Coastal Engineering* 12:43–62.

Nielsen, P. 1992. Coastal bottom boundary layers and sediment transport. In *Advances in ocean engineering 4*. Singapore: World Scientific.

Ozasa, H., and A. H. Brampton. 1980. Mathematical modeling of beaches backed by seawalls. *Coastal Engineering* 4(1):47–64.

Pilkey, O. H., R. S. Young, R. R. Stanley, A. W. Smith, W. Wu, and W. D. Pilkey. 1993. The concept of shoreface profile equilibrium: A critical review. *Journal of Coastal Research* 9(1):255–278.

Powell, M. A., R. J. Thieke, and A. J. Mehta. 2006, Morphodynamic relationships for ebb and flood delta volumes at Florida's tidal entrances. *Ocean Dynamics* 56:295–307. doi: 10.1007/s10236-006-0064-3.

Riggs, S. R., W. J. Cleary, and S. W. Snyder. 1995. Influence of inherited geologic framework on barrier shoreface morphology and dynamics. *Marine Geology* 126: 213–234.

Riggs S. R., W. J. Cleary, and E. T. Snyder. 1996. Morphology and dynamics or barrier and headland shorefaces in Onslow Bay, North Carolina. In *Environmental Coastal Geology: Cape Lookout to Cape Fear, NC,* ed. W. J. Cleary, 29–40. North Carolina: Carolina Geological Society.

Rosati, III, J., A. E. Frey, and R. C. Thomas. 2013. *Erosion control and environment restoration plan development: Matagorda County, Texas, phase 2: Preliminary design*. ERDC/CHL TR-12-11. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Schoonees, J. S., and A. K. Theron. 1993. Review of the field database for longshore sediment transport. *Coastal Engineering* 19:1–25.

Seabrook, S., and K. Hall. 1998. Wave transmission at submerged rubble mound breakwaters. In *Proceedings, 26th Coastal Engineering Conference*, 2000–2013. ASCE.

Shepard, F. P. 1950. *Beach cycles in southern California*. Technical Memorandum 20. Washington, DC: U.S. Army Corps of Engineers, Beach Erosion Board.

Smith, E. R., P. Wang, B. A. Ebersole, and J. Zhang. 2009. Dependence of total longshore sediment transport rates on incident wave parameters and breaker type. *Journal of Coastal Research* 25(3):675–683.

Stauble, D. K., J. M. Hubertz, R. J. Hoban, C. R. Livingston, C. E. Pollock, and D. R. Levin. 1994. *Coastal studies on support of Sargent Beach, Texas, erosion control project*. MP CERC-94-3. Vicksburg, MS: Waterways Experiment Station.

Stauble, D. K. 1998. *Techniques for measuring and analyzing inlet ebb-shoal evolution*. CETN-IV-13. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Thieler, E. R, O. H. Pilkey, Jr., R. S. Young, D. M. Bush, and F. Chai. 2000. The use of mathematical models to predict beach behavior for U.S. coastal engineering: A critical review. *Journal of Coastal Research* 16(1):48–70.

Thomas, R. C., and L. Dunkin. 2012. *Erosion control and environment restoration plan development, Matagorda County, Texas, phase 1*. ERDC/CHL TR-12-08. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Walton, T. L., and W. D. Adams. 1976. Capacity of inlet outer bars to store sand. In *Proceedings, 15th Coastal Engineering Conference*, 1919–1937. ASCE.

Wang, P., N. C. Kraus, and R. A. Davis. 1998. Total rate of longshore sediment transport in the surf zone: Field measurements and empirical predictions. *Journal of Coastal Research* 14(1):269–283.

Young, R. S., O. H. Pilkey, D. M. Bush, and E. R. Thieler. 1995. A discussion of the generalized model for simulating shoreline change (GENESIS). *Journal of Coastal Research* 11(3):875–886.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED *(From - To)*
August 2014	Final	**May 2013 – June 2014**

4. TITLE AND SUBTITLE
Recommendations and Requirements for GenCade Simluations

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Ashley E. Frey, David B. King, and Sophie Munger

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd.
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/CHL TR-14-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This is the second report in a series describing applications with the new shoreline change and sand transport model, GenCade. It is considered as a companion report to the first report in the GenCade series, Frey et al. (2012a), and provides additional details that were not described in that report. This report describes basic assumptions in GenCade, requirements to run the model, and recommendations about important GenCade capabilities. While all of the basic assumptions are discussed, this report also considers if the assumptions are satisfied and describes a procedure to follow when they are not. All of the required and optional input and output files are explained, and common user errors in model setup, with solutions, are detailed. These user errors may not be evident to new users but are easily corrected. Although the model will run even if the recommendations are not followed, the results may not represent the regional system as well as if properly set up. The recommendations section explains specific capabilities like the regional contour and the Inlet Reservoir Model (IRM) and topics such as project work flow and grid cell spacing. By following these recommendations, the user will produce better results. Finally the path forward for the model and future guidance are discussed.

15. SUBJECT TERMS
GenCade
Work flow
Shoreline change
Inlet Reservoir Model
Sand transport
Regional contour
Surface-water Modeling System
Stability parameter

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			**Ashley E. Frey**
Unclassified	Unclassified	Unclassified	Unclassified	163	**19b. TELEPHONE NUMBER** *(Include area code)* **601-634-2006**