GenCade: Introduction, Background, and Formulation

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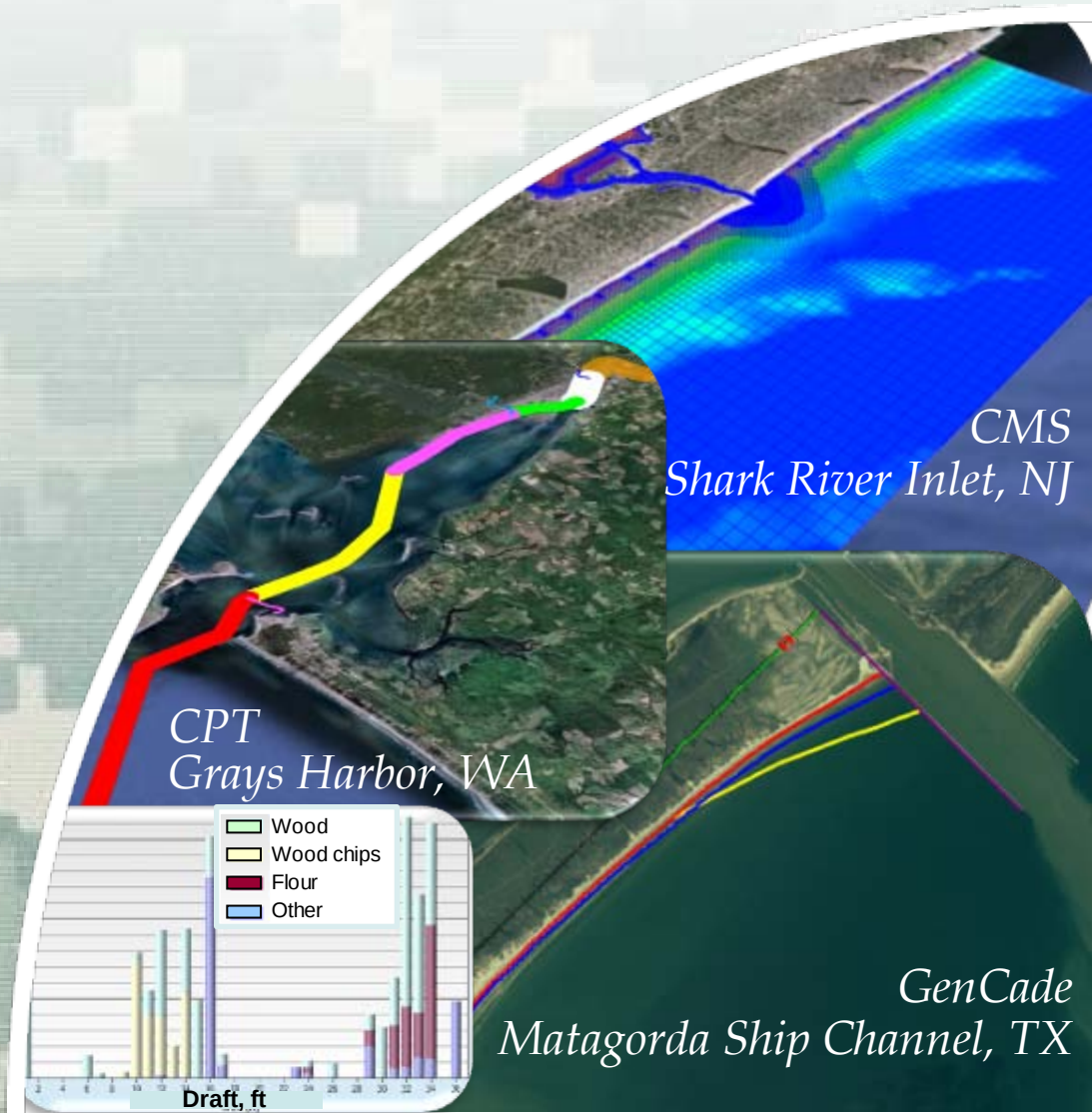

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Outline

- What is GenCade?
- Background, overview, and conceptual coverage
- GenCade capabilities
- GenCade limitations and assumptions
- Workflow
- Model theory and formulation
- I/O Files and Cards
- GenCade interface in SMS
- Future Development

GENESIS + Cascade → GenCade

Cascade (top to bottom)

- Planning tool (RSM Support)
- Time scales: months to centuries
- Multiple inlets, shoals, and barrier islands; cumulative impacts; retains curvature of regional geomorphology
- Fast
- Typical grid resolution ~ 500 m
- Cross-shore processes in future

GENESIS (bottom to top)

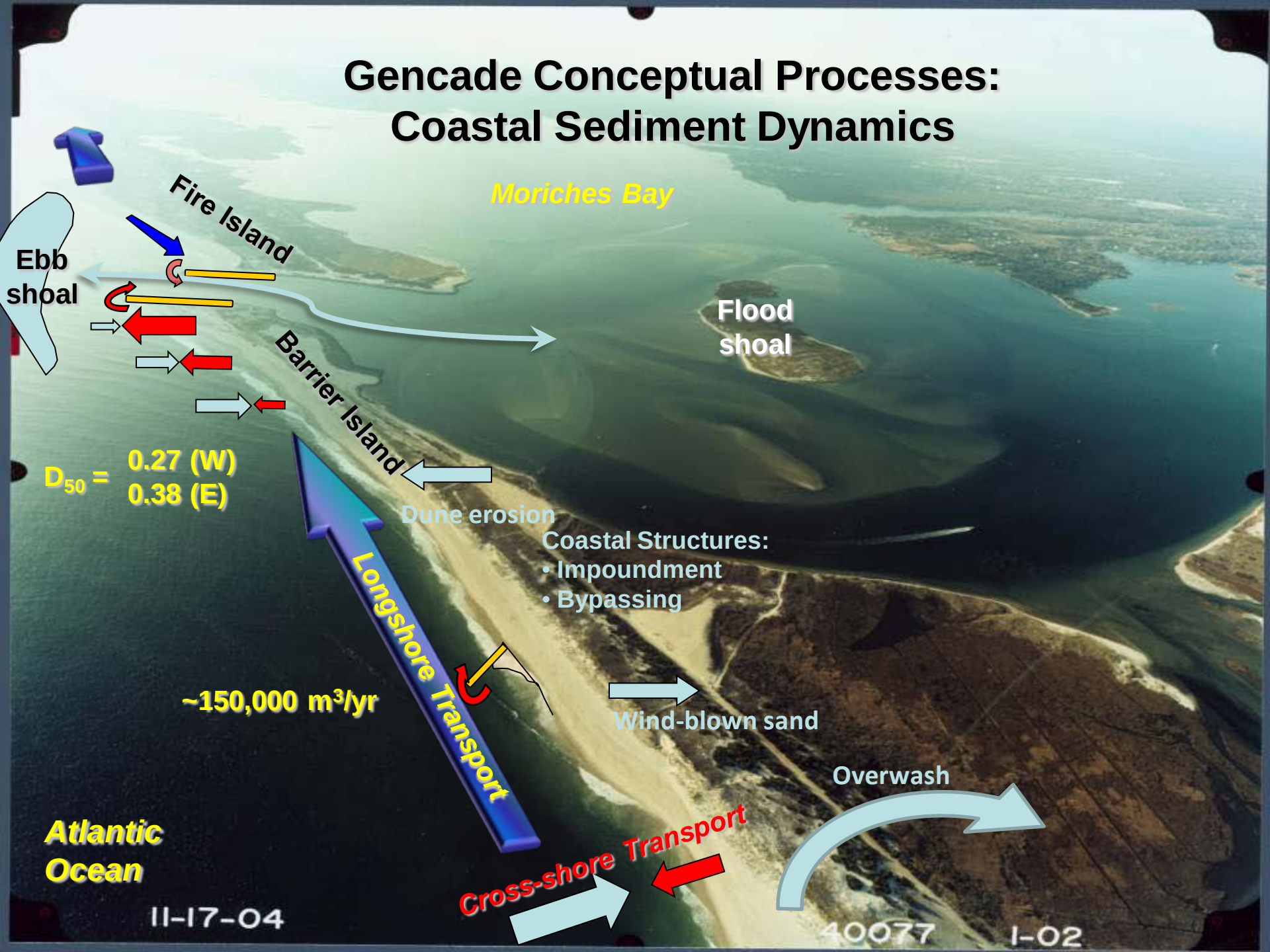
- Engineering design tool
- Can represent all engineering details – structures, etc.
- Mature technology – big payback by updating
- Typical grid resolution ~ 25 m

Strategy: Add Cascade capabilities to GENESIS to automatically include all GENESIS features

GENESIS + Cascade → GenCade

- Integrate from planning through engineering design
- Cover time scales from days to centuries
- Preserve regional trends
- Furnish regionally consistent boundary conditions to local projects
- Represent cumulative local projects interacting regionally
- Represent inlet bypassing and tidal delta evolution
- Resolve engineered elements
- Include variable grid resolution for accuracy and efficiency
- Improve computational efficiency (over GENESIS)

Strategy: Add Cascade capabilities to GENESIS to automatically include all GENESIS features


Gencade Conceptual Processes:
Coastal Sediment Dynamics
Moriches Bay
Fire Island
Ebb shoal
Flood shoal
Barrier Island
D_{50} = 0.27 (W)
0.38 (E)
Dune erosion
Coastal Structures:
• Impoundment
• Bypassing
Longshore Transport
~150,000 m³/yr
Wind-blown sand
Overwash
Cross-shore Transport
Atlantic Ocean
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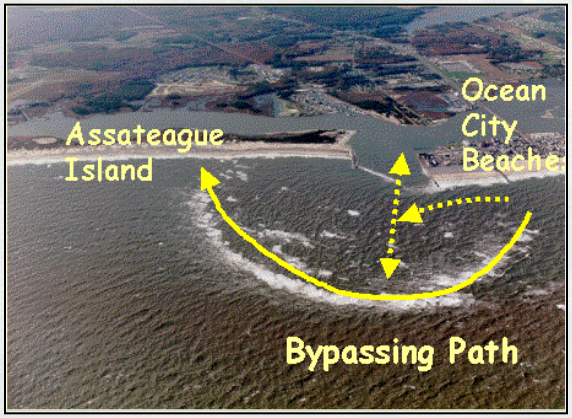
GenCade Applicability

Regional processes,
Long-term morphology change

Project Planning & Design



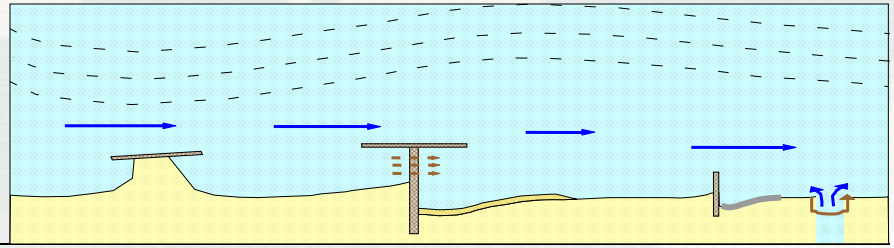
Habitat Change

- Regional Sediment Management
  - Beach fills
  - Inlet bypassing
  - Channel maintenance
- Unifying technology for multiple projects
- Intuitive interface (SMS)

- Storm erosion hazard management
- Dune erosion, overwash, & breach susceptibility; coastal response to SLR
- Habitat evolution (Piping Plover; vegetation)

Model Functionality and Capabilities

- Variable resolution grids
- Inlet bypassing
- Inlet Reservoir Model for calculation of shoal and inlet feature sediment balance
- Representation of regional morphologic trends
- Multiple wave input forcing locations
- Representation of coastal structures: groins, jetties, seawalls, t-head groins, breakwaters, etc.
- Calculation of salients and tombolos behind breakwaters
- Time-dependent detached breakwater transmission
- Efficient calculation of breaking wave properties in internal wave model



GenCade Assumptions

- Beach profile maintains a constant average shape
- Longshore transport occurs only between top of berm and depth of closure (or active transport)
- Sand transported alongshore by breaking waves is not affected by nearshore current patterns
- There is a long-term trend in shoreline evolution

General Workflow

- Coastal Problem
  - Formulate question
  - Identify constraints
  - Develop criteria to review and evaluate the solutions
- Assemble and analyze relevant input data
- Develop engineering solutions and alternatives
- Develop and execute GenCade to optimize project solutions and alternatives
- Calibrate, Validate, Evaluate Alternatives
- Monitor and evaluate results

GenCade Workflow

Pre-Process

- Compile project data
- Assimilate data as GenCade forcing or BC input
- Develop conceptual model from input data
- Develop GenCade project grid and alternatives

Simulate

- Execute calibration simulations/sensitivity tests
- Review and analyze calibration results
- Refine setups
- Execute production simulations

Post-Process

- Review results
- Analyze and post-process results

Inputs:
Survey data
Waves
Structure information
Inlet information
Beach Fill
Dredging

Pre-process inputs

GenCade grid regular/irregular

- Develop initial shoreline
- Develop regional contour
- Assign wave inputs
- Supply input control parameters
- Structures or coastal projects
- Inlets, shoals, dredging events
- Beach fill events

Simulation outputs:
GenCade solution files

Inputs:

GenCade Solution files;
Measured Data

Post-process

- Transport rates
- Sediment budgets
- Shoreline Change
- Inlet bypass/shoal evolution
- Compare measured
- Compare alternatives

Post-process outputs:
Calculations, figures,
images, exported data

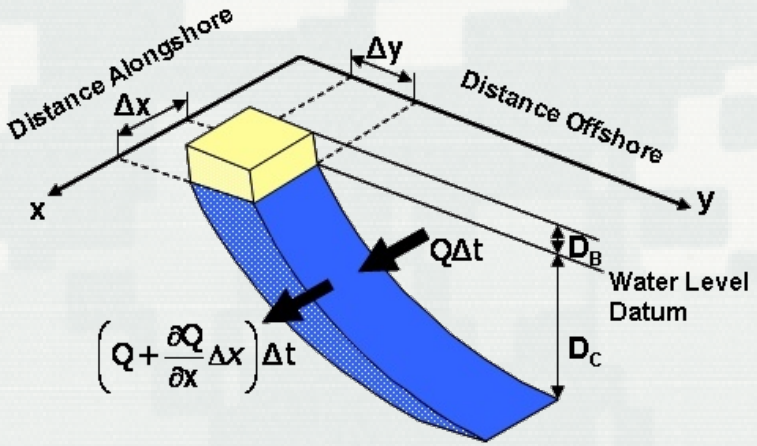
Model Formulation

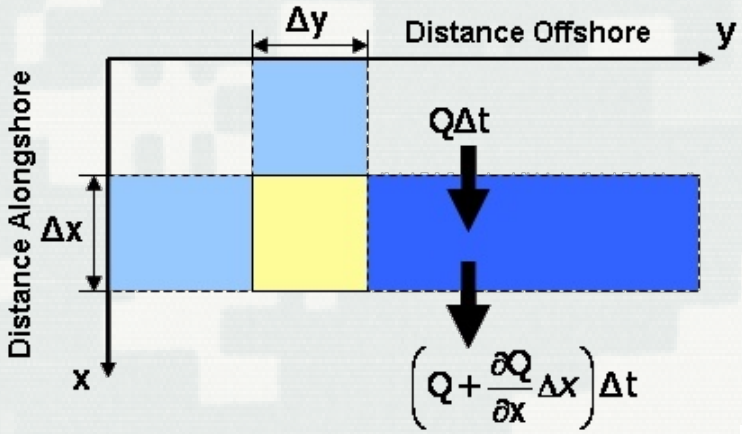
Longshore Net Volume Change: $$\frac{dQ}{dt} = \left(\frac{\partial Q}{\partial x}\right) dxdt$$

Cross-shore Net Volume Change: $$dqdt$$

Total Volume Change: $$dV = dxdy\left(D_B + D_C\right) = \left(\frac{\partial Q}{\partial x}\right) dxdt + qdxdt$$

$$\therefore \text{ as } dt \rightarrow 0: \quad \frac{\partial y}{\partial t} + \frac{1}{D_B + D_C} \bullet \left[\frac{\partial Q}{\partial x} - q\right] = 0$$



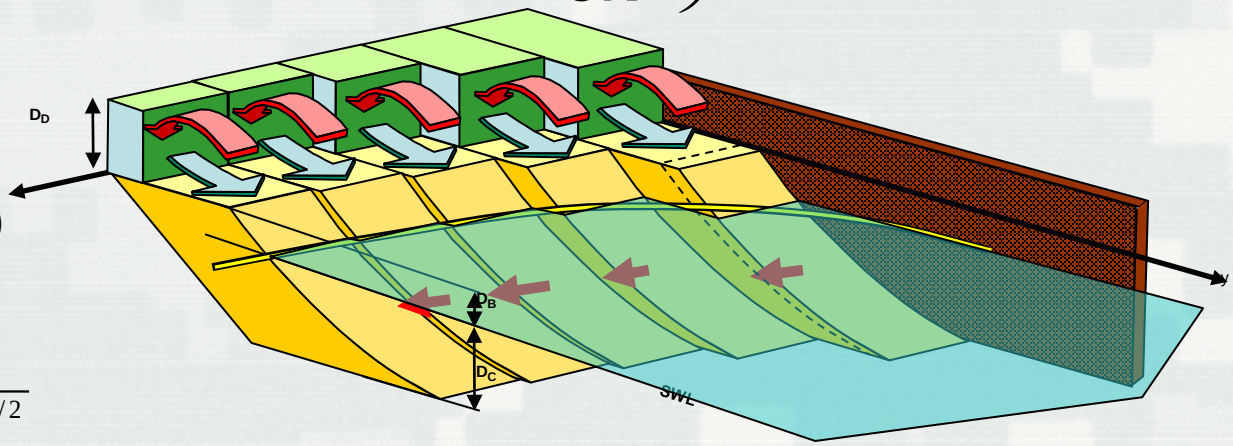


Model Formulation

Sediment transport rate Q (m³/s):

$$Q = \left(H^2 C_g \right)_b \left(a_1 \sin 2\alpha_{bs} - a_2 \cos \alpha_{bs} \frac{\partial H_b}{\partial x} \right)$$

Where,
H = wave height (m)
C_g =wave group speed (m/s)
α_{bs} = angle of the breaking



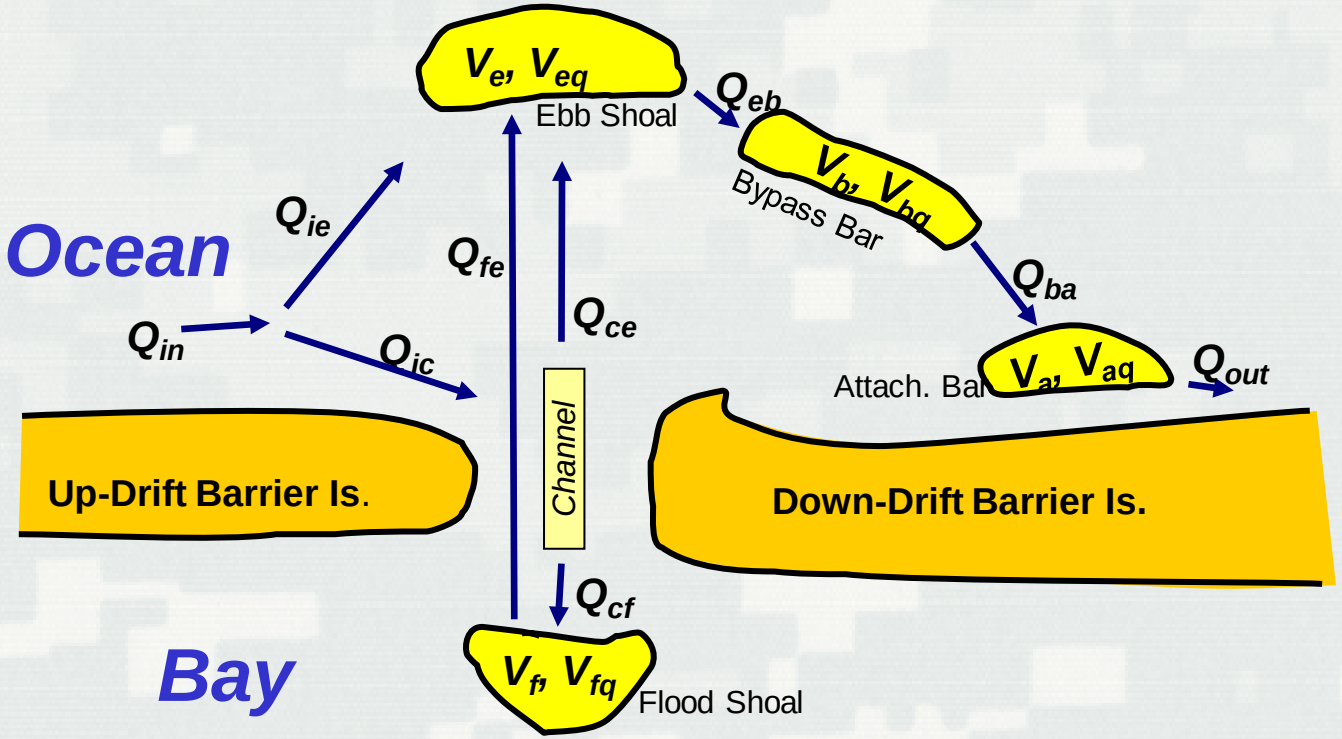
$$a_1 = \frac{K_1}{16(\rho_s / \rho - 1)(1 - p)1.416^{5/2}}$$

$$a_2 = \frac{K_2}{8(\rho_s / \rho - 1)(1 - p)\tan\beta \; 1.416^{5/2}}$$

Typically, value of K_2 is:
$0.5K_1 < K_2 < 1.5K_1$

Where,
K_1 = Primary empirical transport coefficient (controls magnitude of longshore transport rate)
K_2 = Secondary empirical transport coefficient (controls distribution of sand within an area; esp. where large wave height gradients, e.g. salients)
tanβ = average bottom slope

Inlet Reservoir Model
Inlet bypassing and evolution of inlet deltas



$$Q_{ie} = \delta Q_{in}$$
$$Q_{ic} = (1-\delta) Q_{in}$$
$$Q_{ce} = \beta Q_{ic} = \beta(1-\delta) Q_{in}$$
$$Q_{cf} = (1-\beta) Q_{ic} = (1-\beta)(1-\delta) Q_{in}$$
$$Q_{fe} = (V_f - V_{fq})/dt,\ V_f > V_{fq}$$

$$Q_{eb} = \frac{V_e}{V_{eq}}(Q_{ie} + Q_{fe} + Q_{ce})$$
$$Q_{ba} = \frac{V_b}{V_{bq}} Q_{eb}$$
$$Q_{out} = \frac{V_a}{V_{aq}} Q_{ba}$$
$$\delta = (V_e + V_f)/(V_{eq} + V_{fq})$$

$$dV_e = (Q_{ie} + Q_{fe} + Q_{ce} - Q_{eb})dt$$
$$dV_f = (Q_{cf} - Q_{fe})dt$$
$$dV_b = (Q_{eb} - Q_{ba})dt$$
$$dV_a = (Q_{ba} - Q_{out})dt$$
$$\beta = (1 - V_e/V_{eq})/(2 - V_e/V_{eq} - V_f/V_{fq})$$

Output File Format for GenCade

Instantaneous Net Transport at Output Time (*.qtr) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	Net sediment transport (length^3/year) for each grid cell

Mean Net Transport Over Simulation or Specified Time (*.mqn) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	Net sediment transport (length^3/year) for each grid cell averaged over entire simulation (and optionally from start to specified times)

Mean Left Transport Over Simulation or Specified Time (*.mql) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	sediment transport (length^3/year) to left for each grid cell averaged over entire simulation (and optionally from start to specified times)

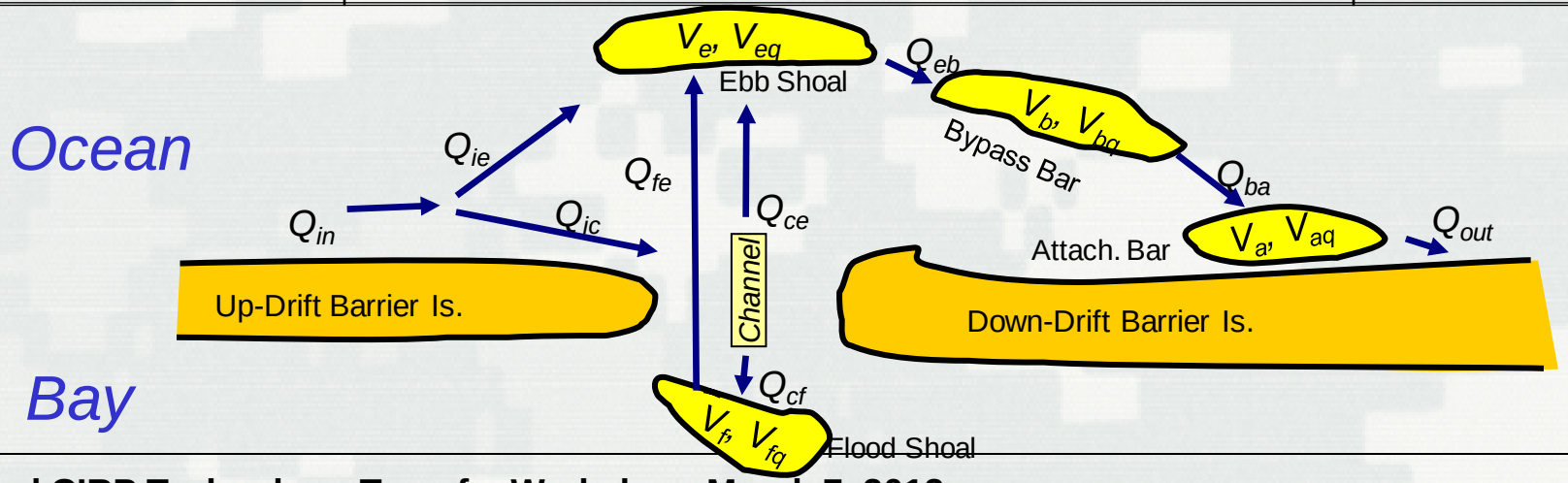
Mean Right Transport Over Simulation or Specified Time (*.mqr) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	sediment transport (length^3/year) to right for each grid cell averaged over entire simulation (and optionally from start to specified times)

Output File Format for GenCade

Shoreline Position at Output Time (*.slo) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	Y-position of shoreline (length unit) for each grid cell

Calculated Offshore Contour at Output Time (*.off) File	
Column 1	**Column 2 through Column NX**
Date (yyyymmdd)	Y-position of offshore contour applied to wave transformation (length unit) for each grid cell

Inlet Shoal Volume Output (*.irv) File (one file for each inlet)		
Column 1	**Column 2 Through Column 16**	**Column 17**
Time-step at which shoal volumes are printed as output	Shoal volume (length^3) or in /.out volume at each shoal output time-step for the morphological shoal features identified in the figure below	Date (yyyymmdd)



GenCade Input Cards

- TITLE Title of simulation run
- INIFILE Path and name of initial shoreline file
- REGFILE Path and name of regional shoreline file
- NUMWAVES Number of wave input locations/files
- WAVEID Cell ID; Depth; number of wave events; and file path/name of wave input data (1 WAVEID line/file)
- PRFILE Path and name of printed output file
- GENUNITS (ft) or (m) System of units for model I/O
- X0 X-origin
- Y0 Y-origin
- AZIMUTH Angle (deg) of grid rotation about origin
- NX Number of alongshore cells
- DX Cell resolution or -1 indicates variable resolution
- SIMDATS YYYYMMDD Start date of simulation
- SIMDATE YYYYMMDD Ending date of simulation
- DT 5.0 Time step in hours
- DTSAVE 10.0 Data (shoreline/transport) output times
- K1 0.5 Longshore sediment transport coefficient 1
- K2 0.25 Longshore sediment transport coefficient 2
- PRTOUT Output to PRFILE yes (t), no (f)
- PRWARN Print warnings yes (t), no(f)
- PRDATE Dates to save simulated shoreline
- ISMOOTH 11 #cells in offshore contour smoothing
- IREG Include regional contour (1 = yes; 0 = no)
- HAMP 1.0 Height amplification factor
- THETAAMP 1.0 Angle amplification factor
- THETADEL 0.0 Angle offset
- LMOVY 0.0 Leftward shoreline displacement velocity
- D50 0.33 Grain size diameter in millimeters
- BERMHT 2 Average berm height
- DCLOS 8 Depth of closure
- LBCTYPE 0 Left boundary condition type
- LMOVY 0.0 Leftward shoreline displacement velocity
- LMOVPER 1 Simulation period (0), day(1), time step (2) period for LMOVY
- LGROINY 0.0 Length of left groin from shoreline to seaward tip
- RBCTYPE 0 Right boundary condition type
- RMOVY 0.0 Rightward shoreline displacement velocity
- RMOVPER 1 Simulation period (0), day(1), time step (2) period for RMOVY
- RGROINY 0.0 Length of right groin from shoreline to seaward tip

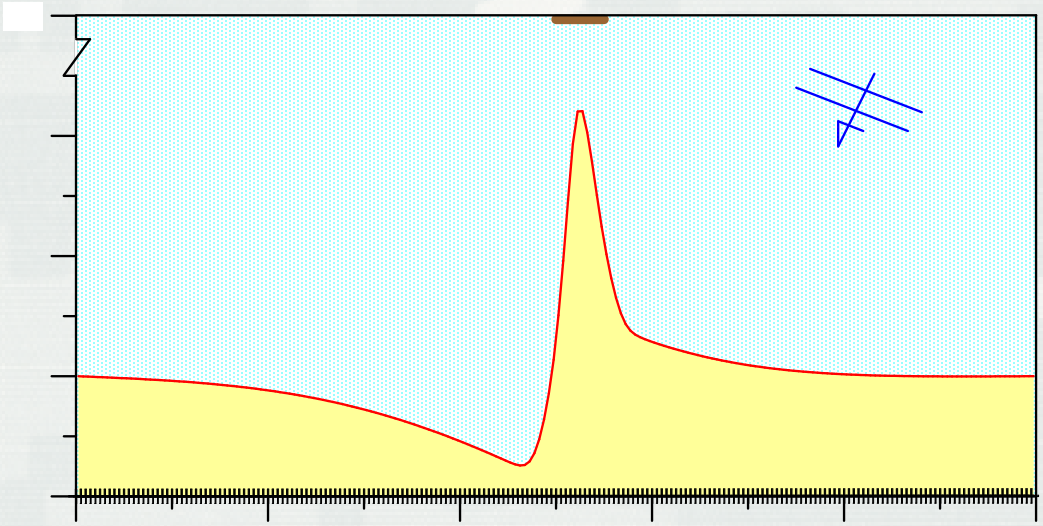
GenCade – Variable Grid Alongshore

Detached Breakwater
3-month simulation

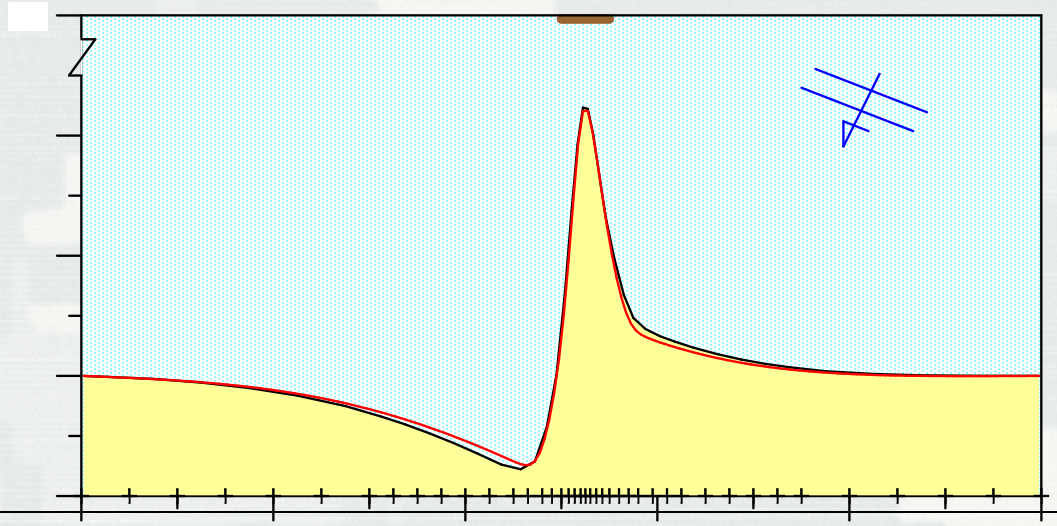
250 m offshore
100 m long

H = 1 m, T = 5 sec, θ = -5 deg.

N = 200
DX = 10 m



N = 40
DX_{max} = 100 m
DX_{min} = 10 m



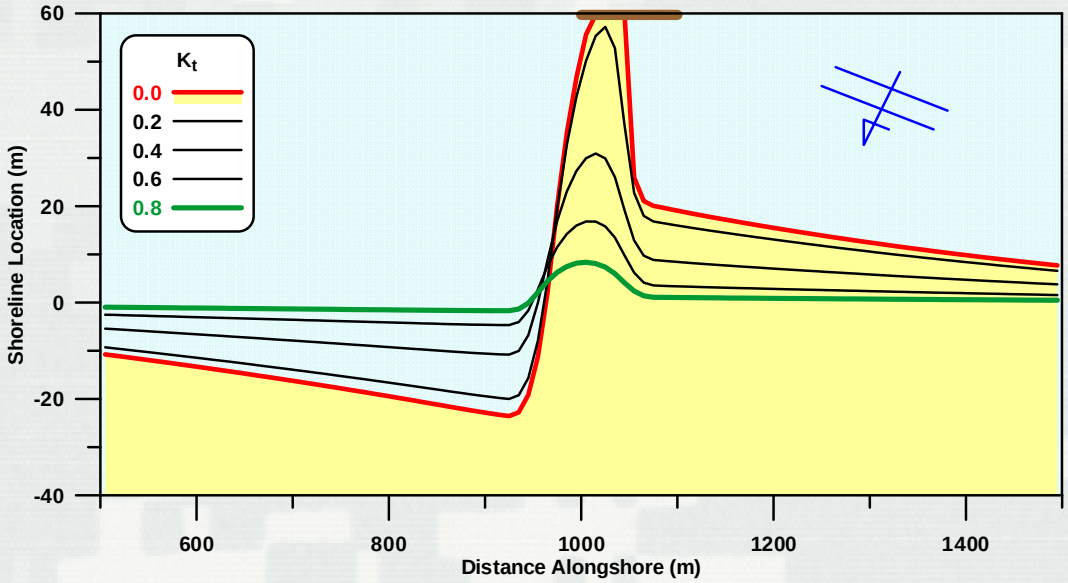
GenCade – Transmissive Breakwater

Detached Breakwater
12-month simulation

60 m offshore
100 m long

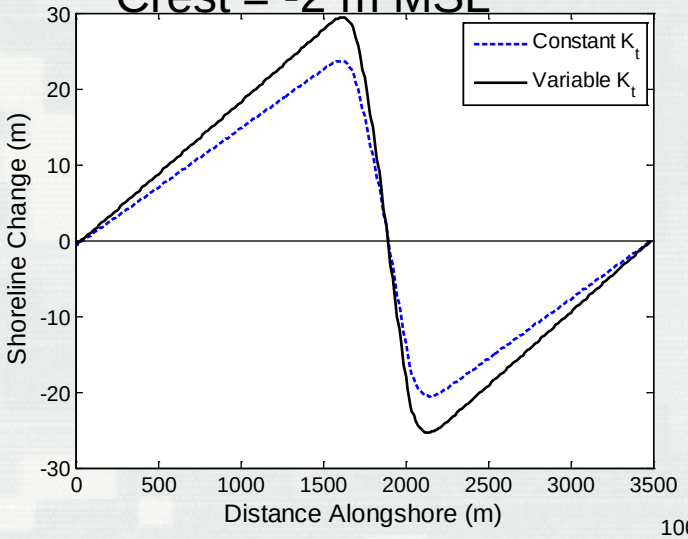
H = 1 m, T = 5 sec, θ = -5 deg.

N = 200
DX = 10 m

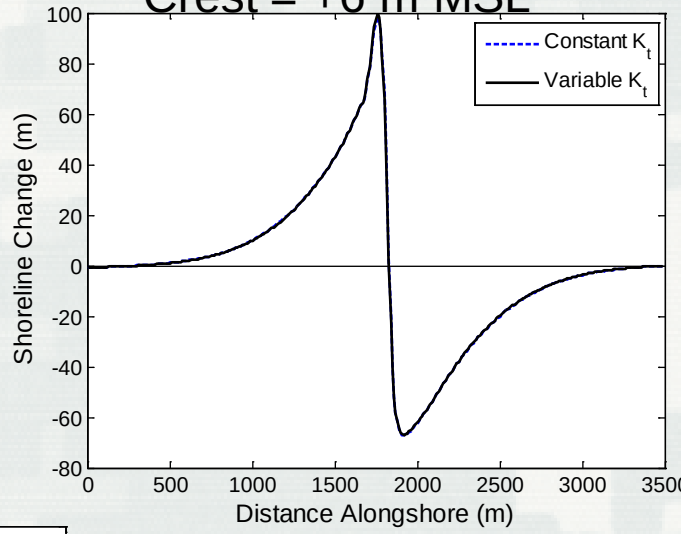


Example -- Variable Wave Transmission

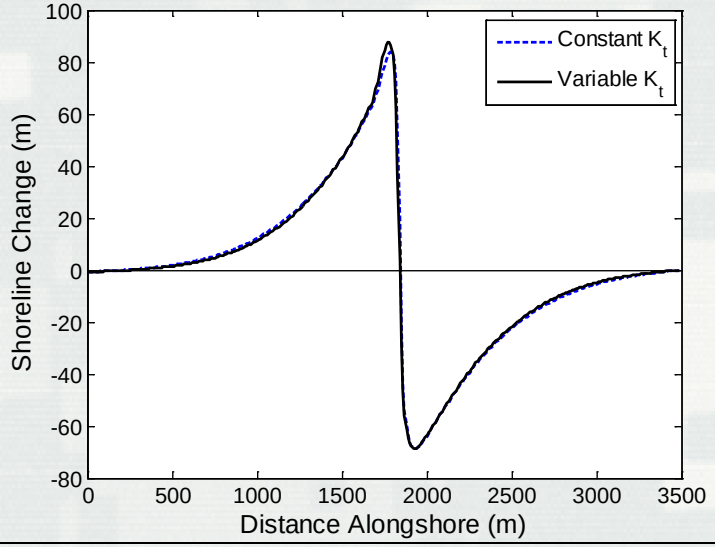
Crest = -2 m MSL



Crest = +6 m MSL

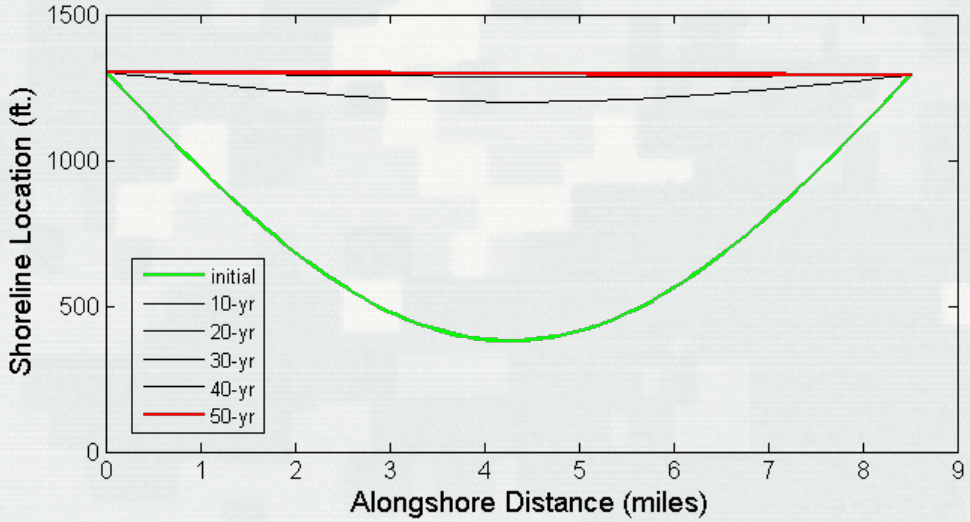


Crest = +1 m MSL

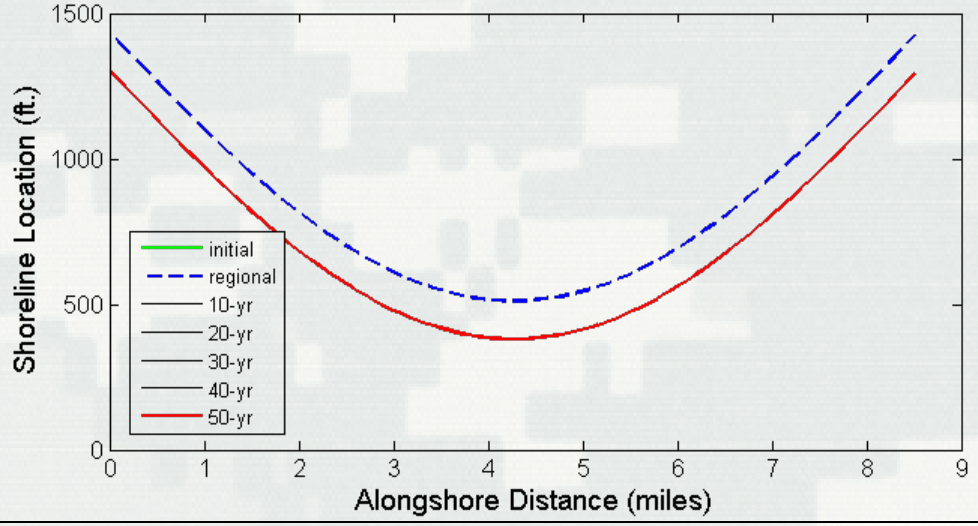


Example
Necessity for Regional Contour

No regional contour

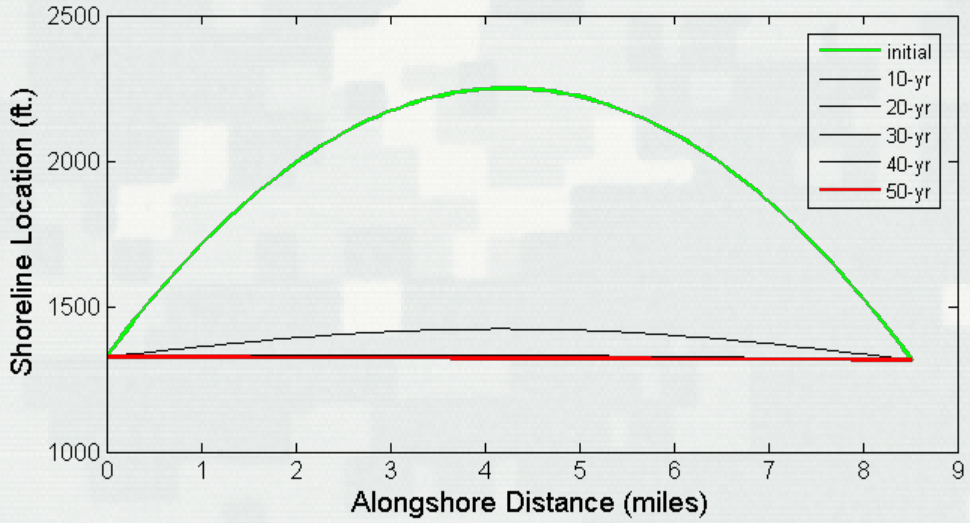


With Regional Contour

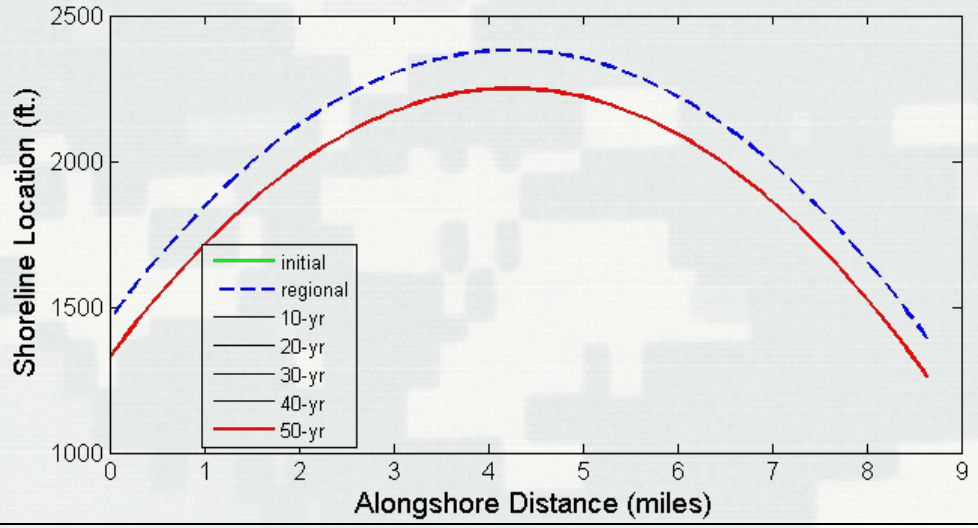


Example
Convex Coast

No regional contour

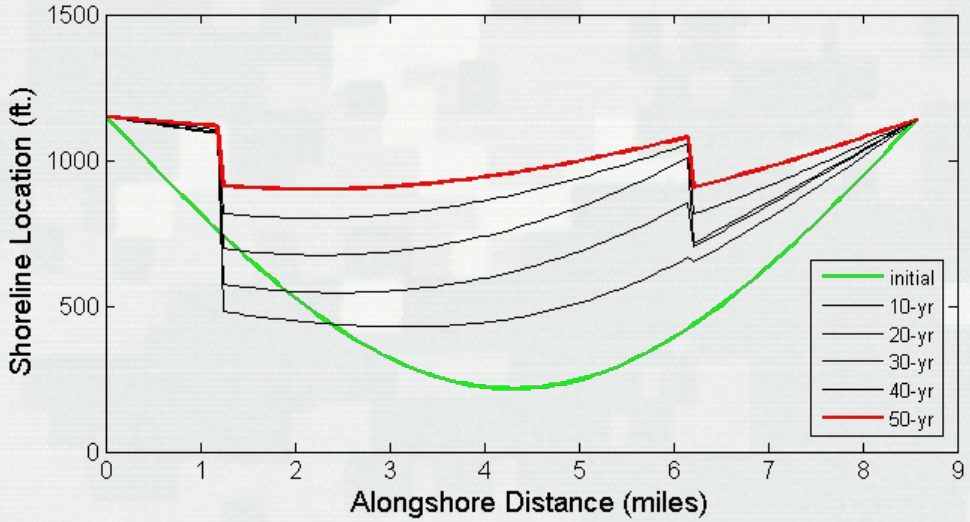


With regional contour

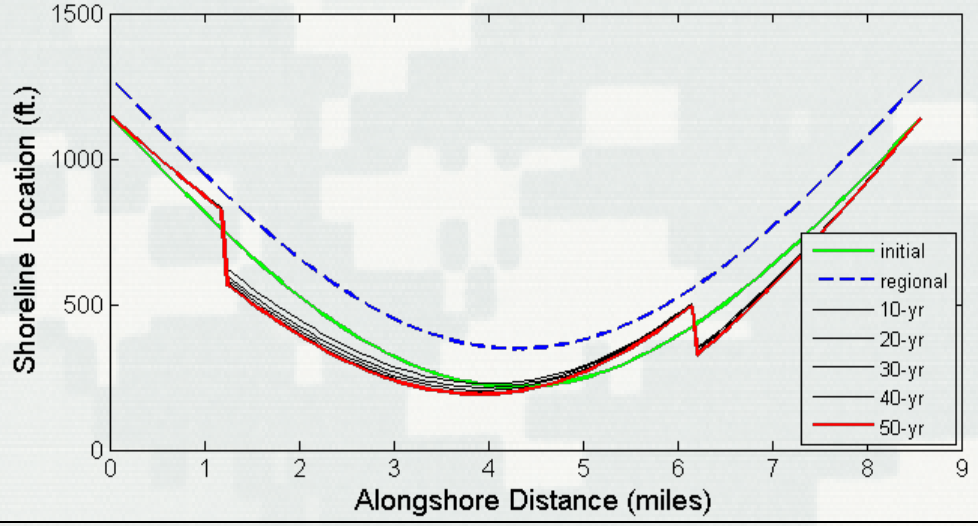


Example – Jetties on Concave Coast

No regional contour



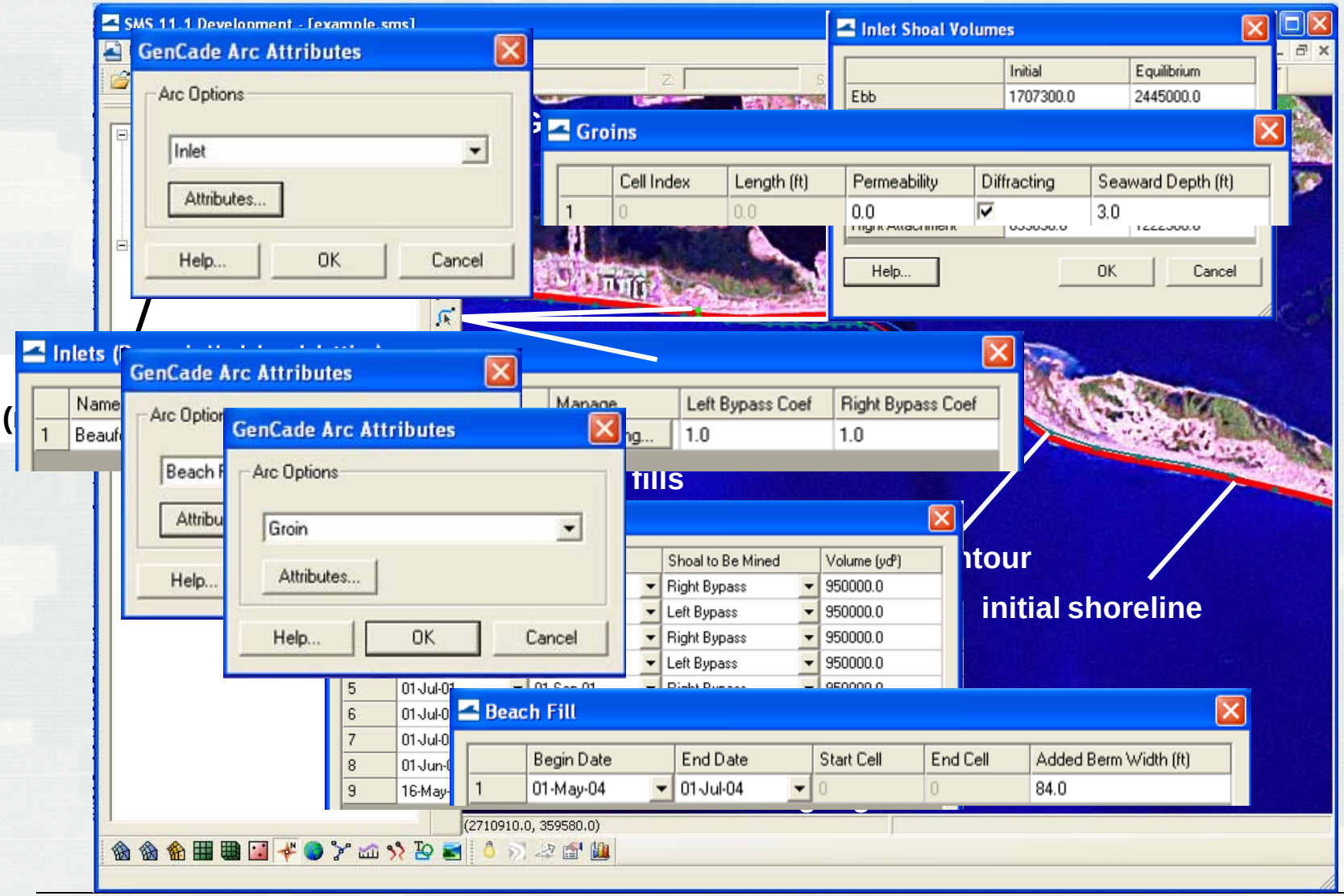
With regional contour



GenCade in the SMS Interface
Surface-water Modeling System

- Intuitive interface for project: conception → completion
  - Data entry, cleaning, and archiving
  - GenCade grid and input development: baseline and alternatives
  - GenCade simulations: baseline and alternatives
  - Post-processing, analysis, and figure generation
- World coordinates – everything georeferenced
- Datum reprojection and transformation
- Georeferenced aerial photograph support
- Improved graphics
- Potential to connect to other USACE numerical models in the SMS

GenCade in the SMS (conceptual model)



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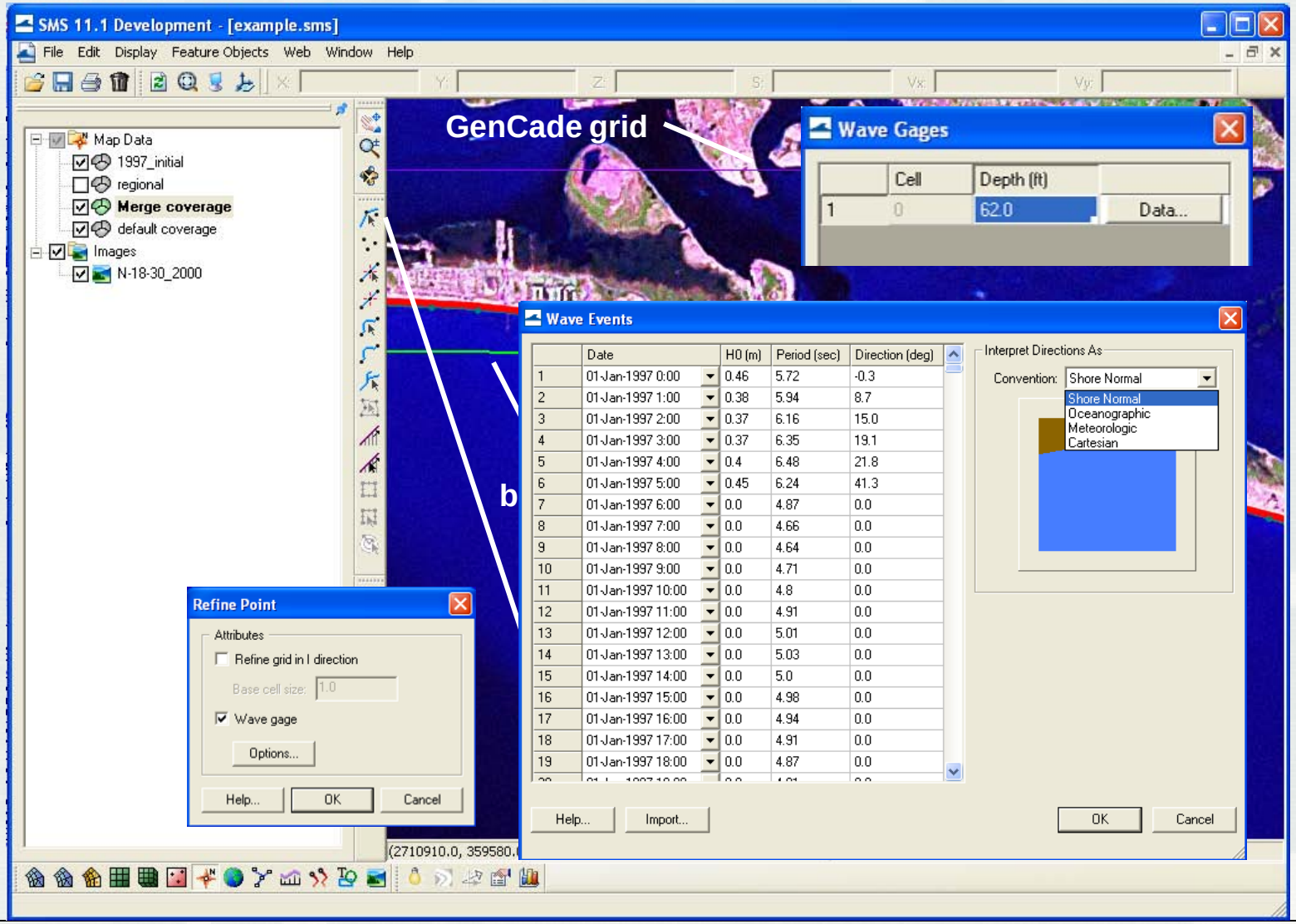

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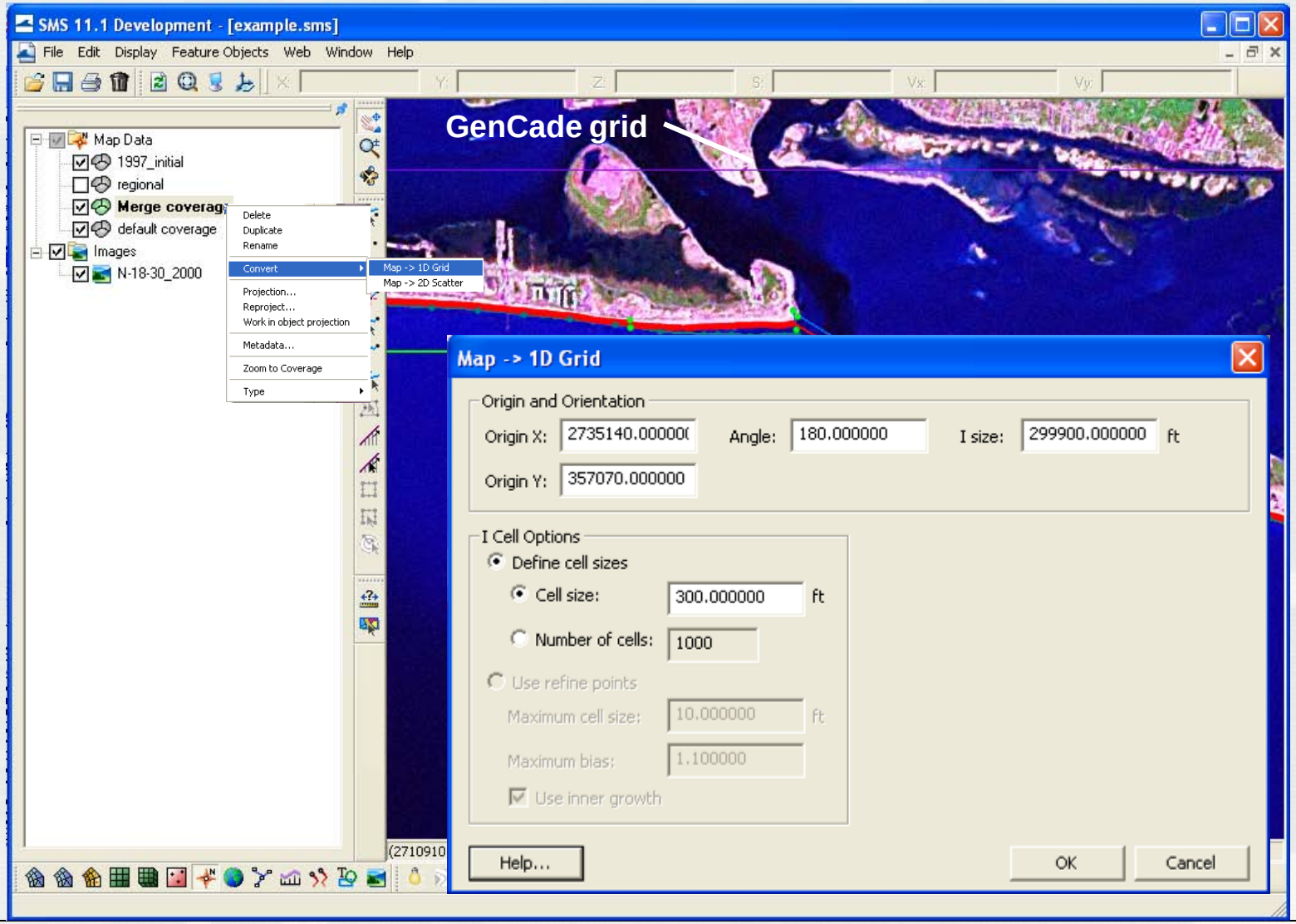
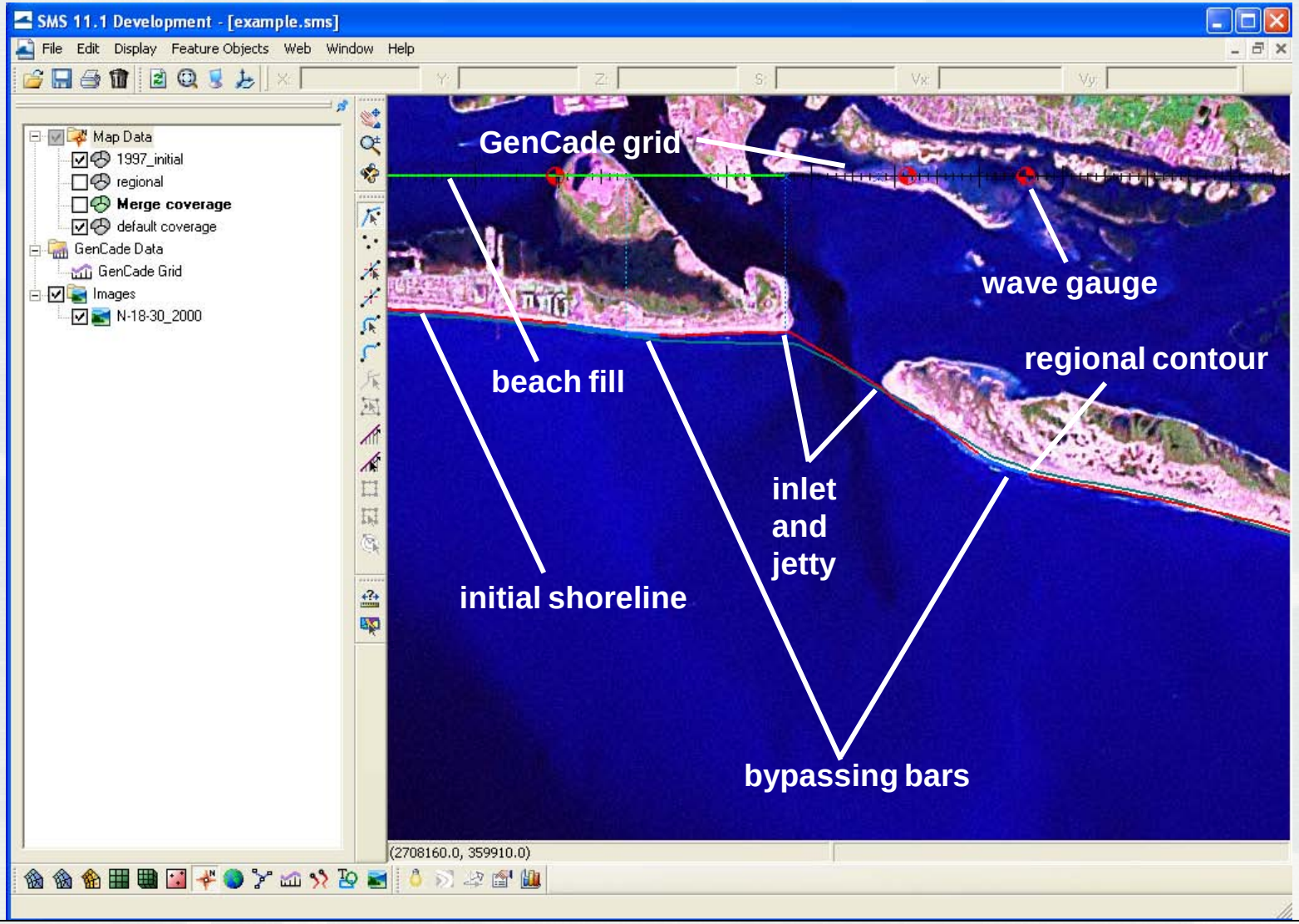


GenCade in the SMS



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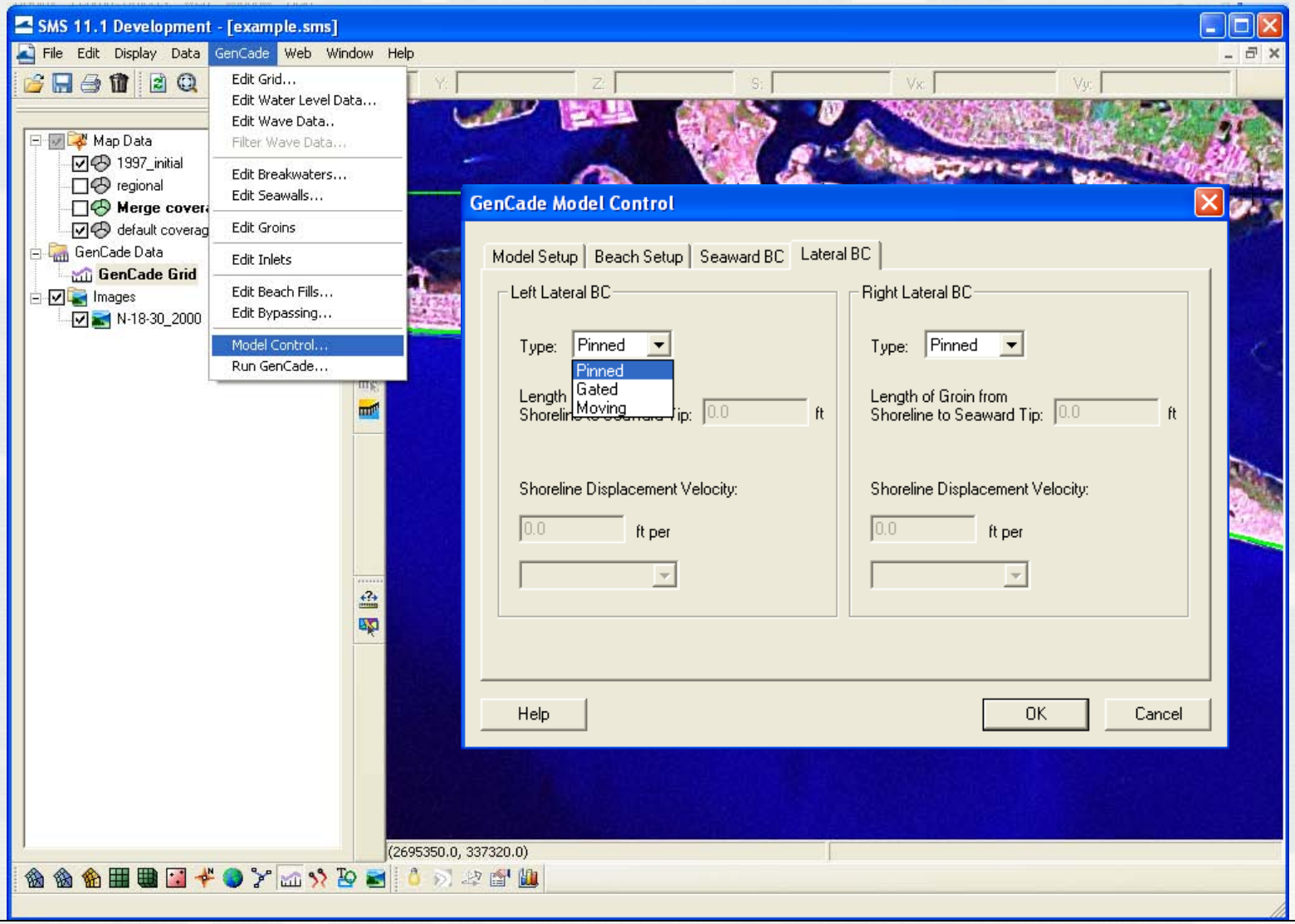

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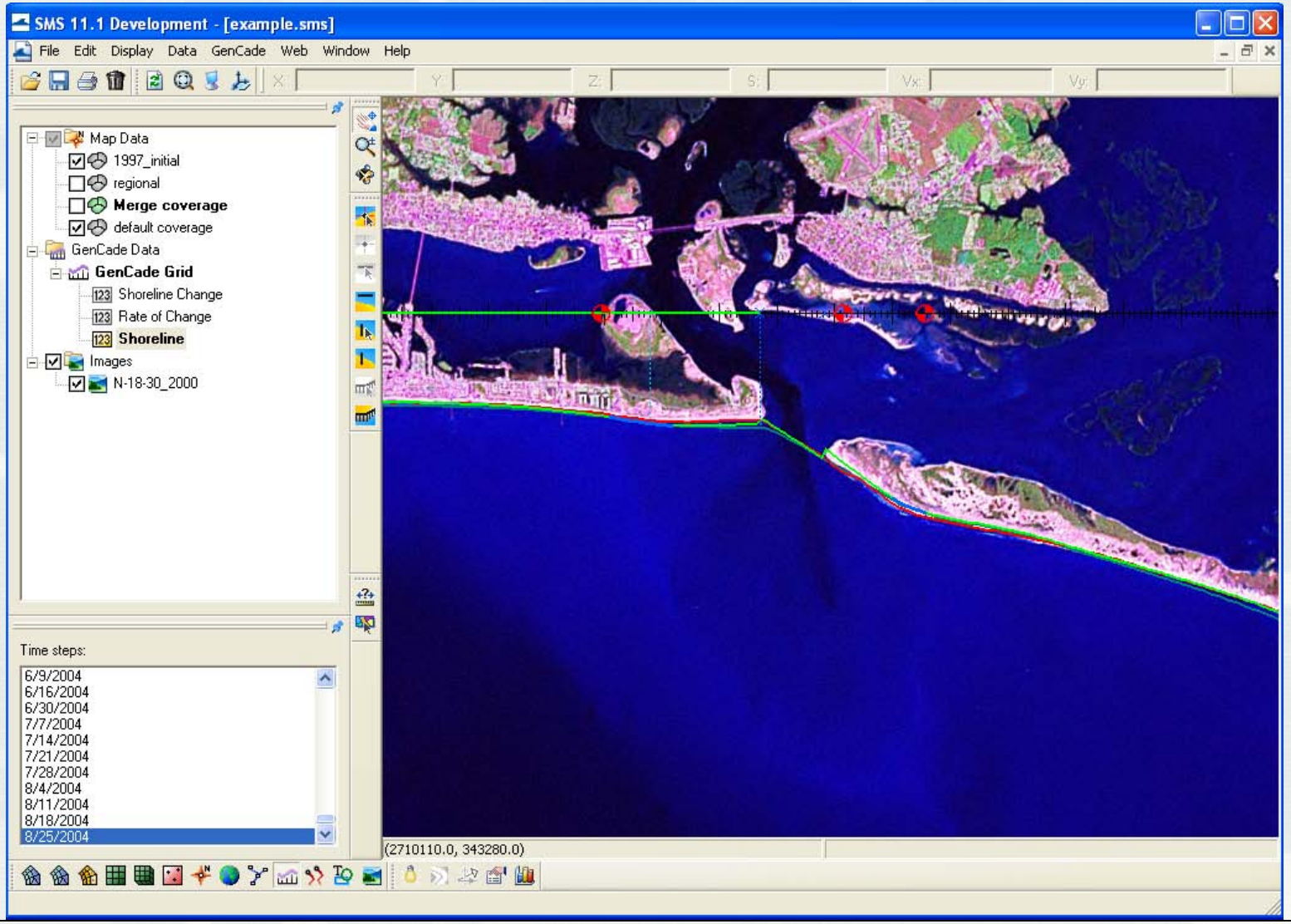

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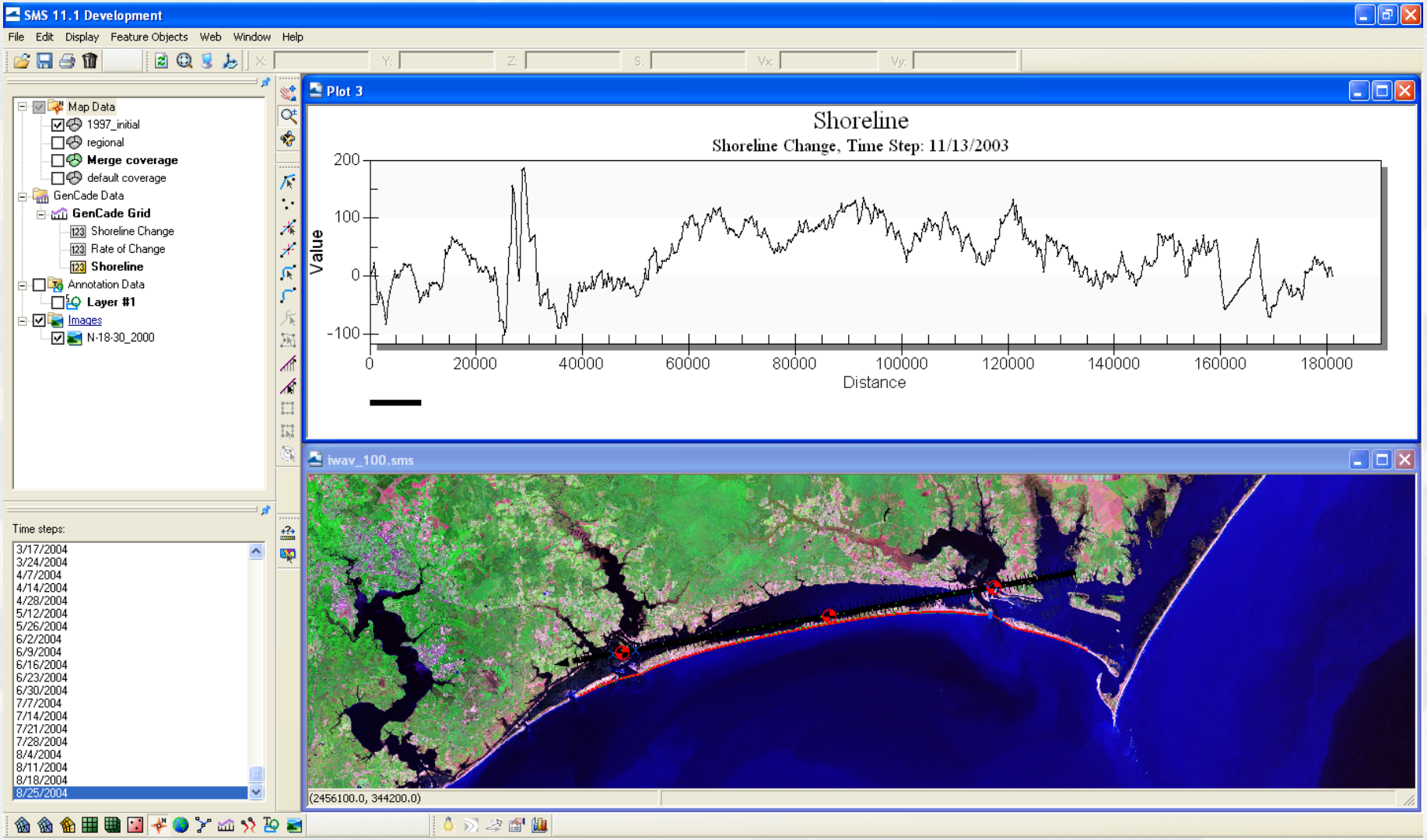

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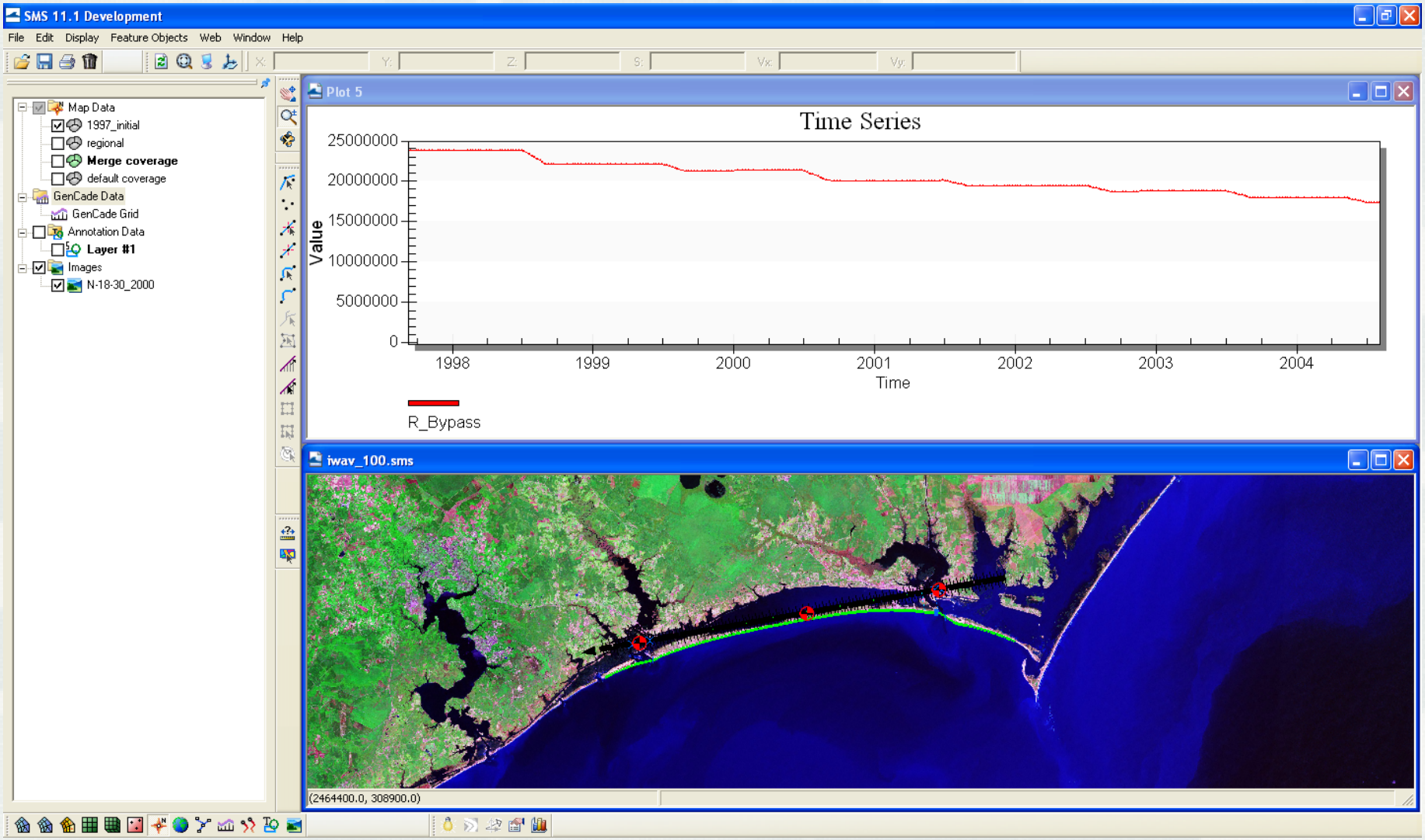
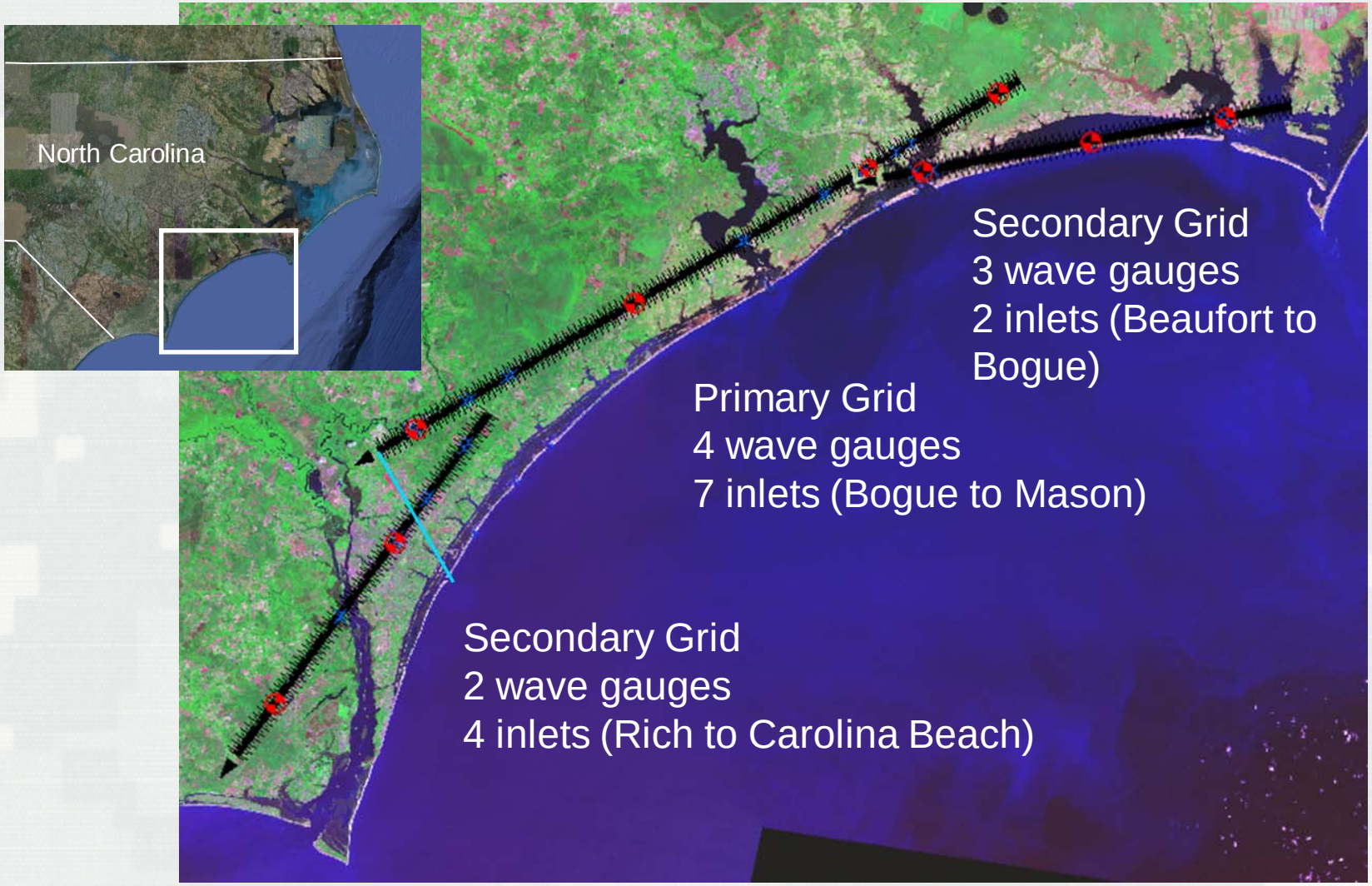


GenCade Application – Onslow Bay, NC



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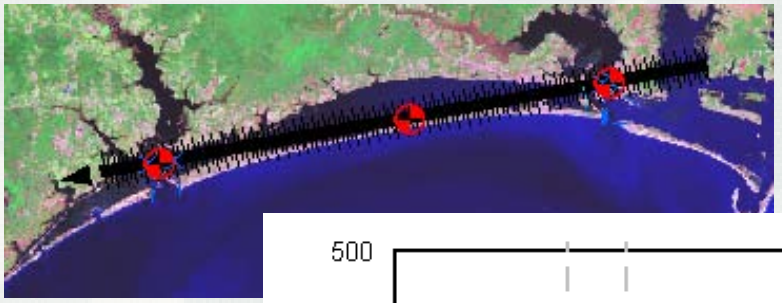

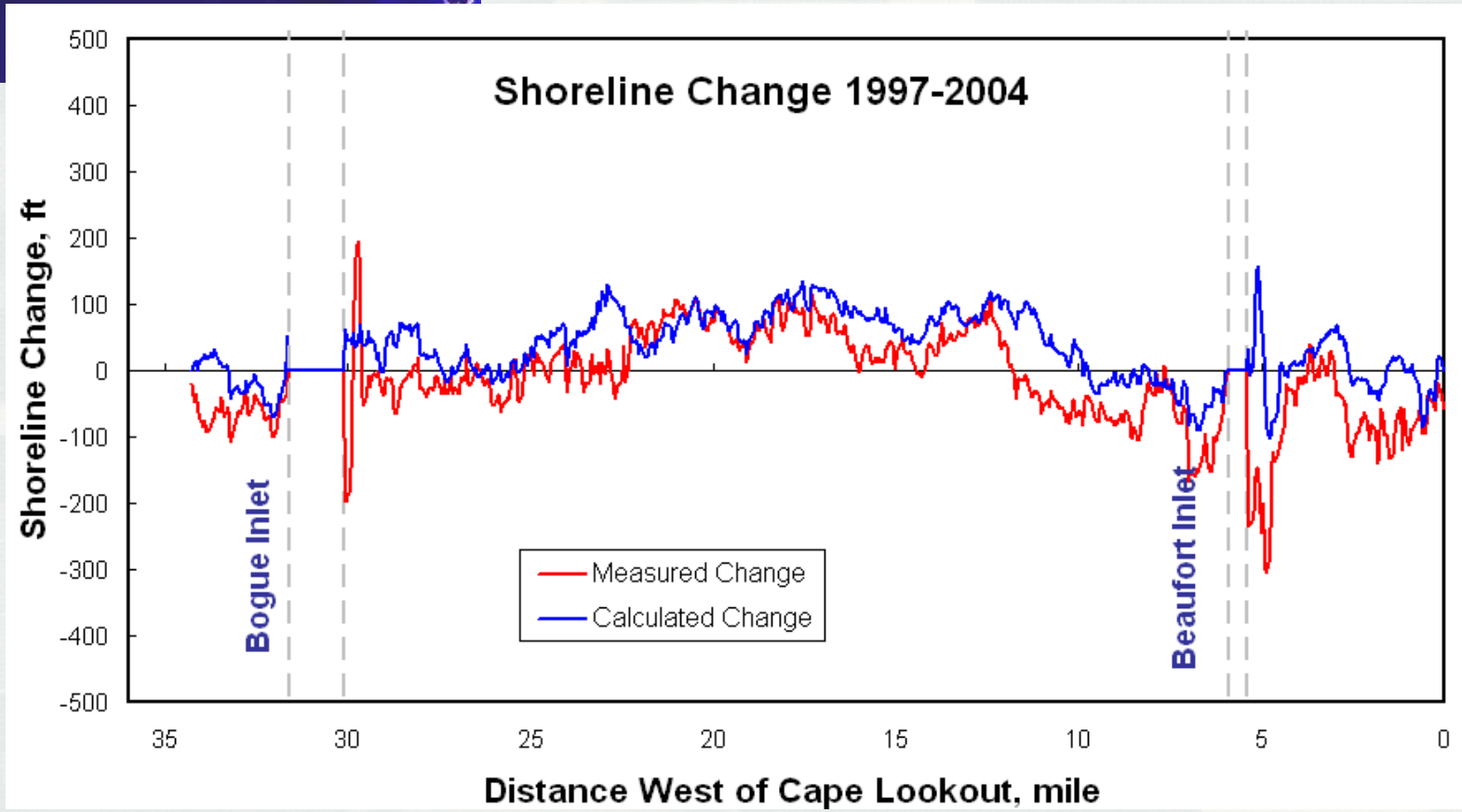

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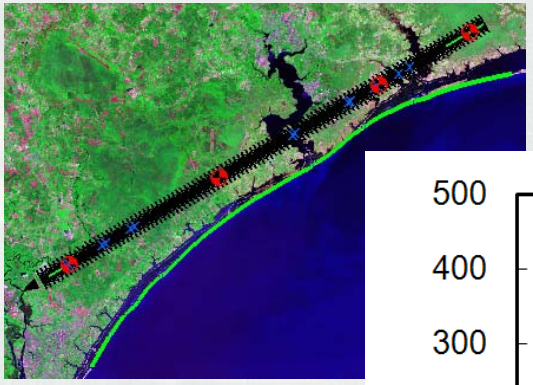
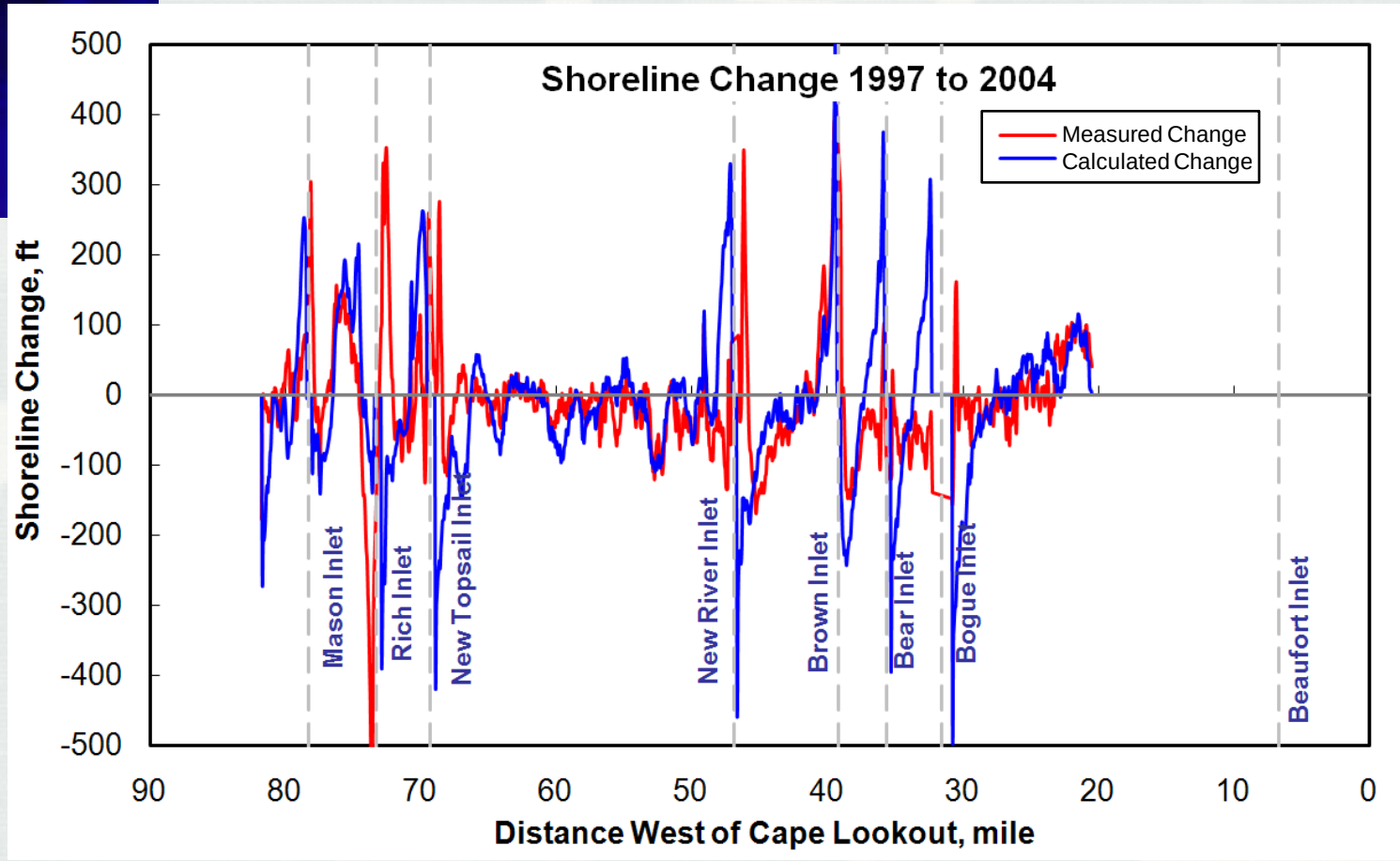
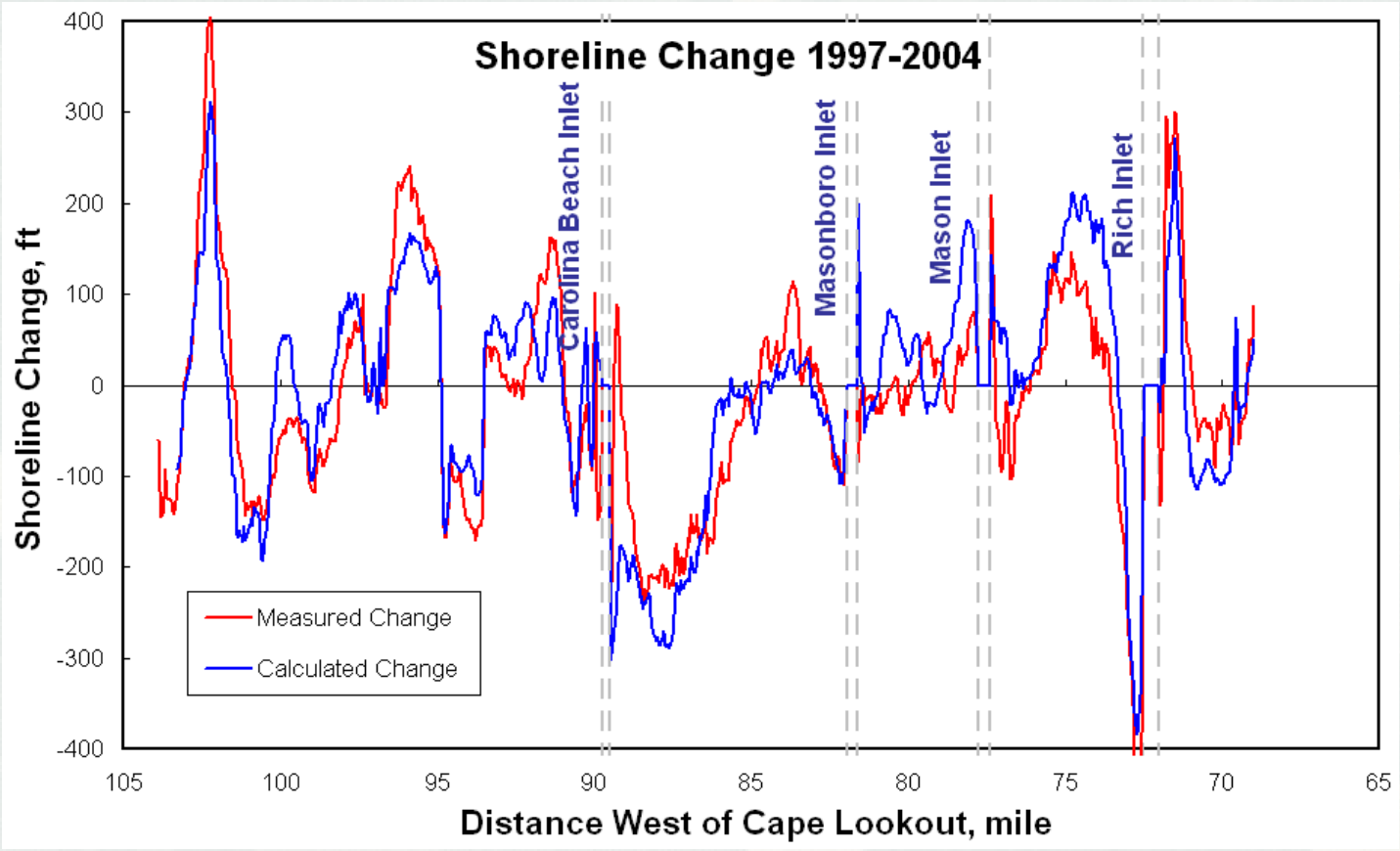




GenCade Application – Onslow Bay, NC

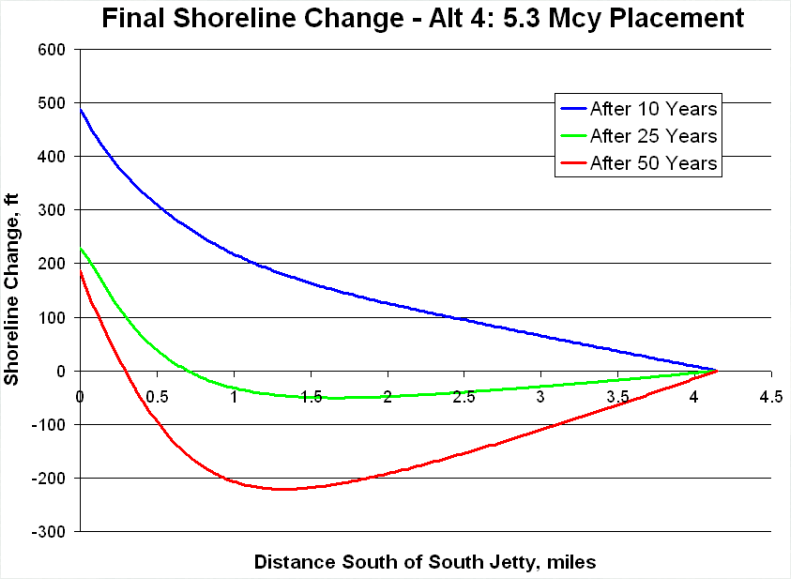


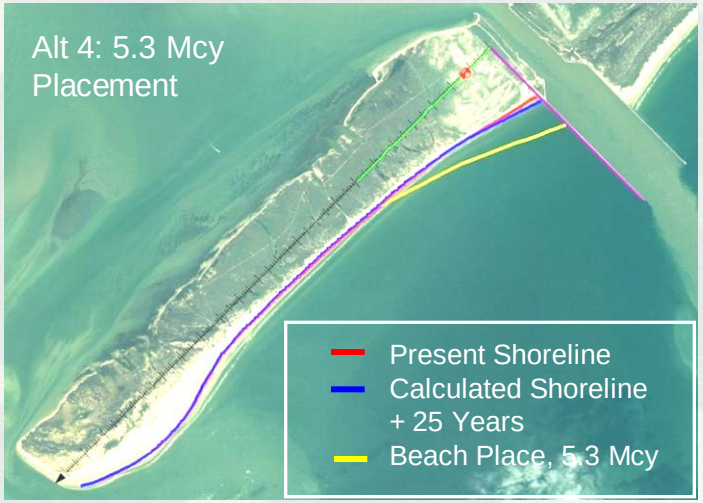
GenCade Application – Matagorda, TX

- Estimated shoreline change south of south jetty on Matagorda Peninsula for three beach placement scenarios after 10, 25, and 50 years

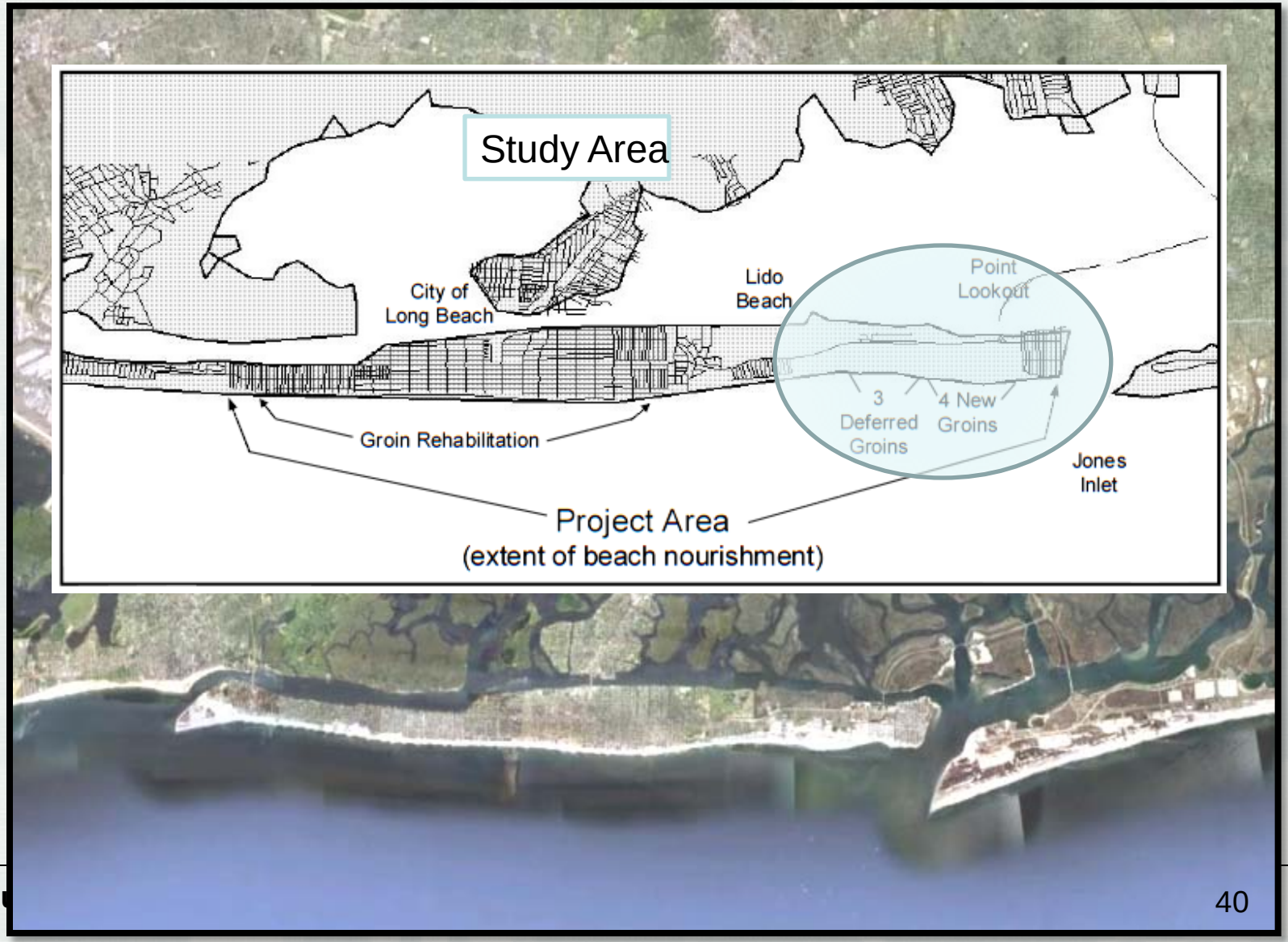
GenCade Application – Matagorda, TX

- Maximum recession after 25 years was about 200 ft for the existing scenario, 120 ft for the 2.65 Mcy placement, 80 ft for the 4 Mcy placement, and 50 ft for the 5.3 Mcy placement





GenCade Application – Point Lookout, NY

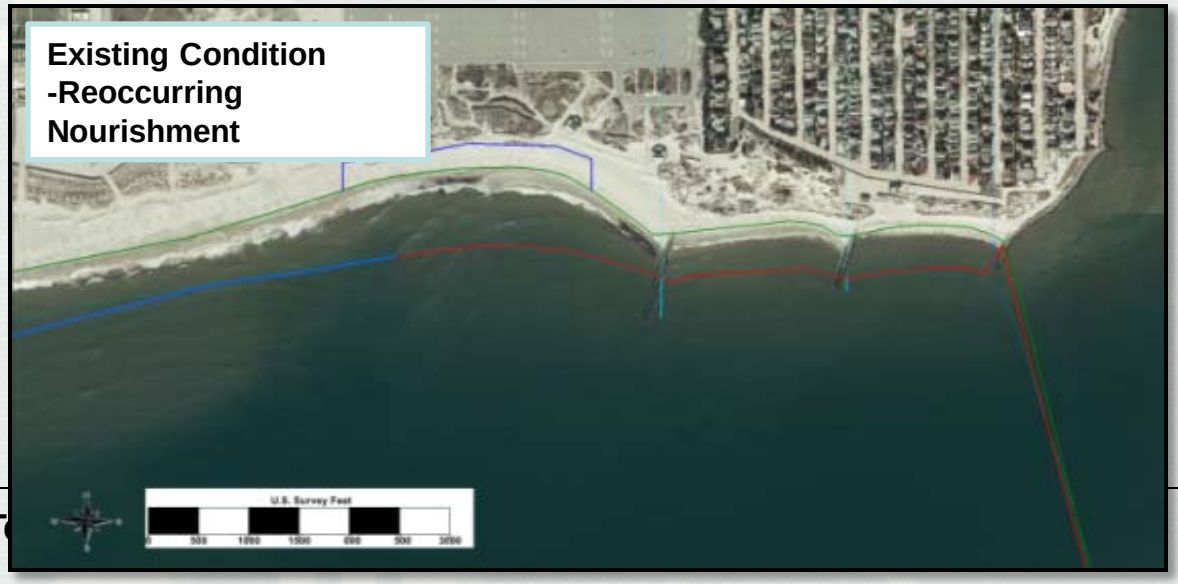


GenCade – Application at Point Lookout, NY

1994 Shoreline Comparison

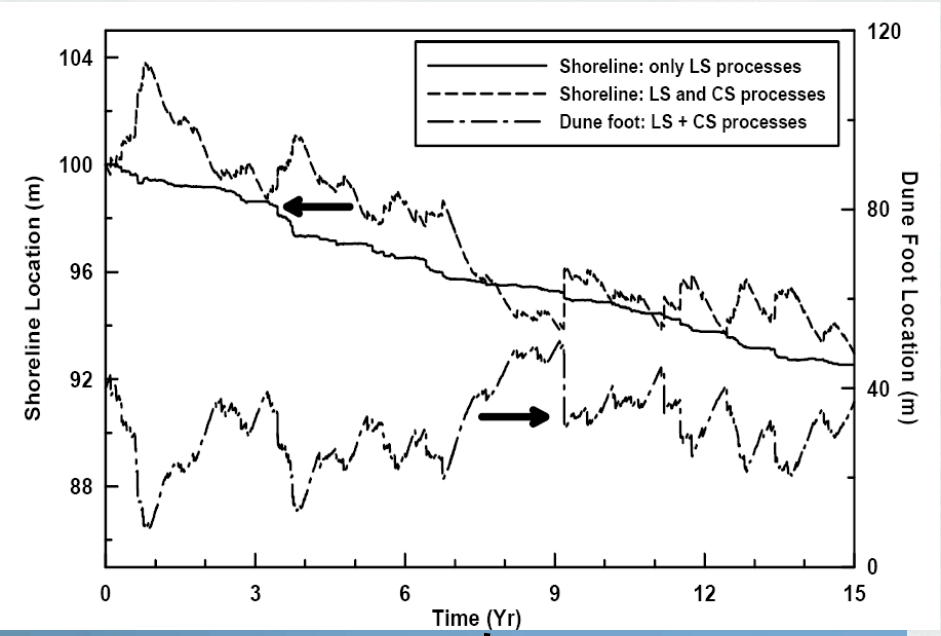
GenCade – Application at Point Lookout, NY

Modeling Results

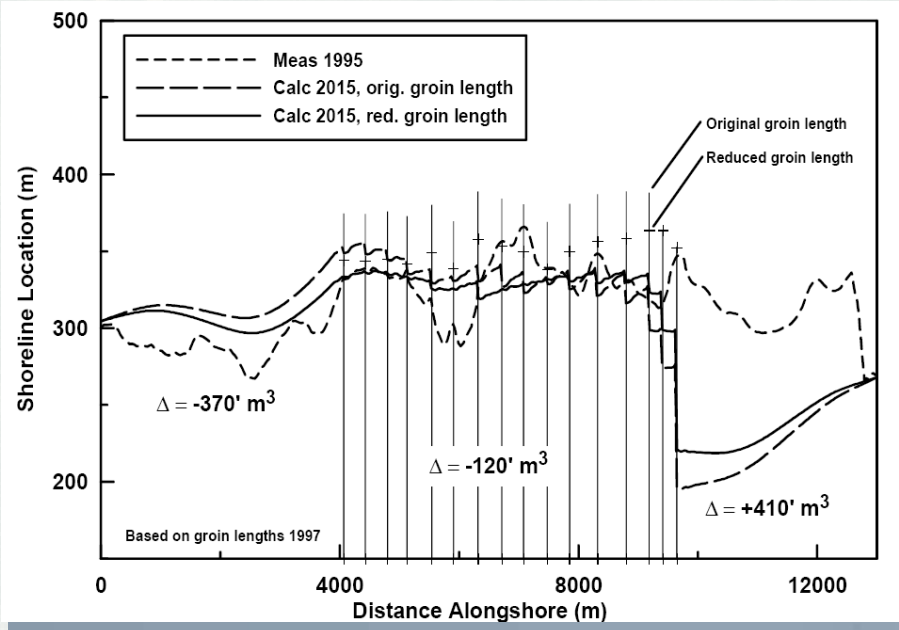


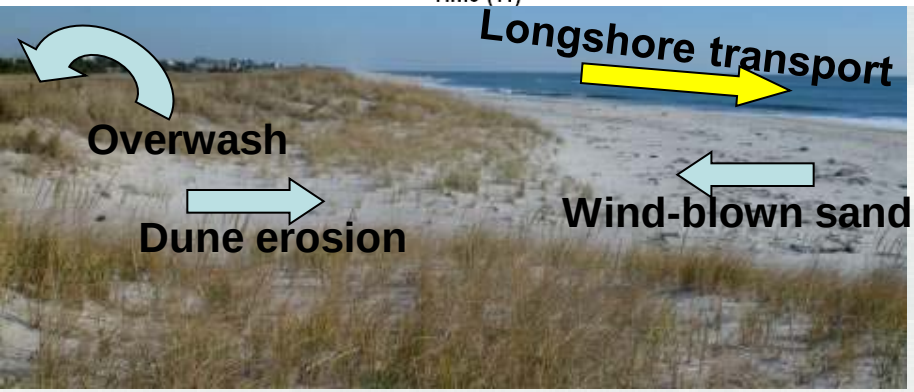
GenCade Development Available in 2012

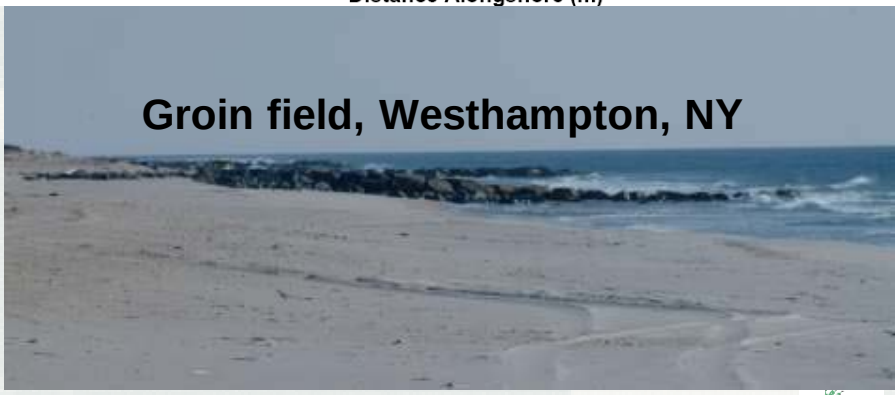
Longshore processes only vs. longshore with cross-shore processes



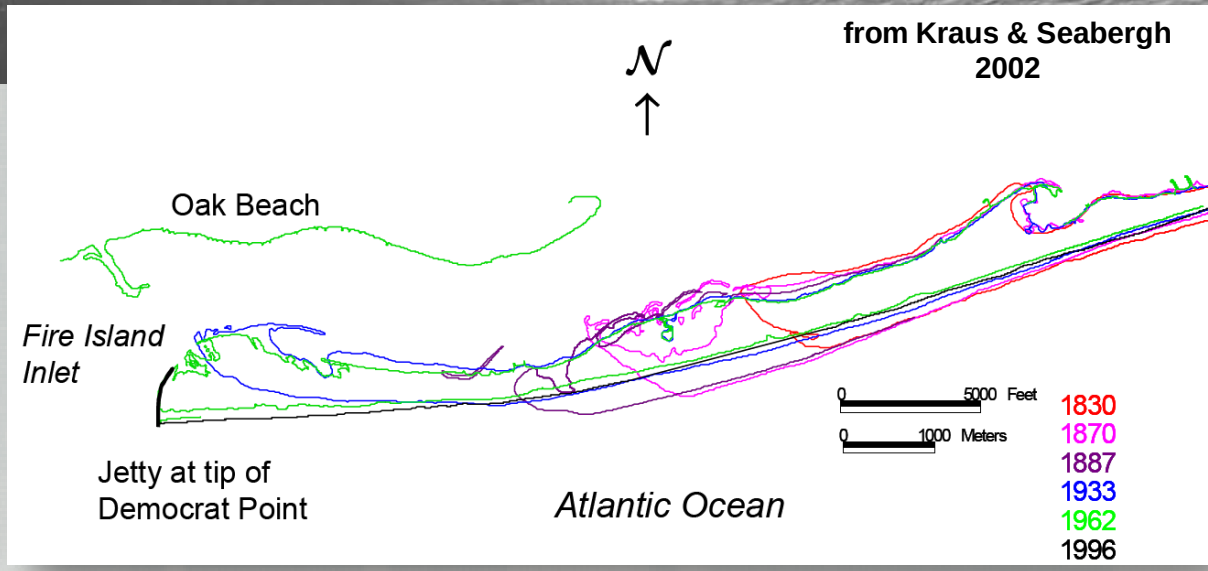
Measured and calculated shoreline change and analysis of reduced groin length





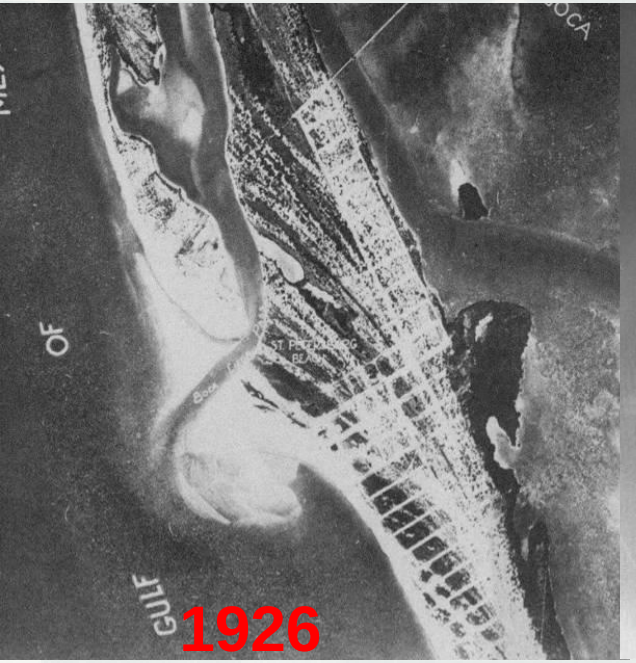


GenCade Development



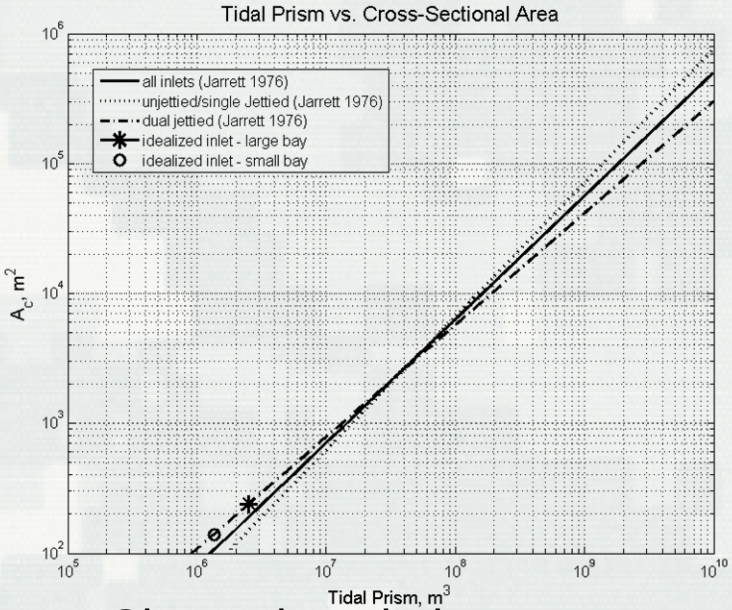
Spit Growth in GenCade

GenCade Development

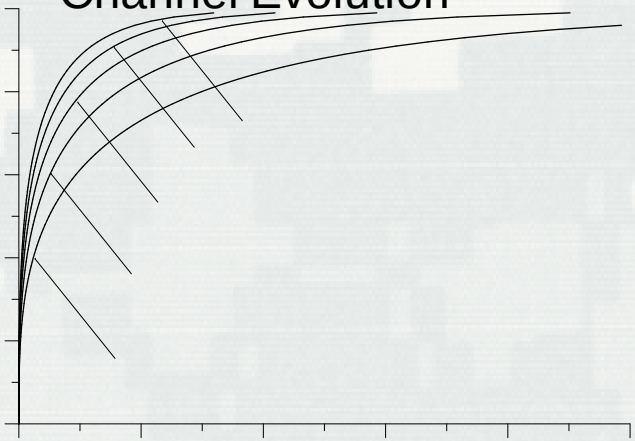


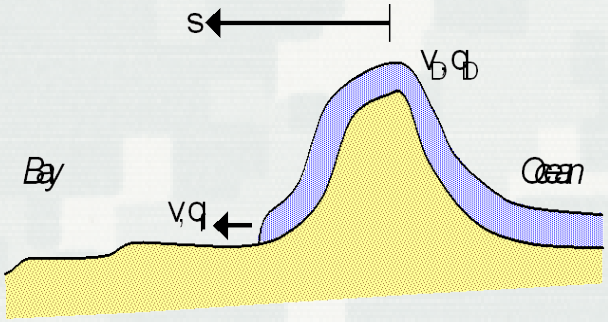
Inlet and Barrier Migration

GenCade Development

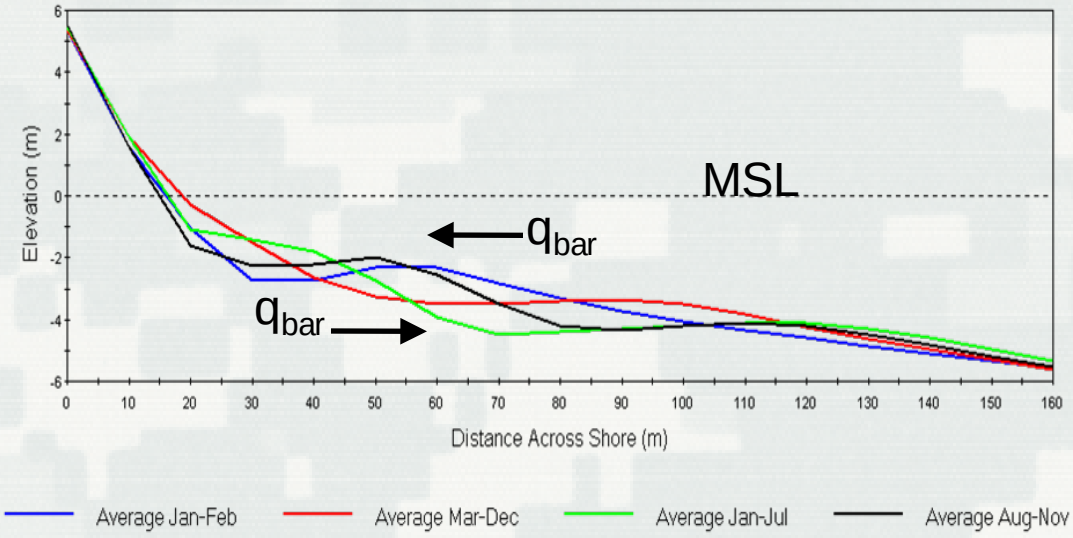


Channel Evolution





Overwash Representation



Subaqueous cross-shore response

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http://cirp.usace.army.mil/wiki/GenCade
http://cirp.usace.army.mil/products