ANALYSIS OF SEA LEVEL RISE AND CLIMATE CHANGE SCENARIOS FOR FLORIDA BAY USING THE FATHOM MODEL.

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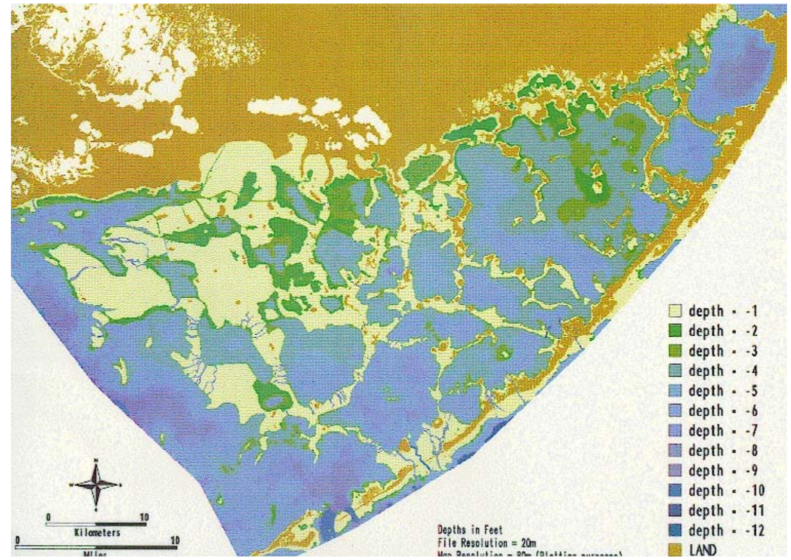
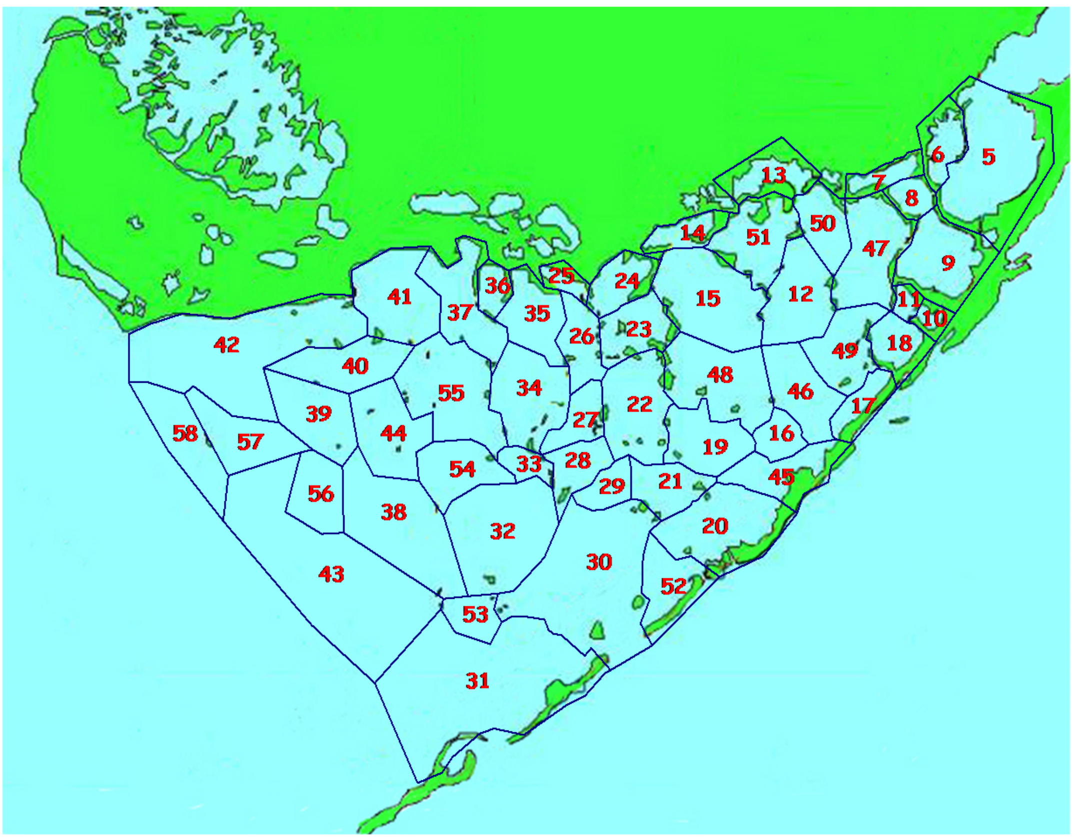
FATHOM Model

Structure

The arrangement of the banks and shoals in Florida Bay effectively divides the bay into a network of interconnected basins with exchange between the basins limited by the shallowness of the banks and the presence of islands in the bay.





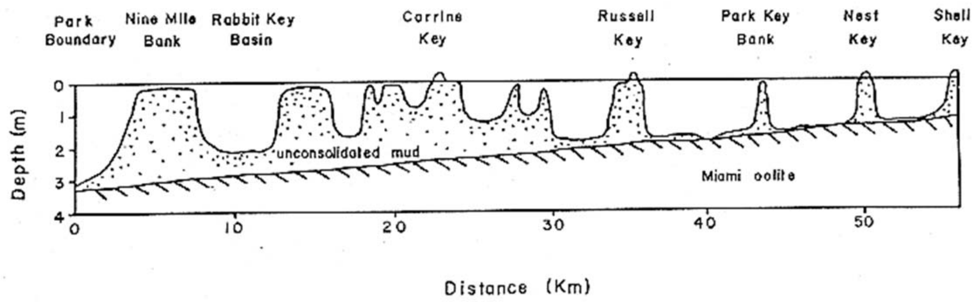
Based on bathymetric data for the bay, 54 distinct basins can be identified. These basins form the basic structure of the FATHOM model.

Transfer of water and solutes between basins is controlled by the bathymetry of the banks.

Model Structure

Volume transport across banks

(Velocity) x (Cross-Section Area)



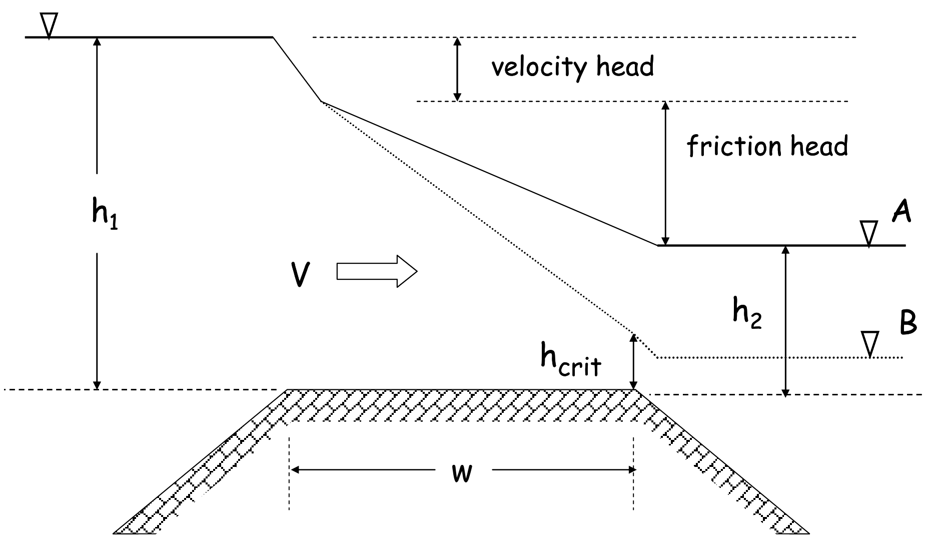
Velocity = f [friction - depth of flow
substrate material,
width of bank, …]

X-section = f [bathymetry – width,
depth distribution]

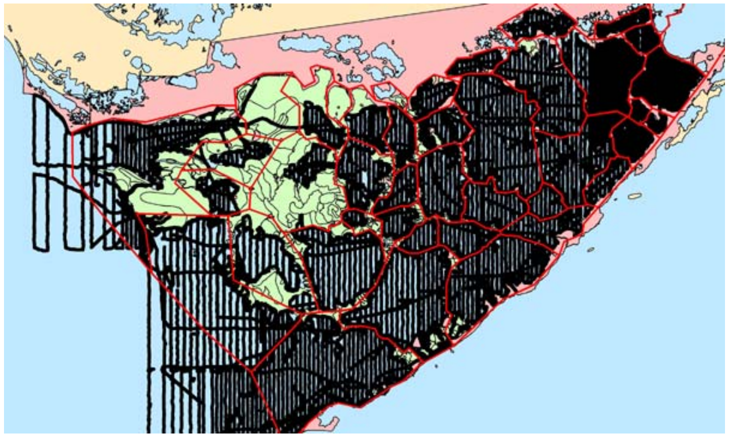
Manning's Equation

$$v^2 = \frac{2g\left[h_1 - h_2\right]}{1 + 2g\,n^2\,w\,R^{-4/3}}$$

$$R = \frac{1}{2}\left[h_1 - \frac{v^2}{2g} + h_2\right]$$



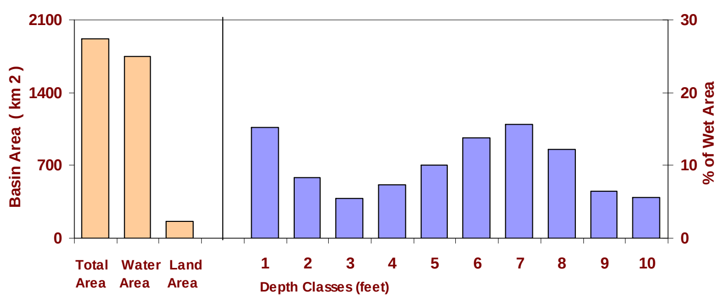
USGS bathymetric survey



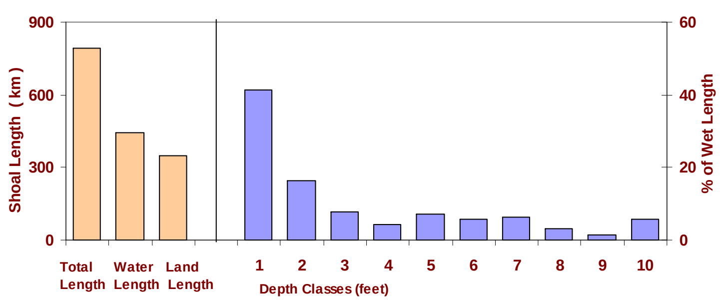
Bathymetric Inputs to FATHOM

Spatial Arrangements and characteristics of FATHOM Basins and Shoals

Basins



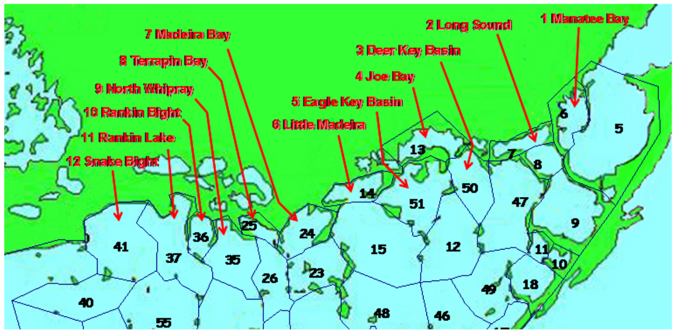
Shoals



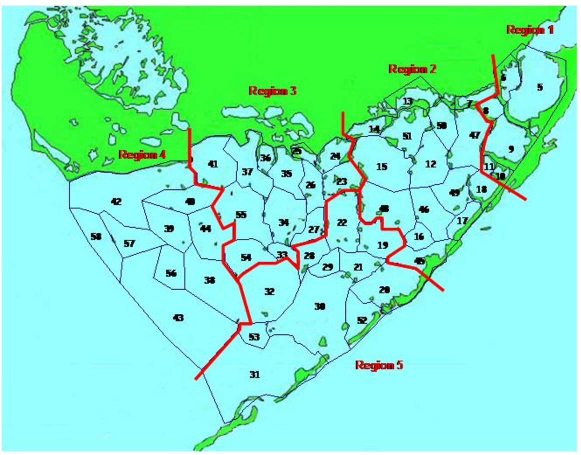
Sea Level Rise (SLR scenarios)

- **sea level constant**
  - Base Case - Basin areas, shoal lengths and bathymetric profiles as in FATHOM version 6.1 documentation and MFL study
- **1 foot sea level rise**
  - A1 - No overspill to land; No in-fill of basins or accretion on banks
  - B1 - No overspill to land; Accretion and in-fill (0-1' depth class remains constant)
- **2 foot sea level rise**
  - C2 - Overspill to land (land areas enter 0-1' depth class); No in-fill of basins or accretion on banks
  - D2 - Overspill to land (land areas enter 0-1' depth class); Accretion and in-fill (0-1' depth class remains constant)
  - E2 - Overspill to land, Inland bays inundate upstream wetlands; No in-fill of basins or accretion on banks
  - F2 - Overspill to land, Inland bays inundate upstream wetlands; Accretion and in-fill (0-1' depth class remains constant)

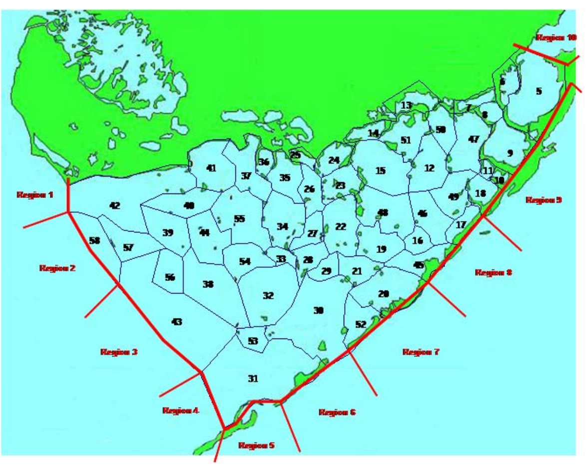
Runoff



Rainfall - Evaporation



Boundary salinity – tides – sea level



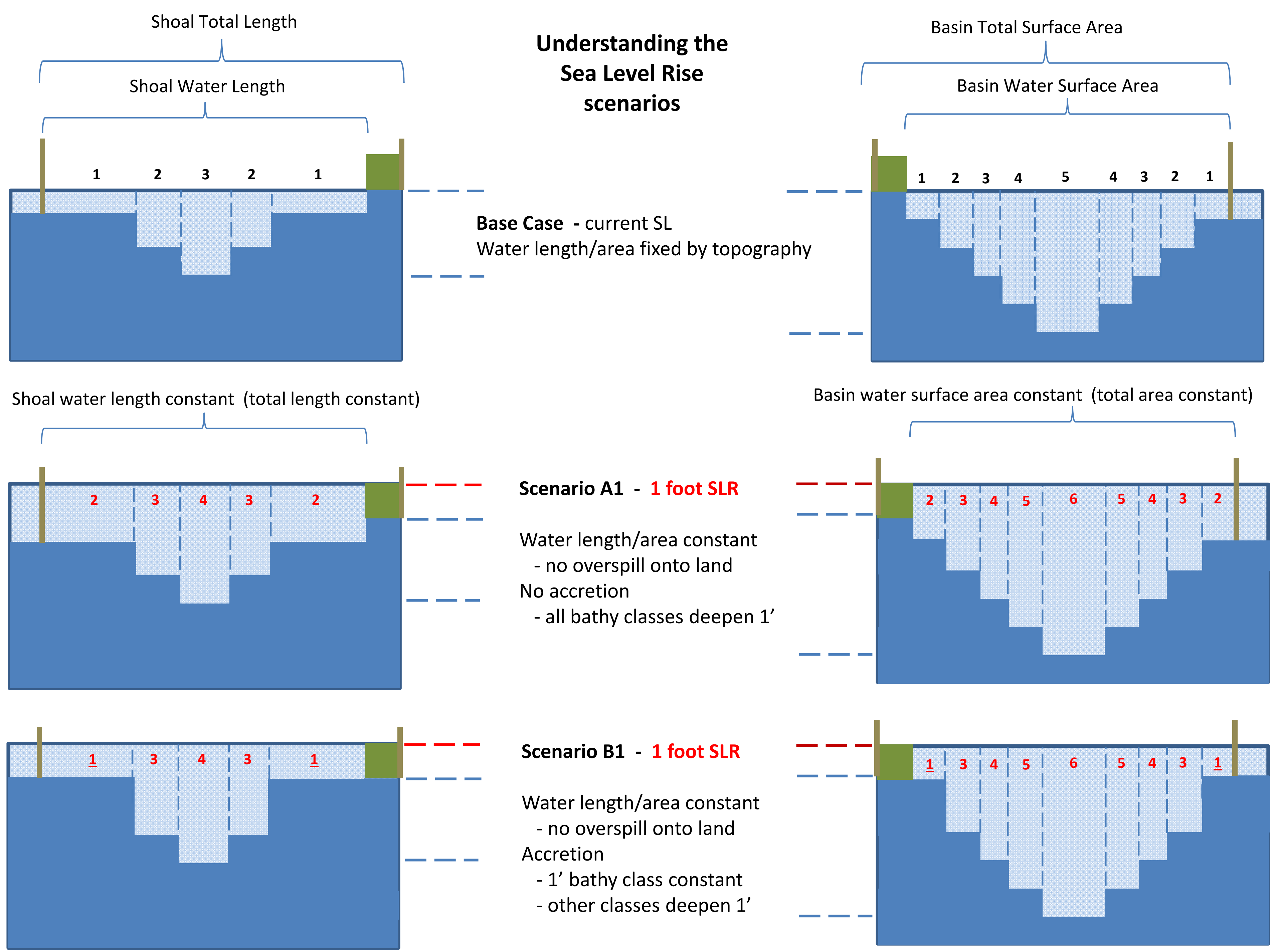
Time Series Inputs to FATHOM

Spatial distribution of monthly climate inputs to FATHOM (hourly tides)

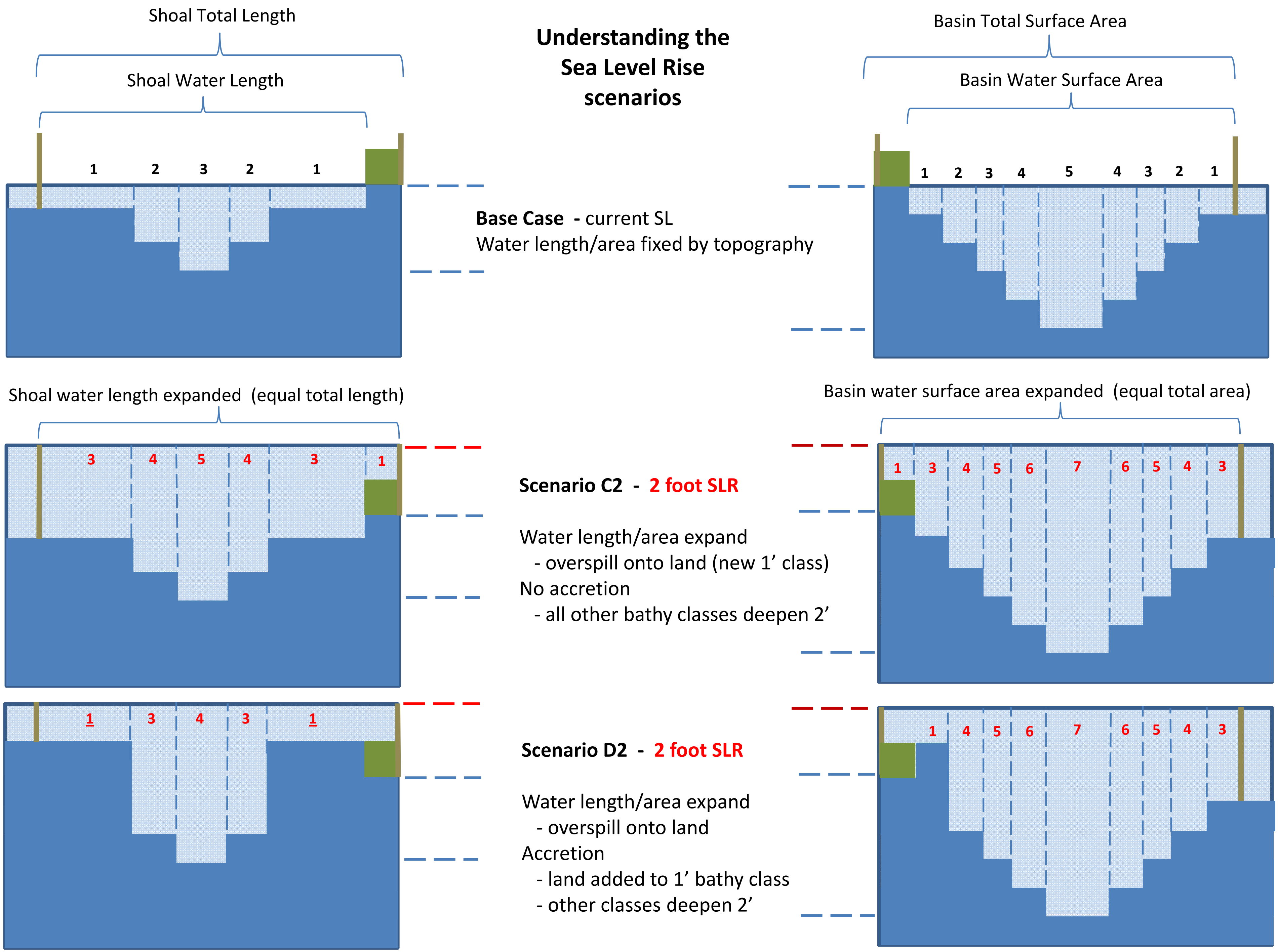
Rainfall 1991 – 2002 Monthly observed at ENP sites at Tavernier, Flamingo and Royal Palm (5 regions)
Evaporation 1991 – 2002 Monthly estimates using SFWMD 'Simple Method' (5 regions)
Runoff 1991 – 2002 Monthly estimates using empirical water budget (EWB) approach based on canals, rivers and wetlands rainfall excess
Boundary salinity 1991-2002 Monthly estimates using observed SERC salinity and regressions with Shark River flows for missing values
Sea Level 1991 – 2002 Monthly average sea level observed at Key West (NOAA)
Tides 28 day cycle (repeated) of hourly tides based on NOAA primary and secondary sites

Sea Level Rise (SLR scenarios)

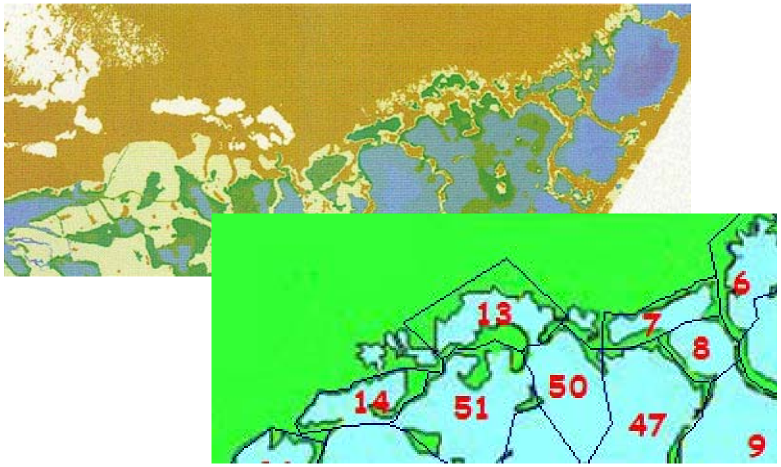
G1 & G2 - Rainfall +/- 20% Increase/decrease applied uniformly to each monthly rainfall total
H1 - Evaporation + 15% Increase applied uniformly to each monthly evaporation total
I1 & I2 - Runoff +/- 20% Increase/decrease applied uniformly to each monthly runoff total
J1 & J2 - Boundary salinity +/- 5% Increase/decrease applied uniformly to each monthly boundary salinity value



Understanding the Sea Level Rise scenarios
Shoal Total Length
Shoal Water Length
1 2 3 2 1
Basin Total Surface Area
Basin Water Surface Area
1 2 3 4 5 4 3 2 1
Base Case - current SL
Water length/area fixed by topography
Shoal water length constant (total length constant)
2 3 4 3 2
Basin water surface area constant (total area constant)
2 3 4 5 6 5 4 3 2
Scenario A1 - 1 foot SLR
Water length/area constant
- no overspill onto land
No accretion
- all bathy classes deepen 1'
1 3 4 3 1
1 3 4 5 6 5 4 3 1
Scenario B1 - 1 foot SLR
Water length/area constant
- no overspill onto land
Accretion
- 1' bathy class constant
- other classes deepen 1'

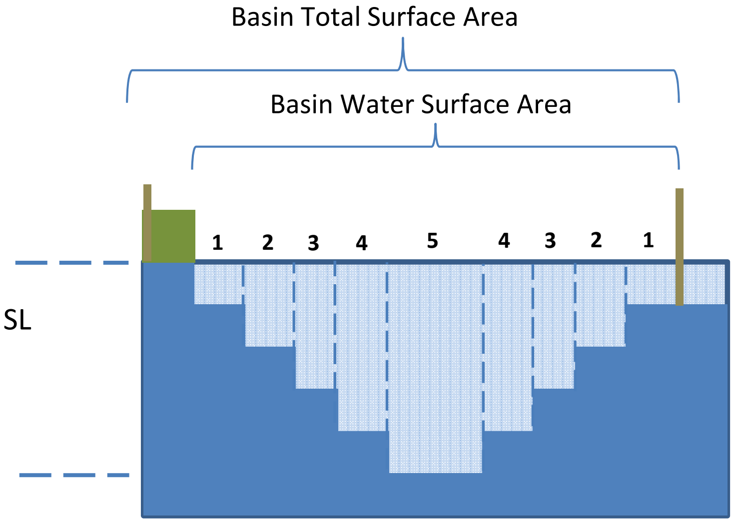


Understanding the Sea Level Rise scenarios
Shoal Total Length
Shoal Water Length
1 2 3 2 1
Basin Total Surface Area
Basin Water Surface Area
1 2 3 4 5 4 3 2 1
Base Case - current SL
Water length/area fixed by topography
Shoal water length expanded (equal total length)
3 4 5 4 3 1
Basin water surface area expanded (equal total area)
1 3 4 5 6 7 6 5 4 3
Scenario C2 - 2 foot SLR
Water length/area expand
- overspill onto land (new 1' class)
No accretion
- all other bathy classes deepen 2'
1 3 4 3 1
1 4 5 6 7 6 5 4 3
Scenario D2 - 2 foot SLR
Water length/area expand
- overspill onto land
Accretion
- land added to 1' bathy class
- other classes deepen 2'

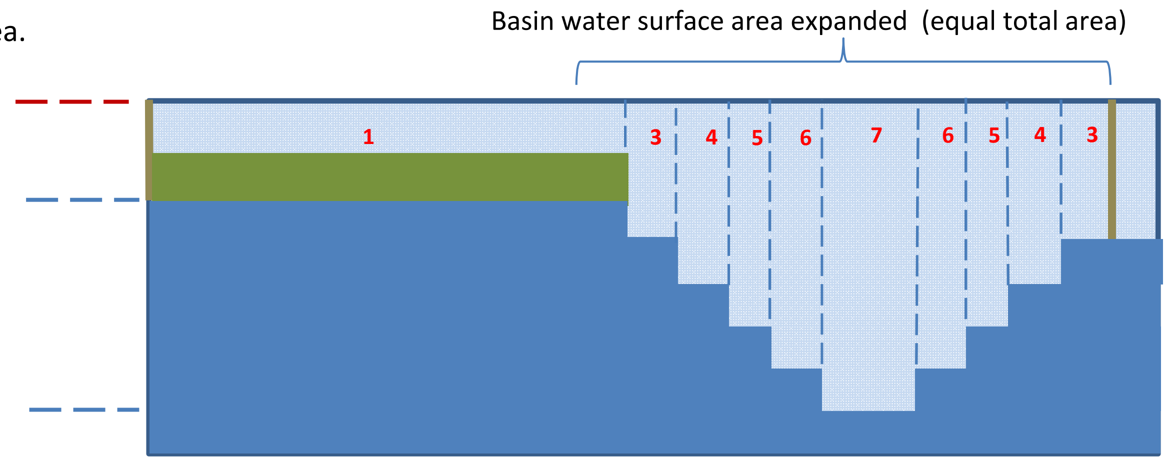


Understanding the Sea Level Rise scenarios

Base Case - current SL
Water length/area fixed by topography



Scenarios E2 and F2
Joe Bay, Long Sound, Little Madeira (only)
inundate upstream wetlands doubling total basin area.

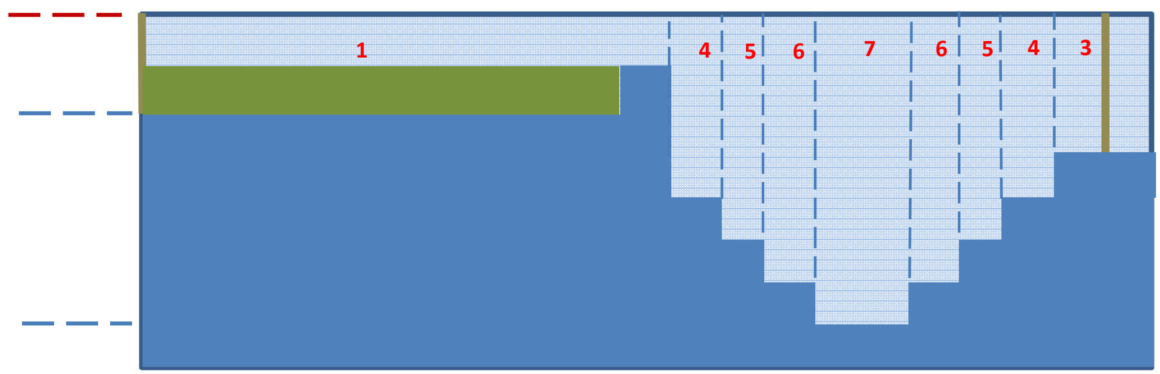


Scenario E2 - 2 foot SLR

Total Area expands (x 2)
- Inundates upstream wetlands

Water area expands
- overspill onto land (new 1’ class)

No accretion
- all other bathy classes deepen 2’



Scenario F2 - 2 foot SLR

Total Area expands (x 2)
- Inundates upstream wetlands

Water area expand expands
- overspill onto land

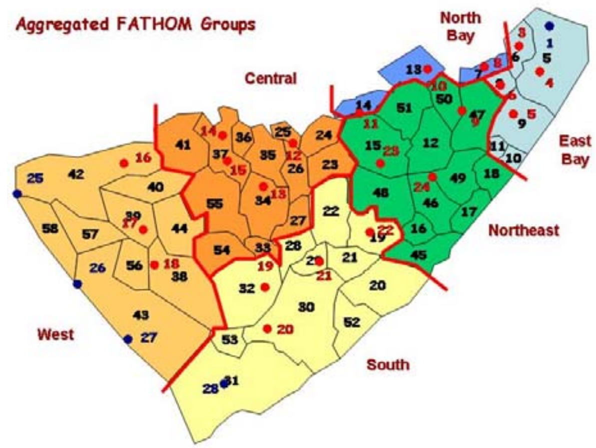
Accretion
- land added to 1’ bathy class
- other classes deepen 2’

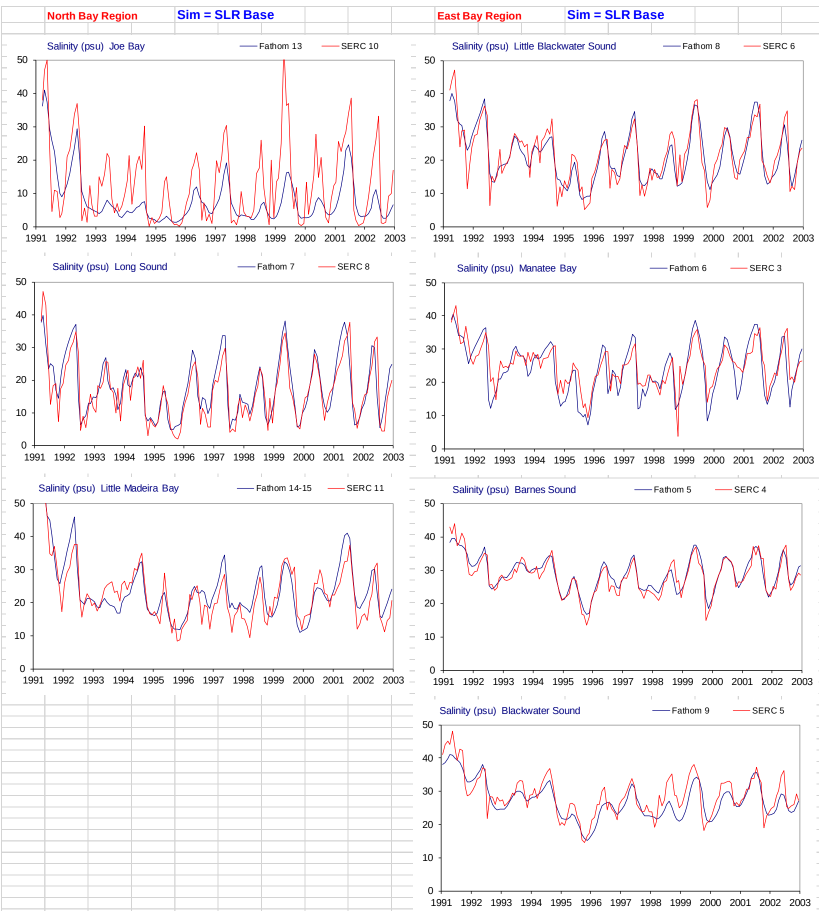
Before beginning –

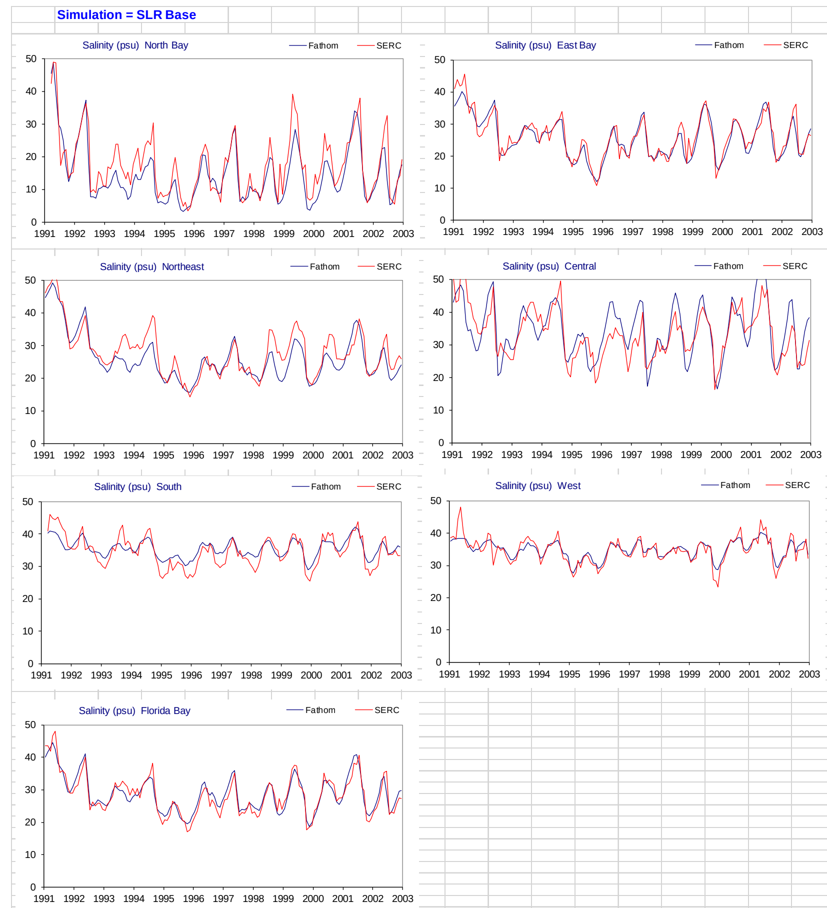
A comparison of simulated and observed salinity 1991 – 2002.

When comparing SLR and CC scenario results to the **base case**, it's useful to know if the base case is a reasonable simulation of reality in the first place.

- 20 SERC sites with long-term observations
- 6 aggregated FATHOM regions



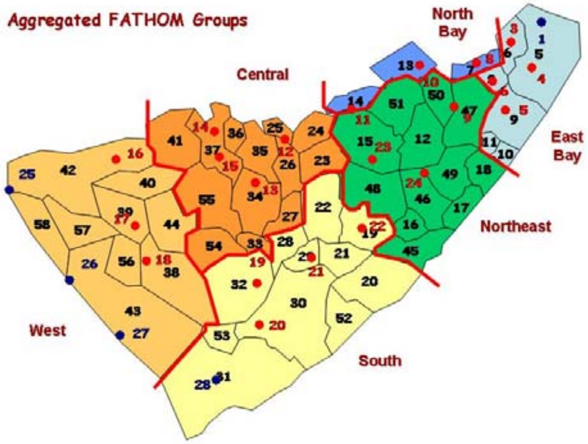


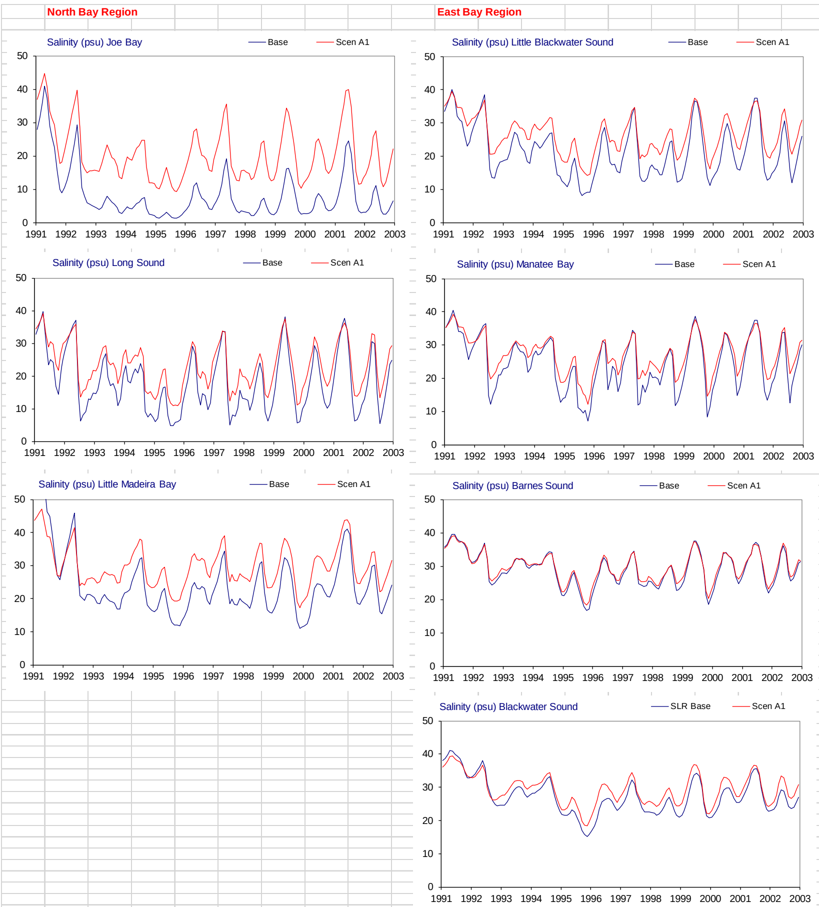


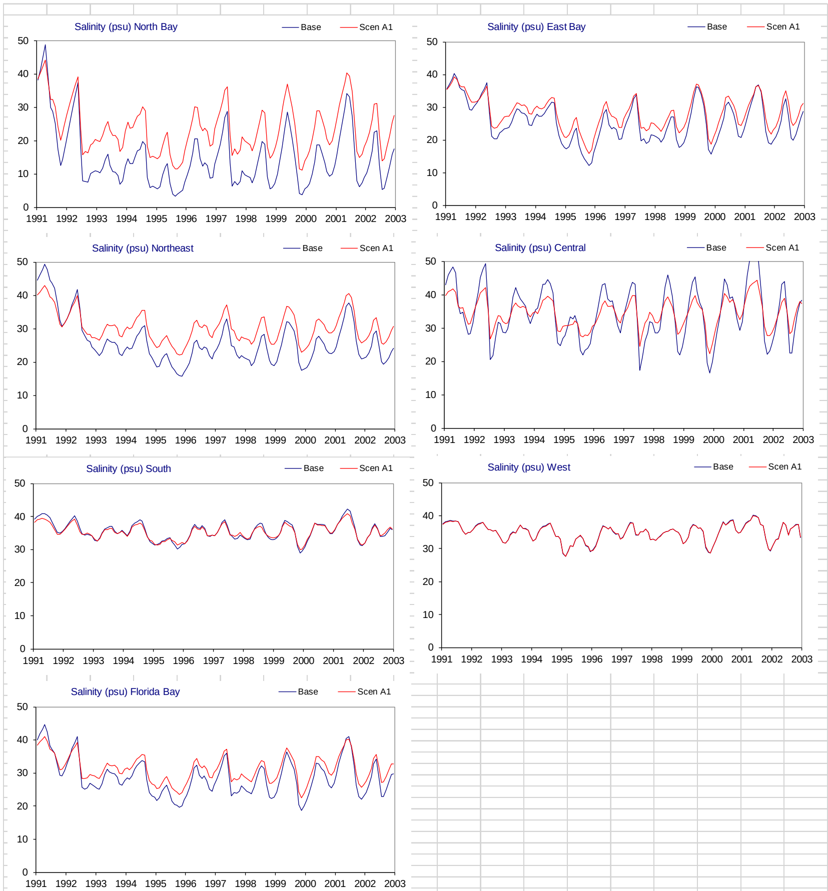
Comparison of Base Case simulation with Scenario A1

A1 - Basin water areas constant - no overspill to land, no in-fill
Shoal water lengths constant - no overspill to land, no accretion

Examining the effects on simulated salinity



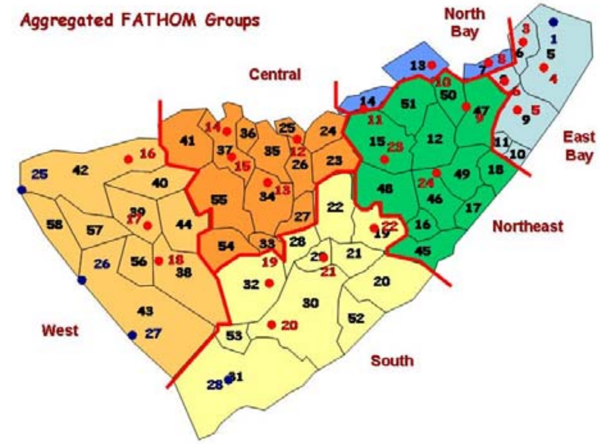


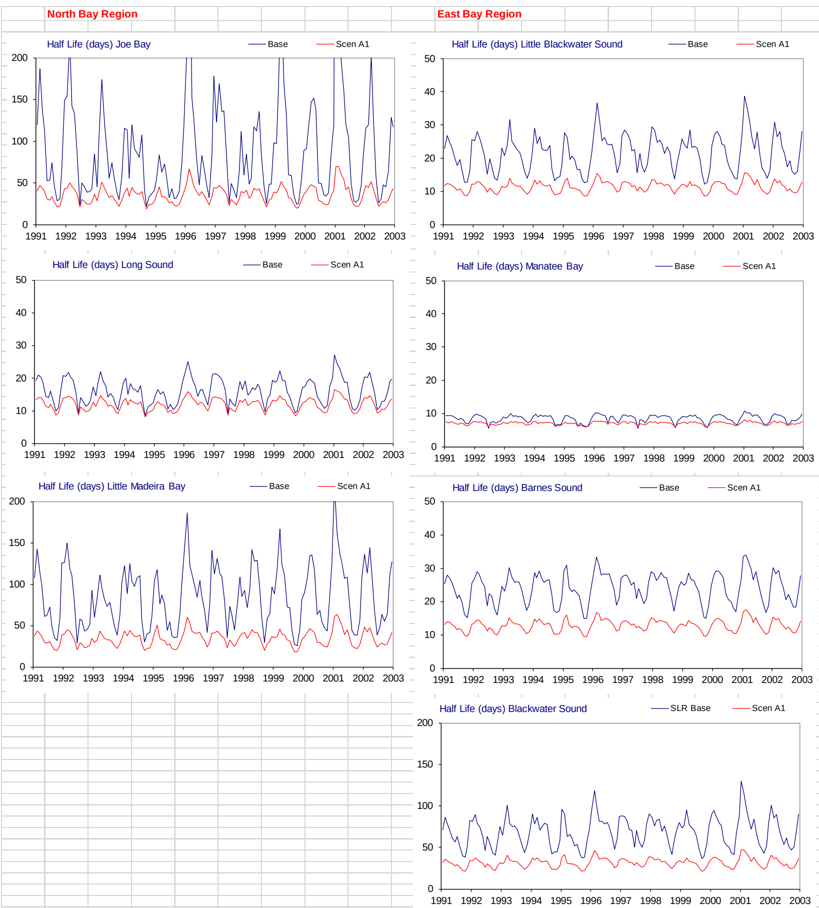


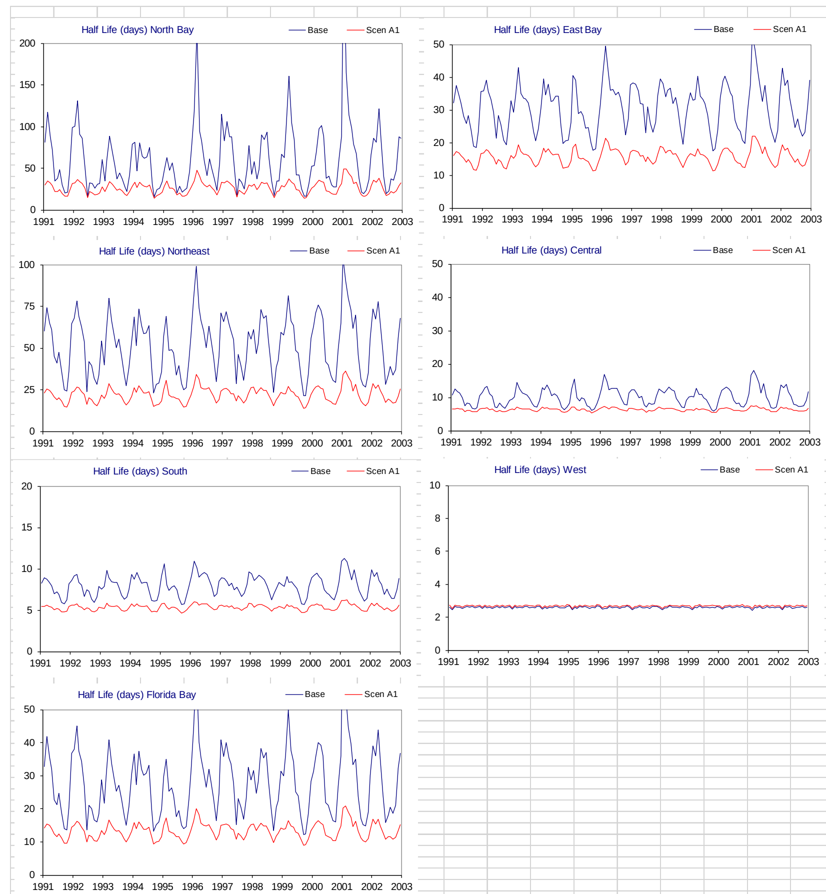
Comparison of Base Case simulation with Scenario A1

A1 - Basin water areas constant - no overspill to land, no in-fill
Shoal water lengths constant - no overspill to land, no accretion

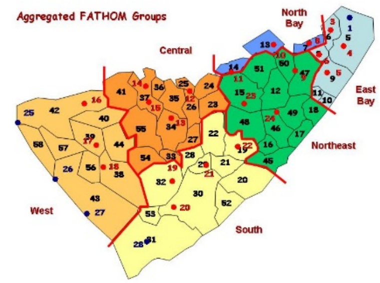
Examining the effects on simulated half-life (residence time)





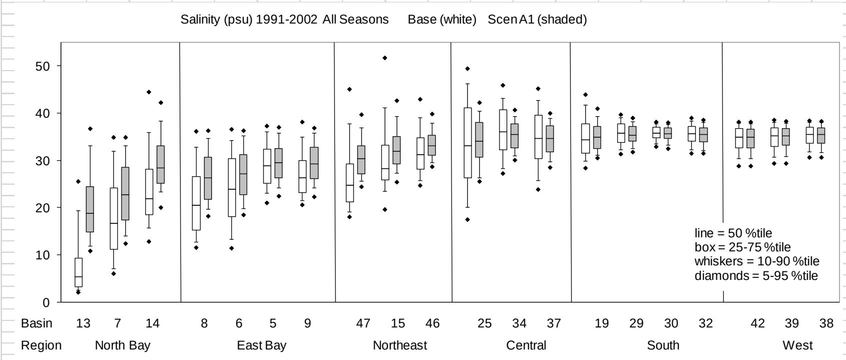


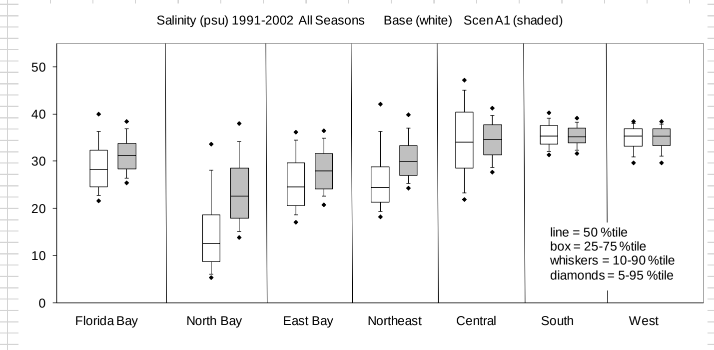
Comparison of Base Case simulation with Scenario A1

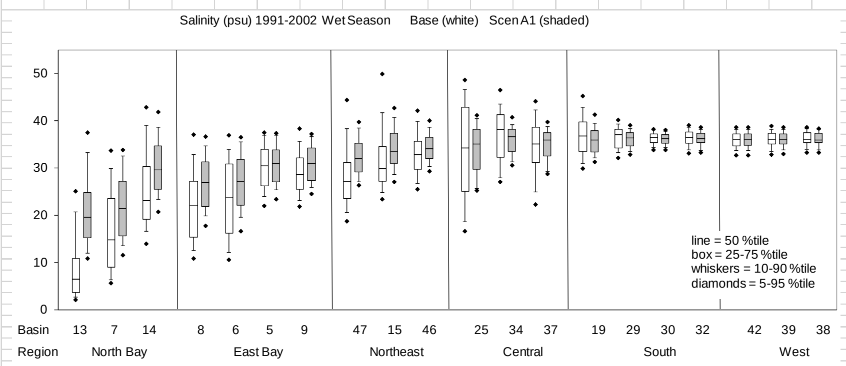


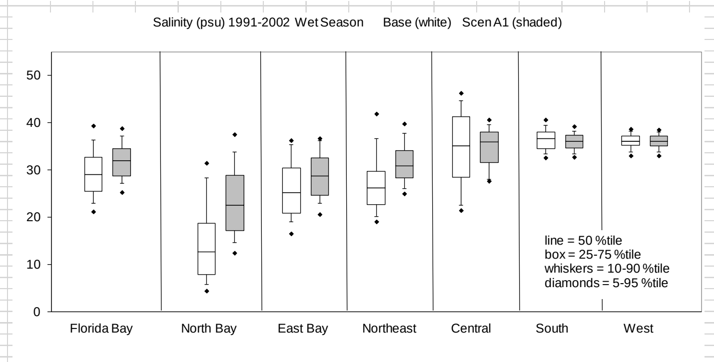
A1 - Basin water areas constant - no overspill to land, no in-fill
Shoal water lengths constant - no overspill to land, no accretion

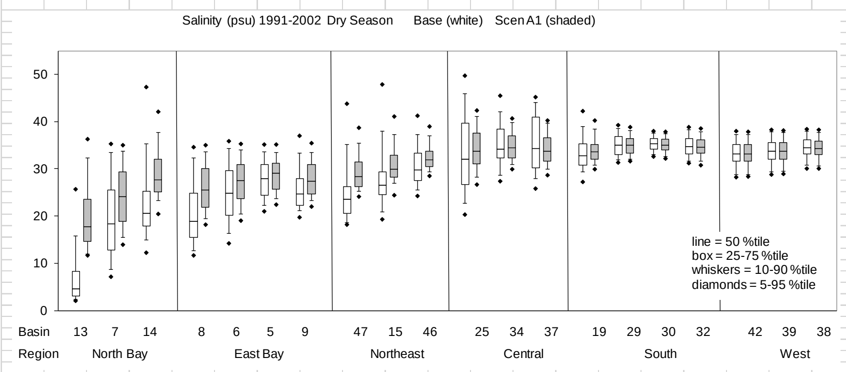
Summary effects on simulated salinity – all months, wet & dry seasons

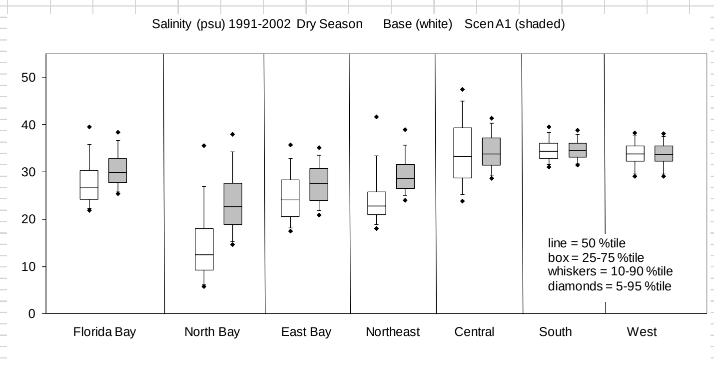




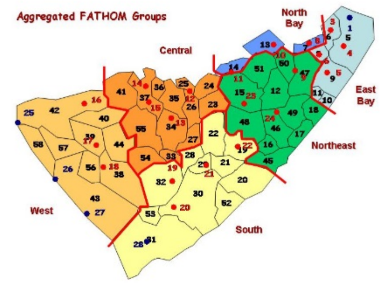








Comparison of Base Case simulation with Scenario A1



A1 - Basin water areas constant - no overspill to land, no in-fill
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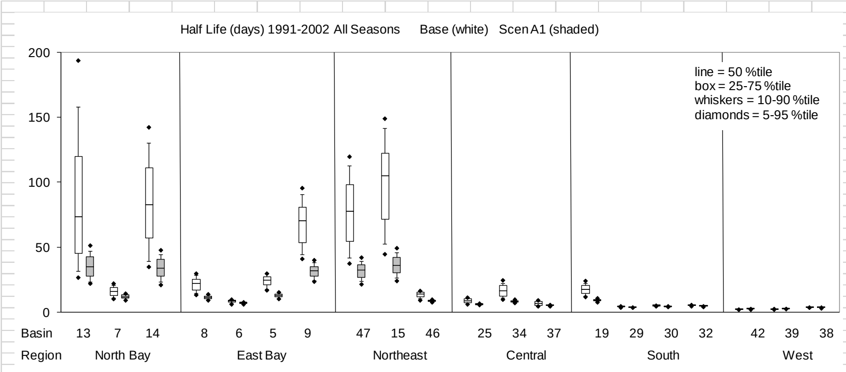
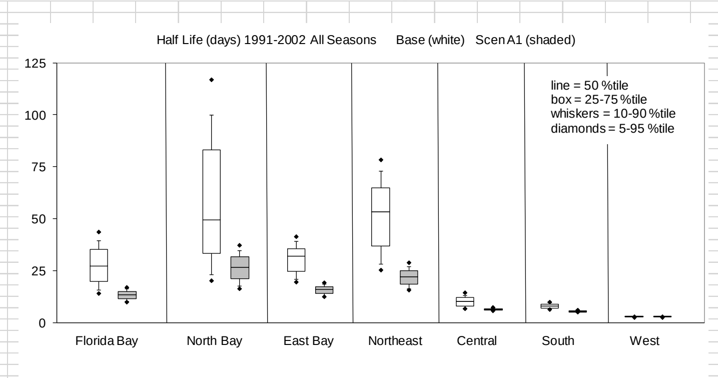
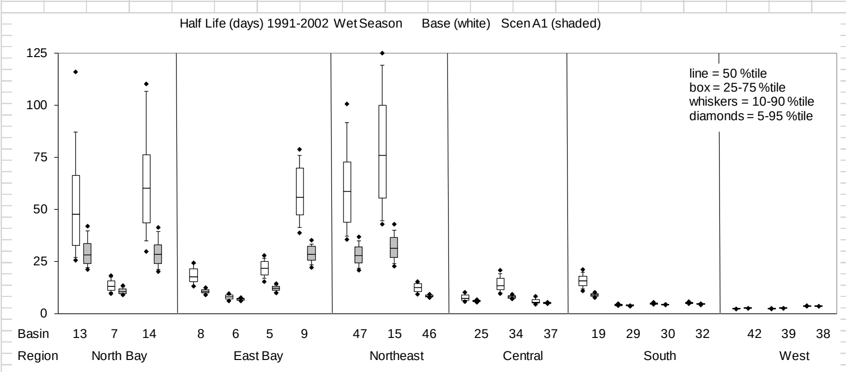
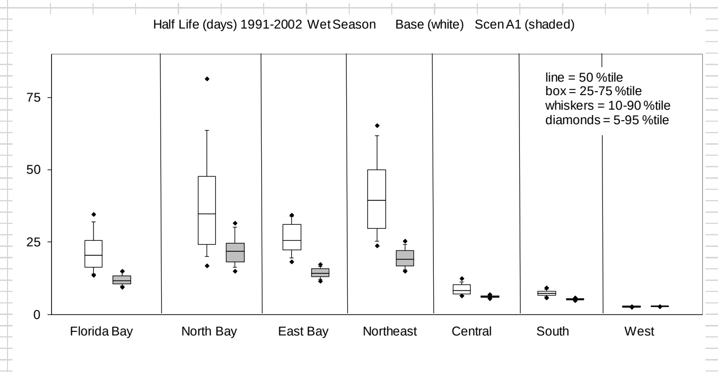
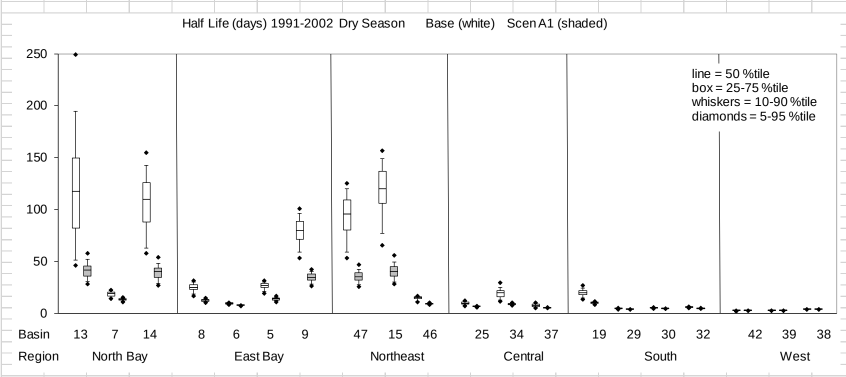
Summary effects on simulated half-life – all months, wet & dry seasons

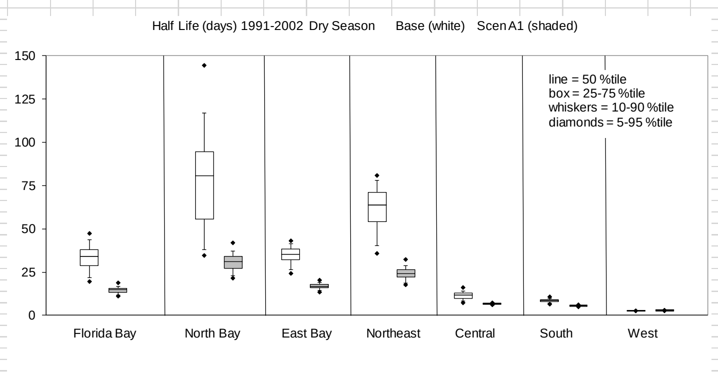






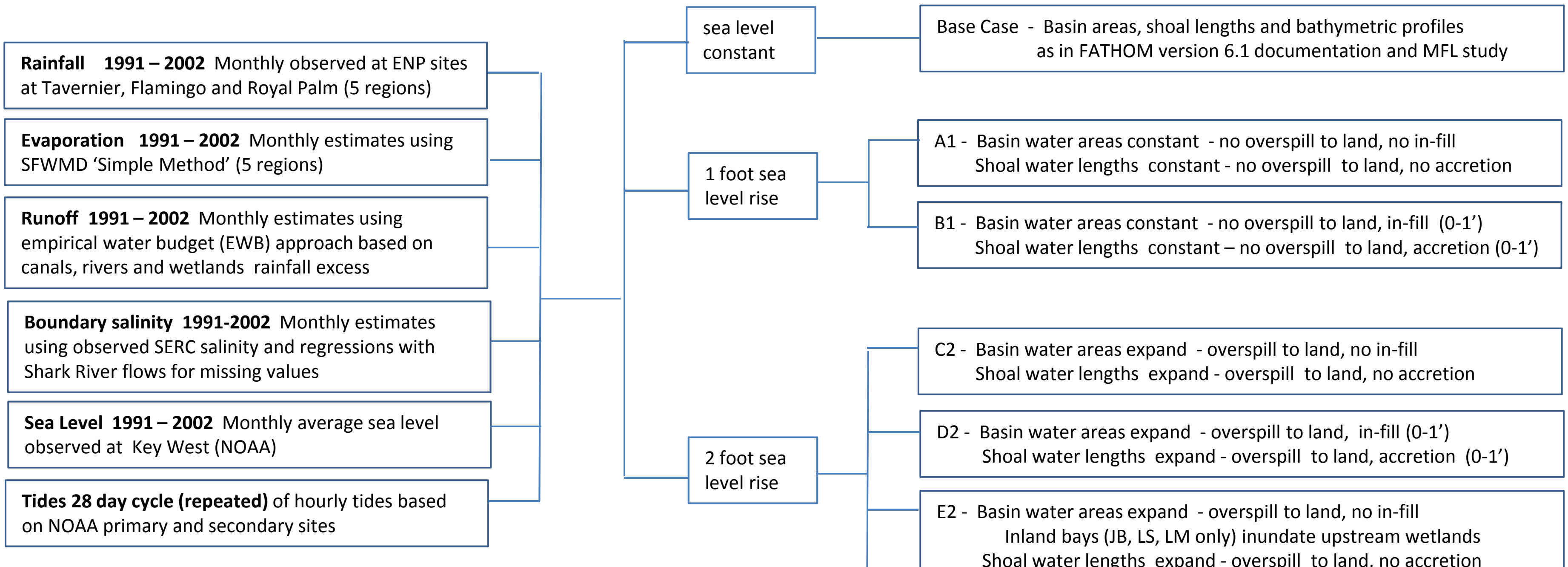






Simulating Sea Level Rise (SLR) Effects in Florida Bay Using FATHOM

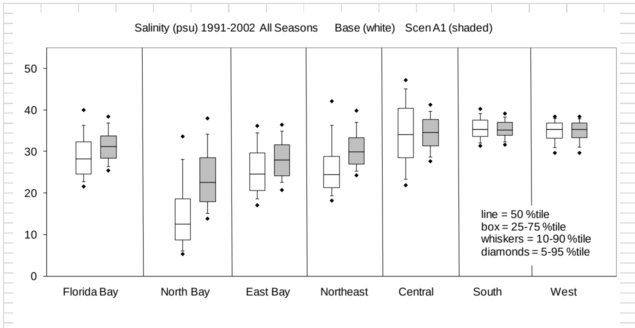
- Base case and six SLR scenarios simulated.
- Base case and all scenarios run for the period 1991-2002 -
  standard monthly climate, runoff and boundary condition drivers used for all.
- Transitions from base to final scenario sea level or bathymetry not simulated -
  scenarios simulate responses expected when new SLR conditions have reached steady state.



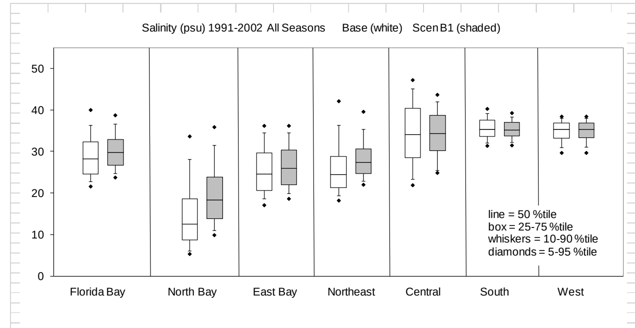
The standard climate, runoff, and boundary condition drivers above are time series as used in the FATHOM vers 6.1 documentation and in the SFWMD MFL study.

Sea Level Rise - Effects on Salinity in Florida Bay

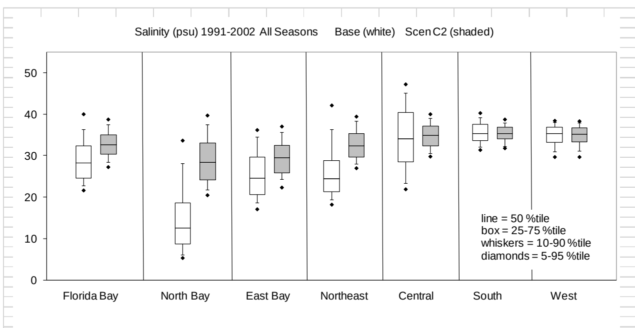
A1 - No overspill to land; No in-fill or accretion



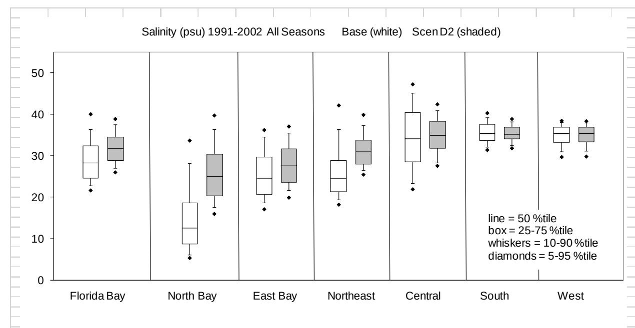
B1 - No overspill to land; Accretion and in-fill (1' class)



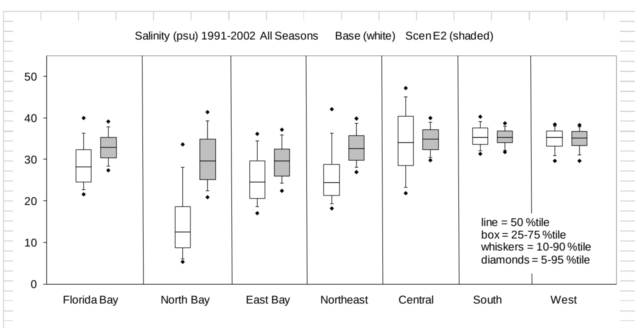
C2 - Overspill to land (1' depth); No in-fill of or accretion



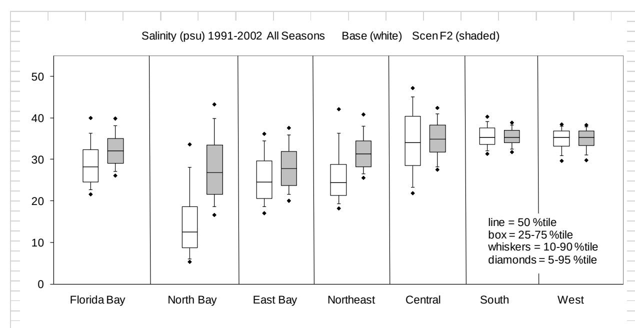
D2 - Overspill to land (1' depth); Accretion and in-fill (1' class)



E2 - Overspill to land, Inland bays inundate; No in-fill or accretion

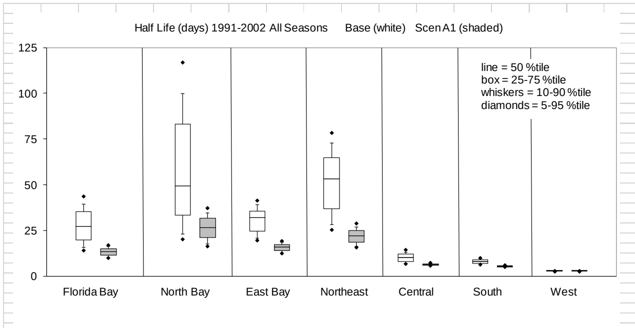


F2 - Overspill to land, Inland bays inundate; Accretion and in-fill

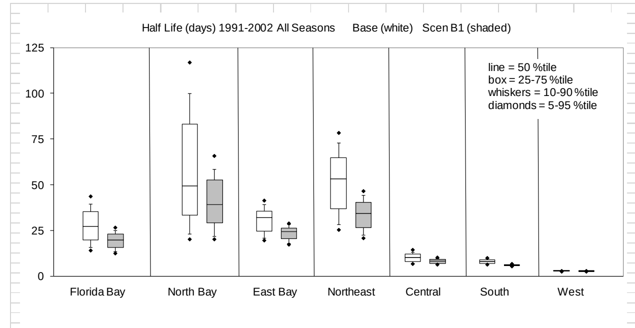


Sea Level Rise - Effects on Half-life in Florida Bay

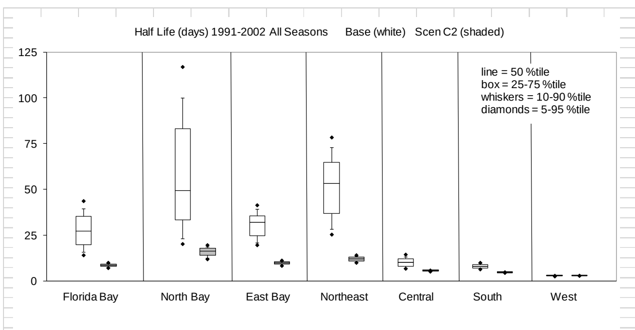
A1 - No overspill to land; No in-fill or accretion



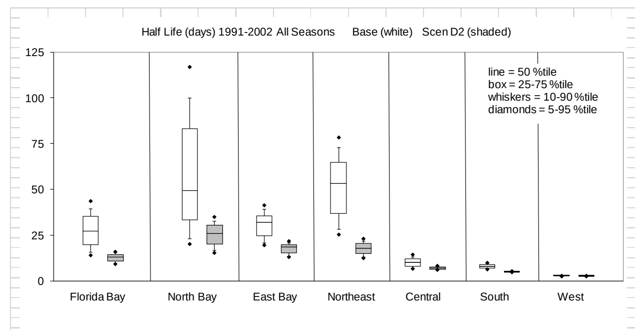
B1 - No overspill to land; Accretion and in-fill (1' class)



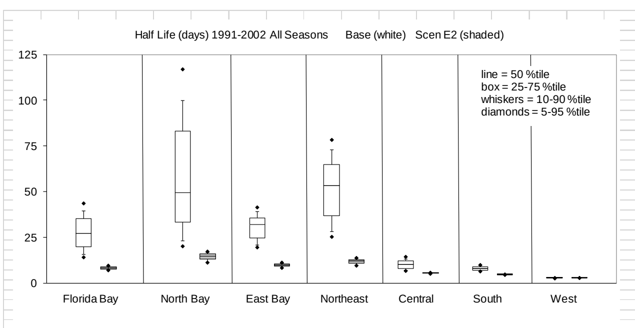
C2 - Overspill to land (1' depth); No in-fill of or accretion



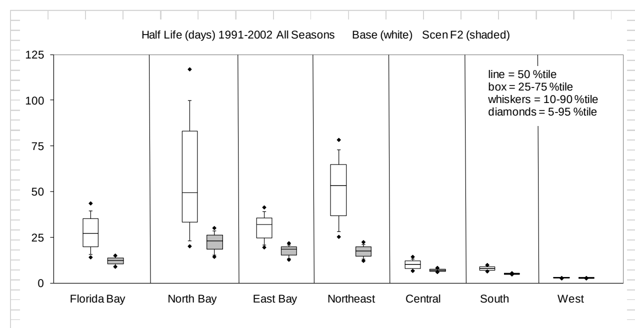
D2 - Overspill to land (1' depth); Accretion and in-fill (1' class)



E2 - Overspill to land, Inland bays inundate; No in-fill or accretion



F2 - Overspill to land, Inland bays inundate; Accretion and in-fill



Simulating Climate Change Effects (CC) Effects in Florida Bay Using FATHOM

- Base case and seven CC scenarios simulated.
- Input drivers were changed individually (one at a time).
- Base case and all scenarios run for the period 1991-2002 –

  standard monthly climate, runoff and boundary condition drivers used for all inputs not being manipulated
- Sea level was not changed during CC scenarios.
- Transitions from base to final scenario sea level or bathymetry not simulated -

  scenarios simulate responses expected when new SLR conditions have reached steady state.

Rainfall 1991 – 2002 Monthly observed at ENP sites at Tavernier, Flamingo and Royal Palm (5 regions)

Evaporation 1991 – 2002 Monthly estimates using SFWMD 'Simple Method' (5 regions)

Runoff 1991 – 2002 Monthly estimates using empirical water budget (EWB) approach based on canals, rivers and wetlands rainfall excess

Boundary salinity 1991-2002 Monthly estimates using observed SERC salinity and regressions with Shark River flows for missing values

Sea Level 1991 – 2002 Monthly average sea level observed at Key West (NOAA)

Tides 28 day cycle (repeated) of hourly tides based on NOAA primary and secondary sites

The standard climate, runoff, and boundary condition drivers above are time series as used in the FATHOM vers 6.1 documentation and in the SFWMD MFL study.

Base Case - Basin areas, shoal lengths and bathymetric profiles as in FATHOM documentation and MFL study

Changes in individual drivers.

G1 & G2 - Rainfall +/- 20% - Increase/decrease applied uniformly to each monthly rainfall total over the simulation period

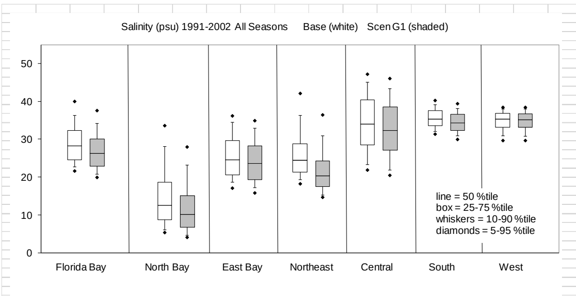
H1 - Evaporation + 15% - Increase applied uniformly to each monthly evaporation total over the simulation period

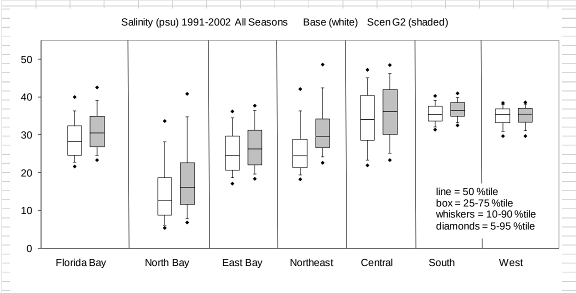
I1 & I2 - Runoff +/- 20% - Increase/decrease applied uniformly to each monthly runoff total over the simulation period

J1 & J2 - Boundary salinity +/- 5% - Increase/decrease applied uniformly to each monthly boundary salinity value over the simulation period

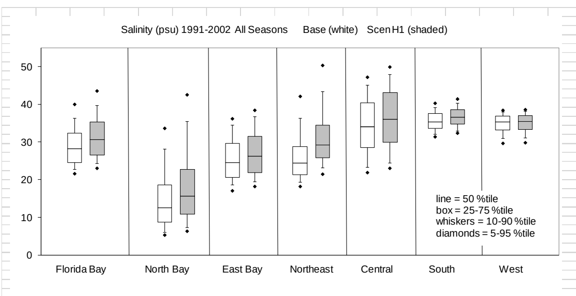
Climate Change -
Effects on Salinity in Florida Bay

G1 & G2 - Rainfall +/- 20%

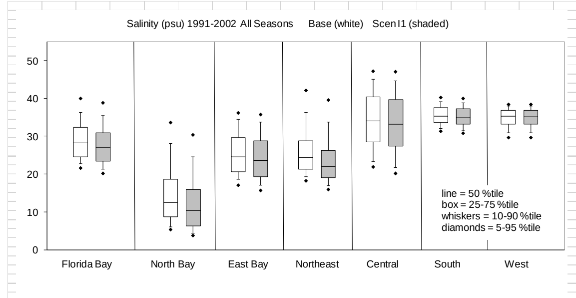


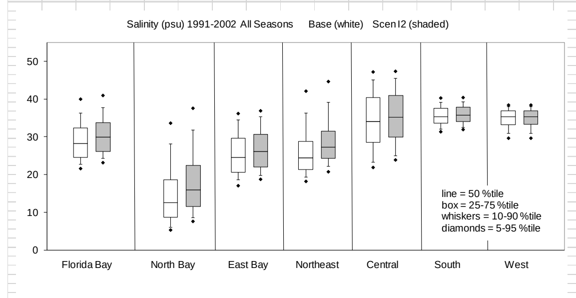


H1 - Evaporation + 15%

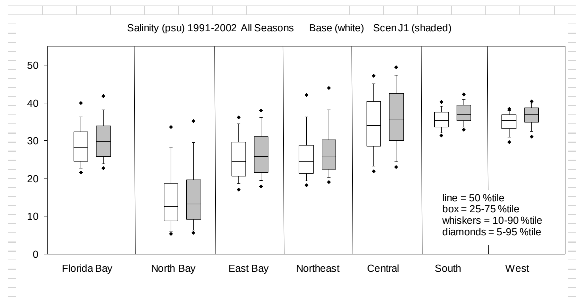


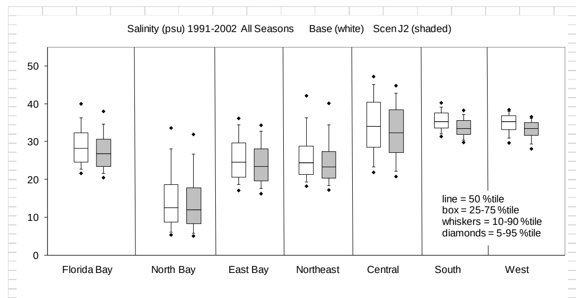
I1 & I2 - Runoff +/- 20%





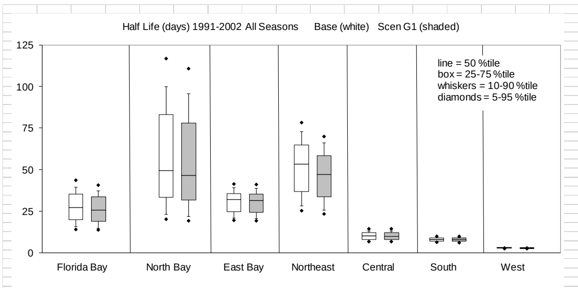
J1 & J2 - Boundary salinity +/- 5%

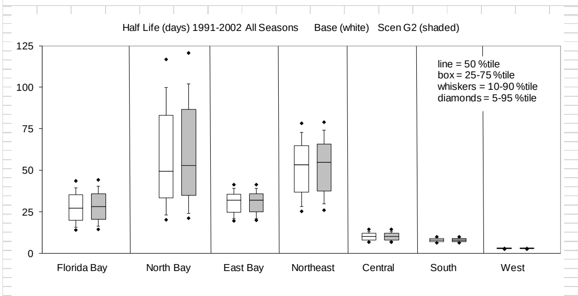




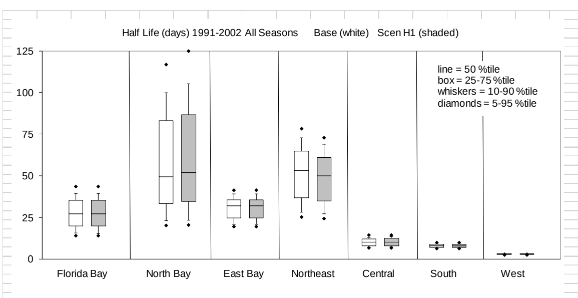
Climate Change -
Effects on Half-life in Florida Bay

G1 & G2 - Rainfall +/- 20%

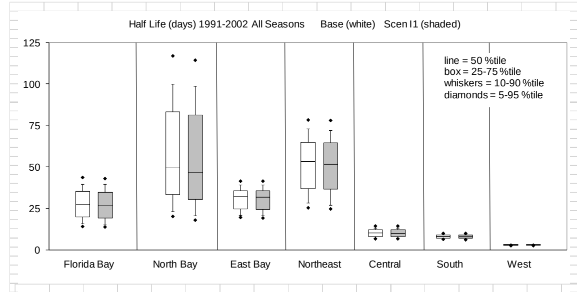


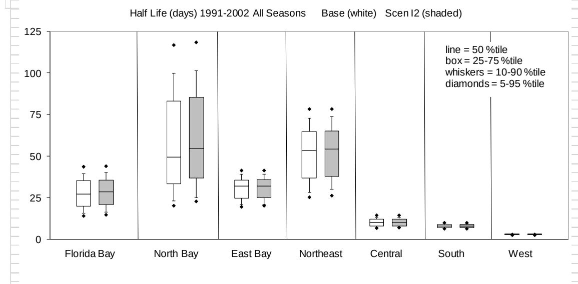


H1 - Evaporation + 15%

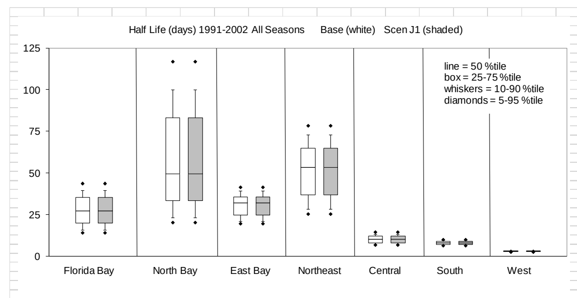


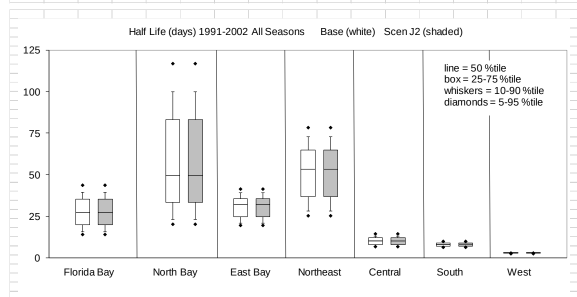
I1 & I2 - Runoff +/- 20%





J1 & J2 - Boundary salinity +/- 5%





ANALYSIS OF SEA LEVEL RISE AND CLIMATE CHANGE SCENARIOS FOR FLORIDA BAY USING THE FATHOM MODEL.

- Base case and six SLR scenarios simulated.
- Base case and seven CC scenarios simulated
- Results for monthly salinity and residence times using 10 years of observed inputs (1991-1000)

Summary for SLR scenarios:

- Changes in Bay-wide average salinity varied from +4% to +14% across the scenarios
- Largest change noted for a 2 foot SLR with no accretion or infill and inundation of upstream wetlands.
- Spatially, the largest salinity changes were in the North and Northeast regions.
- In general, SLR reduced residence times (half-life) throughout most of the Bay; Bay-wide average residence times declined by 30% to 70% across all scenarios.
- SLR significantly affected residence times not only by lowering the average values but also by compressing the annual range (i.e. lower variance) with larger reductions in peak residence times rather than minima).

Summary for CC scenarios:

- Decreases in Bay-wide average salinity (-4% to -7%) were seen for increased precipitation and runoff and decreased boundary salinity.
- Increased average salinity (+5% to +8%) occurred for all other CC scenarios.
- Similar to the SLR scenarios, the greatest changes were seen for the North and Northeast regions.
- CC scenarios did not affect residence times very strongly, producing +2% to -6% changes in the Bay-wide average residence times.

Acknowledgments:
CESU Project: FATHOM Hydrologic Model Development and Application for Linked Florida Bay – Everglades Analysis
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