Southeast Florida Sediment Morphodynamics study (SEFMOD)

A 'System-understanding' Approach to manage navigation & coastal storm risk critical missions.

Miami-Dade County & Port Everglades Metocean, Sediment Tracer and Resource Atlas Study.

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***SAD RSM RCX – Cover Memos on LWI, PE and M-D**

US Army Corps of Engineers®

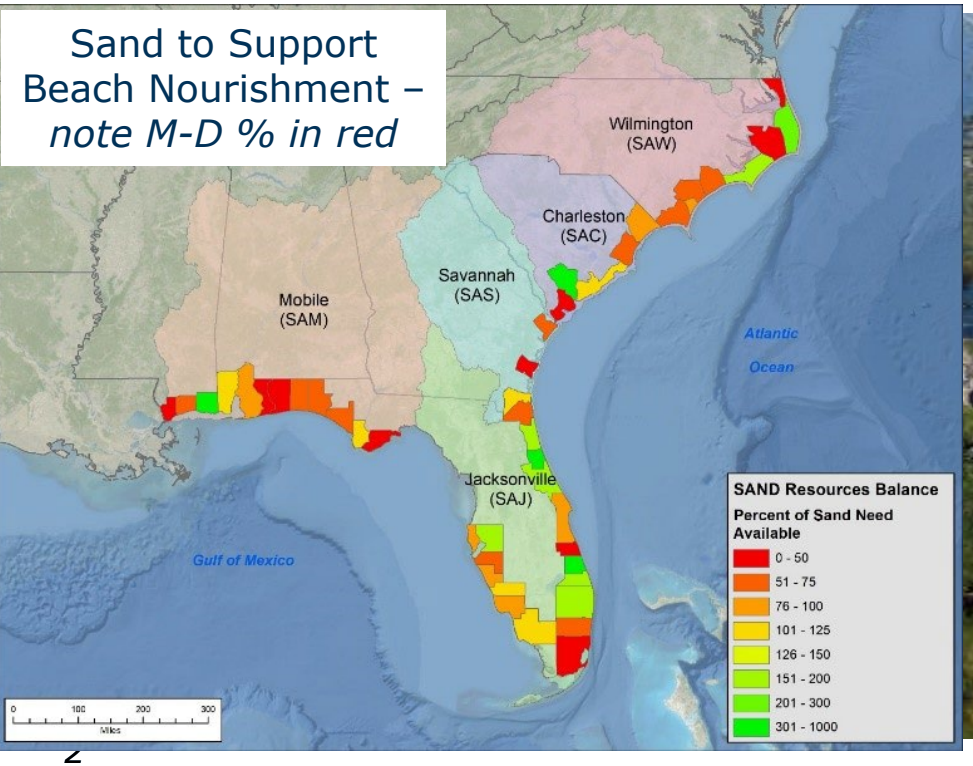
RSM RCX

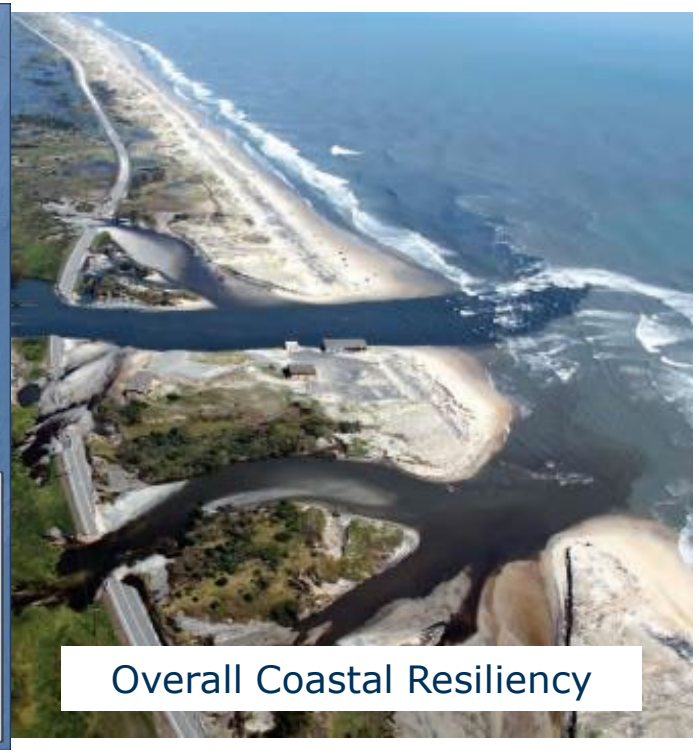
ENVIRONMENTAL TRACING

SEFMOD – Project Overview: Lake Worth Inlet to Miami-Dade

- **Sustainable solutions to improve sediment management for O&M and Coastal Storm Risk Management. SAD need ~1.3 billion CY next 50 yrs.**
- **Scientific approach to better understand the natural system to improve operational efficiencies & cost-savings**

Sand to Support Beach Nourishment – *note M-D % in red*





Overall Coastal Resiliency

https://ewn.el.erdc.dren.mil/nnbf/other/5_ERDC-NNBF_Brochure.pdf

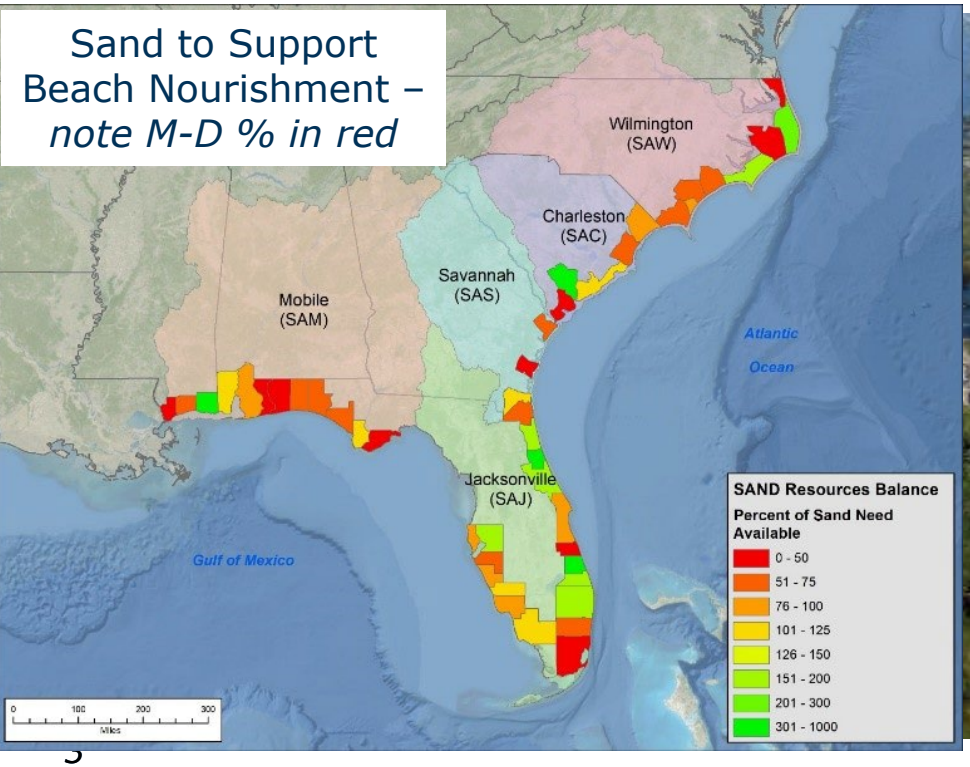
SEFMOD – Project Overview: Lake Worth Inlet to Miami-Dade

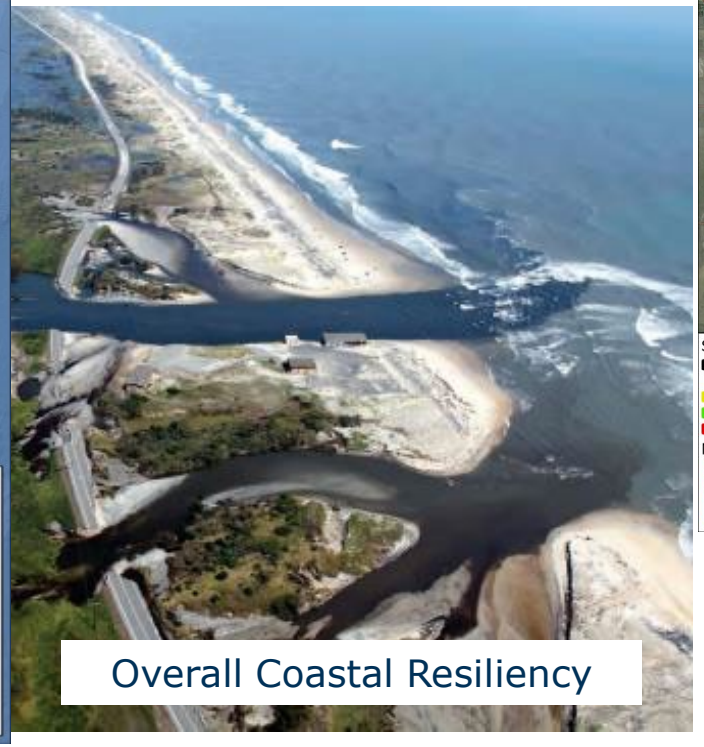
- Sustainable solutions to improve sediment management for O&M and Coastal Storm Risk Management. SAD need ~1.3 billion CY next 50 yrs.
- Scientific approach to better understand the natural system to improve operational efficiencies & cost-savings
- Multi-year, multi-project hydrodynamic and sediment transport & tracing study:

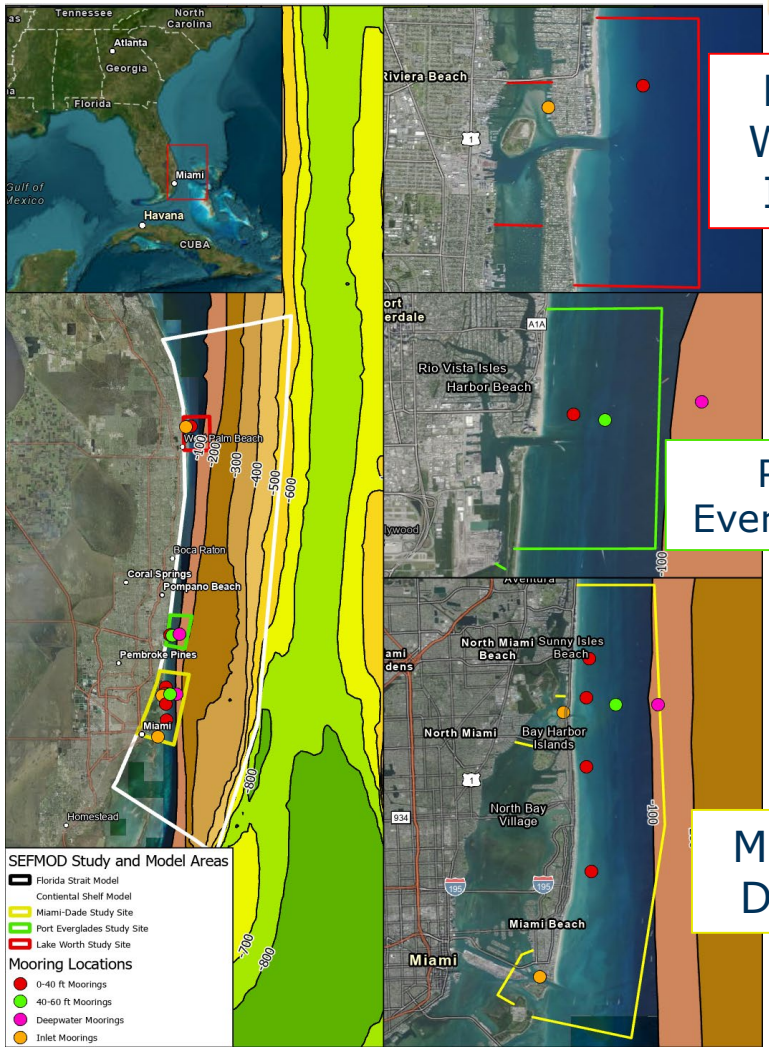
- 80 miles of coast

- 94 cumulative. mths. metocean data alongshore & cross-shore 20’ to 220’

- Silt & sand tracing at 4 sites: 17 specific releases in total, >5000 samples







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Introduction and Background

FSBPA presentation: Lake Worth Inlet Feb. '23

Problem:

Loss of 28' of navigable depth & >25% of channel width.

Re-distributed in <1 week to centre channel as >4' sand waves

= emergency dredging.

Identified:

i) key metocean & sediment transport processes

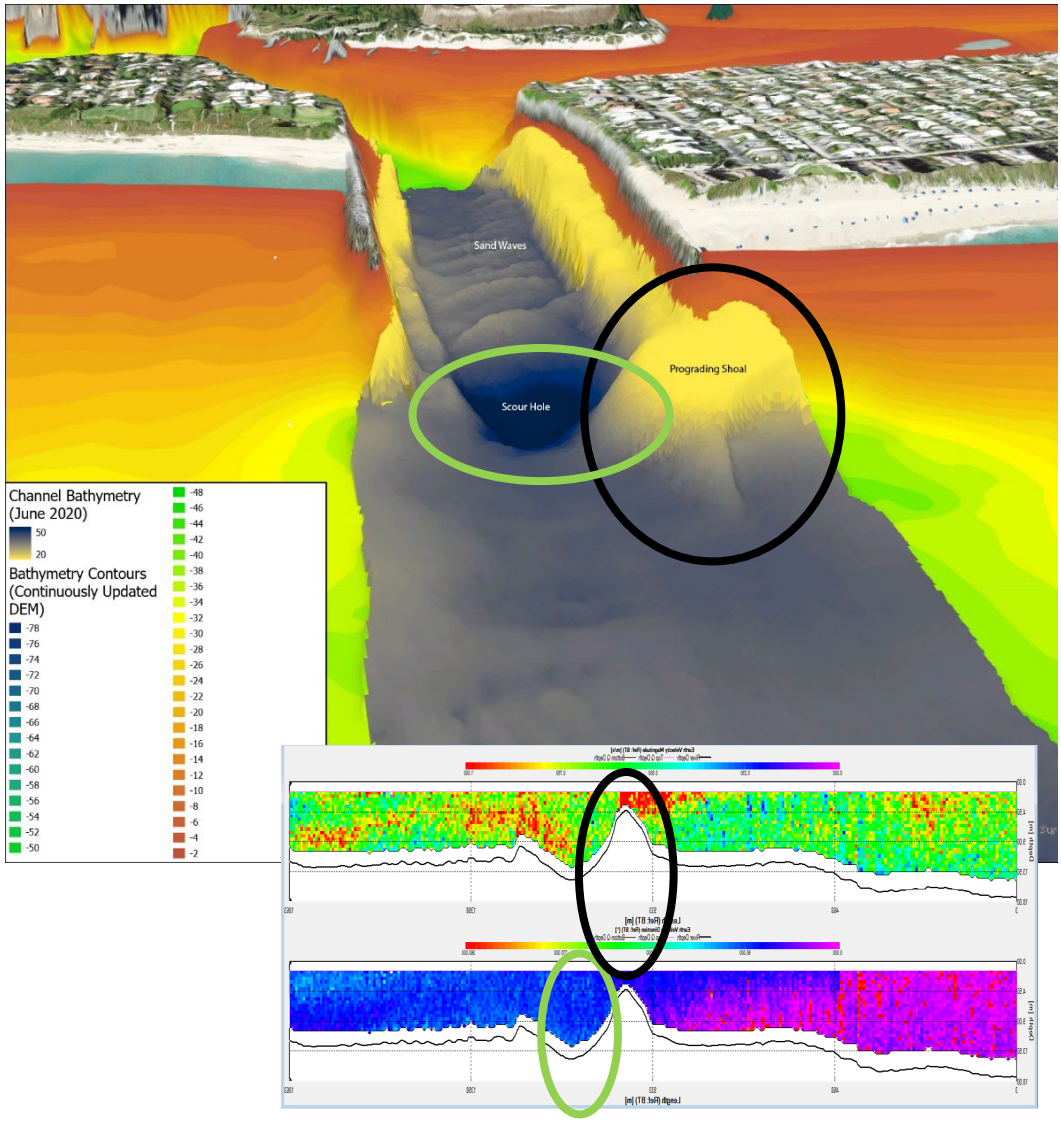
ii) cause of shoaling – bar shoal and sand waves

iii) source of sediment.

Developed conceptual model and system-understanding of the site.

Highlighted sand bypass ineffective & made recommendations.

TODAY – focus (zoom through) PE & M-D & key findings……BUT



Introduction and Background

Port Everglades:
- Now: better understanding of site - key processes, hydrodynamics, importance of tidal/freshwater exchange and ebb jet suspended and bedload transport over wider area.
- *Previously: information did not exist and/or poor understanding of site & processes. Despite numerous studies, modelling efforts.*

Miami-Dade:
- M-D 'run out' of sand (*SAND, 2014; SAD/Taylor Eng. 2021*)
- Considered (FSBPA talks) sand from Martin, St. Lucie or Bahamas. Recent by truck haul.
- HOWEVER, SEFMOD data indicate significant nearshore sources in County.

SO……..why/how has this come about?

Need to take a few steps back to explain how & justify above statements….to answer the WHY?

Introduction and Background: Why/How?

To many, the next heading or discussion would be

Data or Models…..?

Or Perhaps re-write as

*Field** Data *and*** *(or)* Models *(only***)*

* Field – Some models/modellers use & refer to model output as ‘data’ – IT IS NOT

** And – because if predictions or changes are being made, it is AND, not either/or

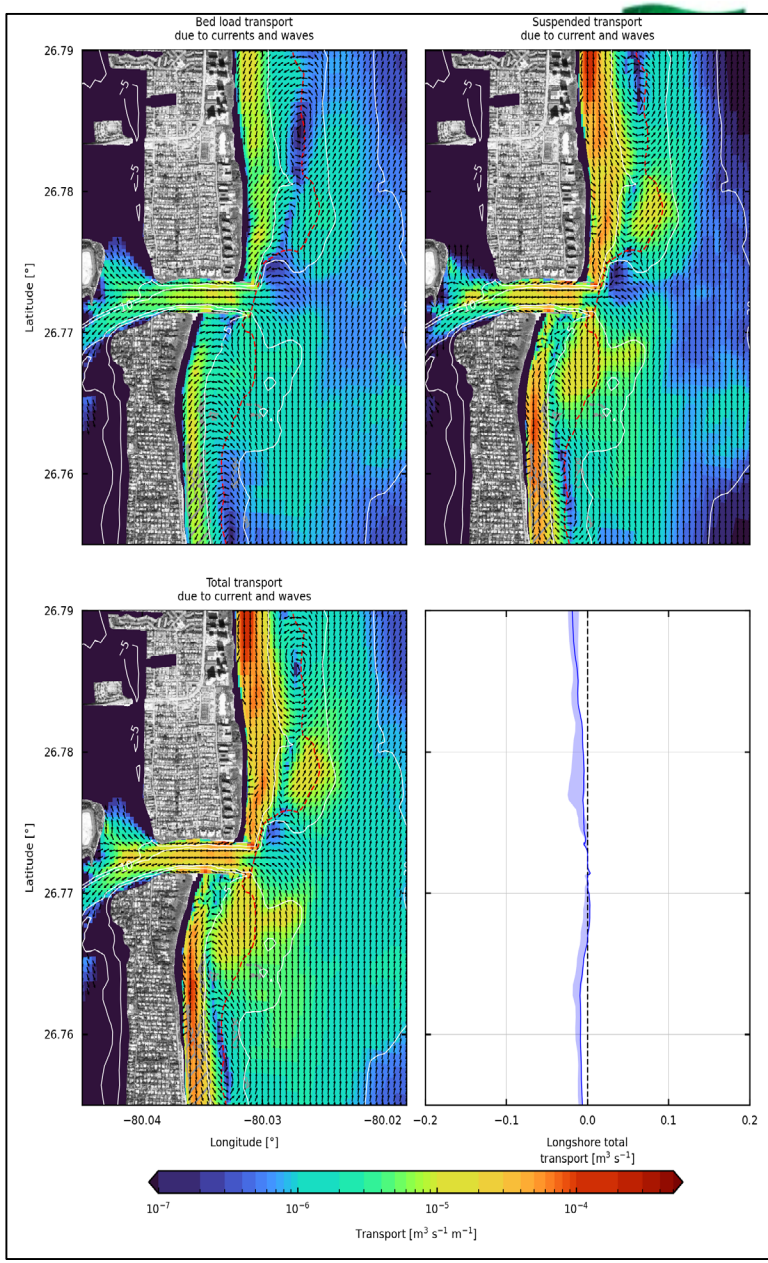
*** Only – because many models are run with no data or almost no (useful) data or even model ‘data’. Appreciate there is cost, difficult to integrate or explain the data or use it.

- Validaton can highlight disagreement between field data & model output: (*needs explaining or ‘correcting’*)
- Graphics, maths or depth-averaged plots never going to be accurate, reliable & hide a lot

Van-Rijn: *models over-simplify (e.g. depth-averaged) complex systems. Cannot resolve small-scale nearshore and (inner/outer) surf zone 3D transport processes – grid at LWI is 150’ cell: simplifies a lot*

>>10 years away from modelling sediment tracing/transport data and results.

Recommends key measurements needed…. Many sediment tracers can answer directly.



Introduction and Background: Why/How?

There is an elephant in the room…..

SEFMOD:

Using focused data measurement: Metocean, sediment transport and sediment tracing at multiple adjacent sites alongshore & cross-shore

Key: Multiple strands of data (methods, timing, sites) supported each other, combined and corroborated

Result: Developed a system understanding and conceptual models

Introduction and Background: Why?

There is an elephant in the room. Scientists, engineers cannot agree!

BUT

Modelling not (yet) deliver same level of understanding, prediction, accuracy. (Elephant - MODELS on their own (i.e. no/little data) never will…)

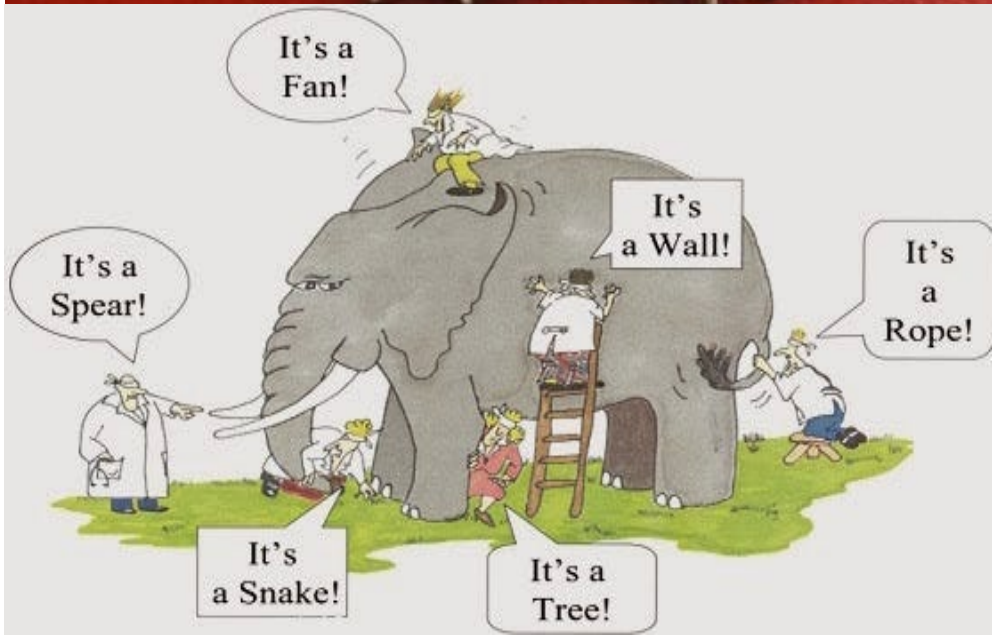
Partly: sites and key driving processes (Florida Current) so complex….

SEFMOD Modellers (incl. van Rijn) concluded too complex to model field data to calibrate/validate the model, even sediment tracer results!

'The measured data reflected combined hydrodynamic forcings that adjust and interact and are more difficult to separate'.

Florida Current modelled as a quasi-dynamic process i.e. fixed forcing conditions used. Did not occur during 10-mth. field measurement period.

Model Output was 'Qualitative'. 'Did not define key hydrodynamic processes and therefore sediment transport features'. Not represented in inner/outer surf zones or shoals.



Copyright: Sophia Tepe

Data and Models (but, the Elephant is still in the room)

1) Models often depth-averaged masking key hydrodynamic features:

PE perfect example:

- Inlet acts as an estuary with flood tidal pumping of sediment into harbor

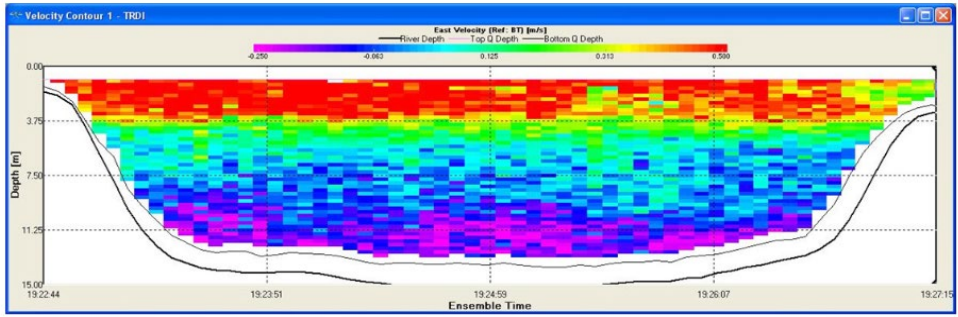
- However….a rainfall event increases freshwater flow, creates stratified water-column and can even completely reverse the flood tide = estuary = large ebb jet

- Ebb tide (plus freshwater) jet >2000 yds out to Inner, Middle and Outer reef

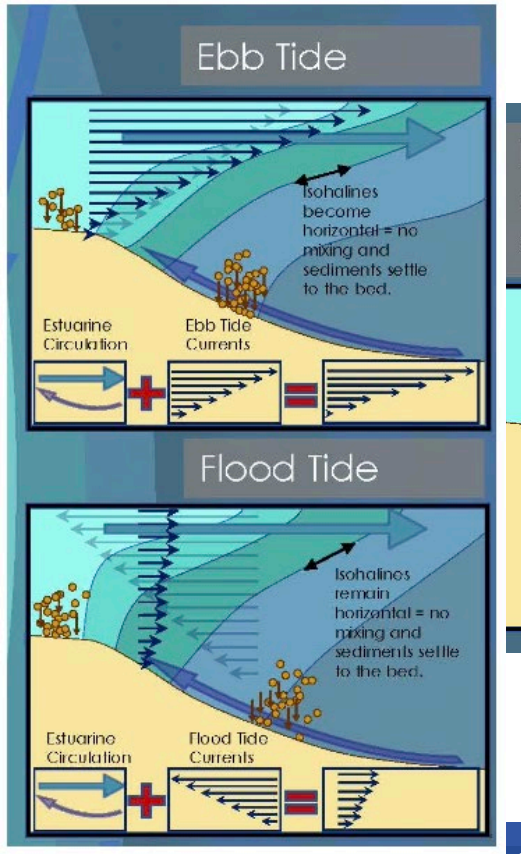
- Known since 2000s BUT ignored, explained or 'corrected' in models to present day, e.g.

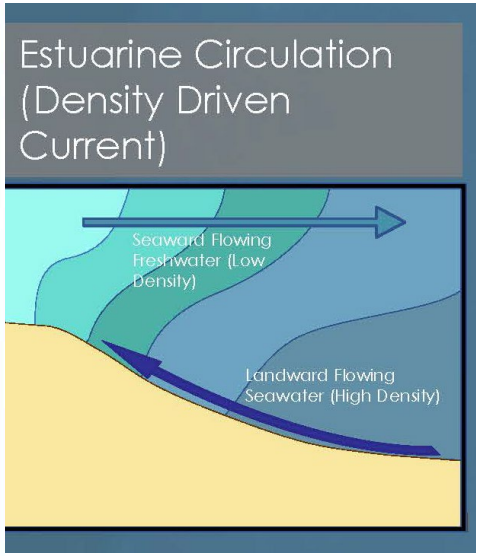
i) proposed PE capital dredge modelling and assessments &

ii) removal of spoil shoal and sediment trap.



(Stamates et al., 2013: opposing flows +0.5 to -0.25m/s Top to Bot.).





<u>Depth-averaged models do not reflect hydrodynamics & also near-bed sediment transport processes, bed shear stress</u>

<u>Simply – won't predict when silt or sand will move or remain stationary.</u>

Data and Models (but, the Elephant is still in the room)

2) Models assume sediment particles are *Either* permanently Suspended load *Or* Bedload, over a uniform or laminar bed often over-predicting transport rates.

3) Models do not accurately reflect bedform (PE, M-D critical due to reefs**), burial, turbulence in reef areas, resuspension and erosion, flocculation, settling-deposition = key 3D sediment transport processes.**

SO…SHOULD WE ALL JUST GIVE-UP, NOT USE MODELS OR RELY ON THEM?

NO. ALL NEED GOOD & ACCURATE MODELS. BUT….

Rubbish in, Rubbish out! One current meter or tide gauge for 2-4 wks. not enough…….

Answer: FIELD MEASUREMENTS of REAL DATA: hydrodynamics AND sediment transport (including tracers) & ACKNOWLEDGE MODEL LIMITATIONS

Data and Models – *System Understanding approach*

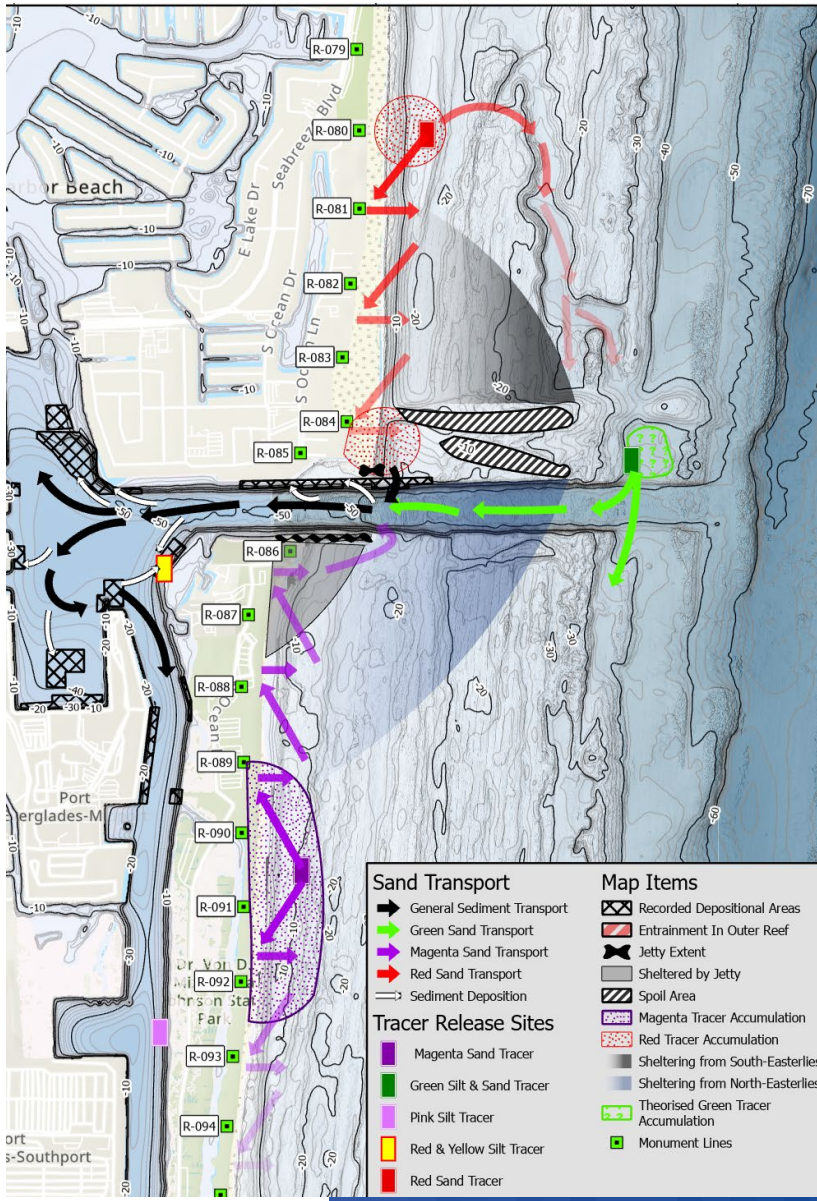
- Currents, waves, tides & wind*, salinity, turbidity**

(wind-driven circulation, setup, oscillation - key process, left out of models; effects 'adjusted' or 'error')*

(** turbidity must be calibrated (SSC mg/L, not NTU) for natural events (storms) and dredging. Must measure currents real-time to know where is 'down-current'. 'Biofouling' does not explain 'elevated' turbidity if returns to <1NTU 1 hour later.)

- Acoustic sensors for bedload transport
- Infra-red sensors for erosion and resuspension measurements
- Swathe bathymetry to assess bed-level change (difference) over time and geophysical surveys to measure sediment thickness and rock interface
- Sediment tracing: silt and/or sand

SEFMOD: Done at multiple sites, depths over 7-10 months



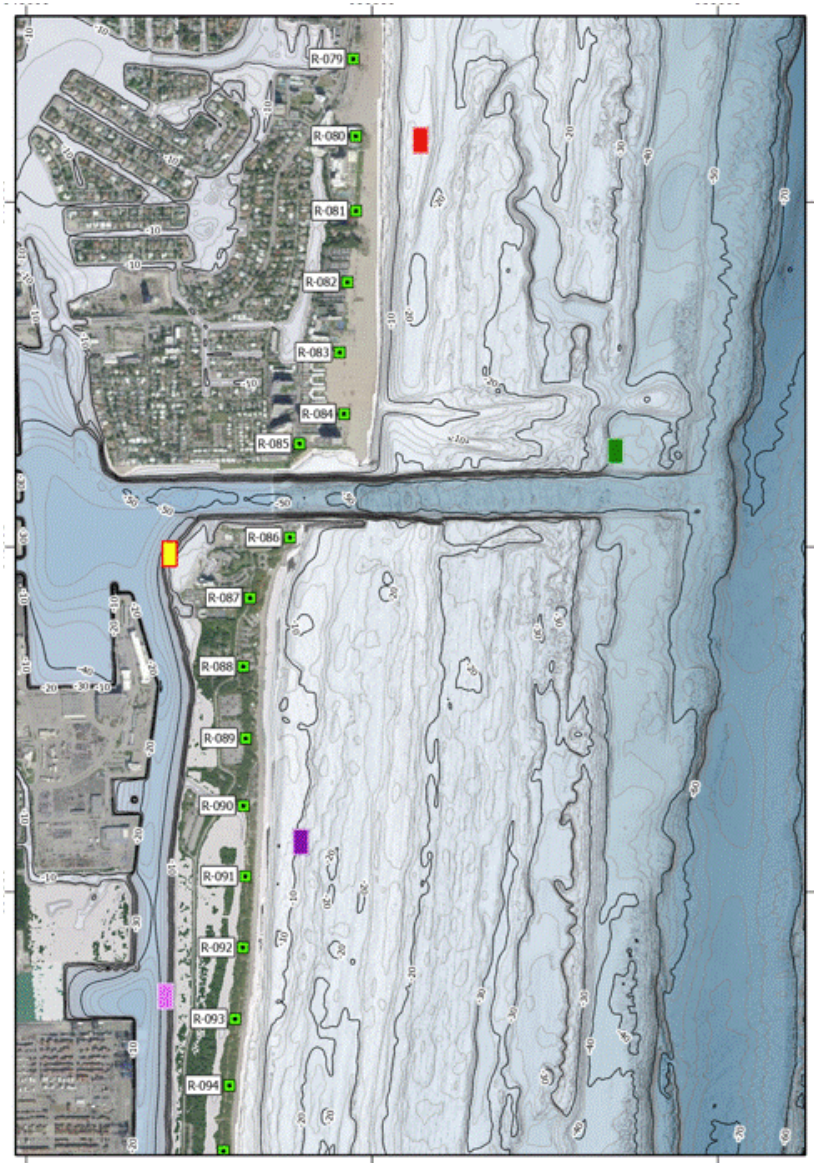
Data and Models – *System Understanding approach*

SEFMOD: Done at multiple sites, depths over 7-10 months

- Silt/sand tracing **complements** numerical modelling AND other data - corroborates.
- Sediment tracers **move exactly like & assimilates** native sediment; it is in constant flux & reflects complex 3D transport processes (erosion-resuspension etc.).
- Directly mimic/reflects **both transport 'modes'** (suspended & bedload) and bedform

Data used to develop, improve, calibrate (setup & drive) model, and validate (compare output with real-data) models. At a higher resolution especially cross-shore transportation between beach, inner and outer surf zone: *critical in PE & M-D.*

ERDC: Sediment tracers provide data on sediment movement not obtained by other means



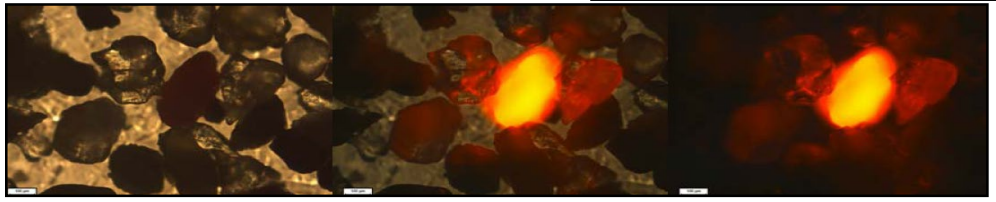
Environmental Tracing: Sediment Tracing

ET carried out >100 silt and sand studies worldwide, >20 Beneficial Use, PIANC 'Working with Nature' award and applications: Longshore sediment transport, barrier island, nearshore placement, ODMDS

- Natural/artificial material with identifiable & unique signature: fluorescence
- Track particles spatially over time: measure transport pathways and map where deposited (or not).
- Release, collect samples, analyse & interpret all metocean & tracer data
- Direct, tangible, unequivocal for stakeholders, public: from A to B
- Sediment tracers reflect constant cycle & to-fro motion of natural sediment

EcoTrace® key characteristics:

Behave as native sediment: clay, silt or sand.	Match size (1-1000µm) and density (1->2.65 g/cm^3).	Test behaviour: settling & fall velocity.
Detectable over years & >100 km^2	Different colours & sizes: label different sources for same metocean & environmental conditions.	Environmentally inert particles; non-polymer available
Detect v. low concentrations: 1 particle in a 0.5kg/1lb of sand	Viable in high energy systems. Mouth of Columbia River, Hurricane Irma & Dorian.	Detect using image analysis. Size tracer particles - relate to hydraulics, size of storm or waves

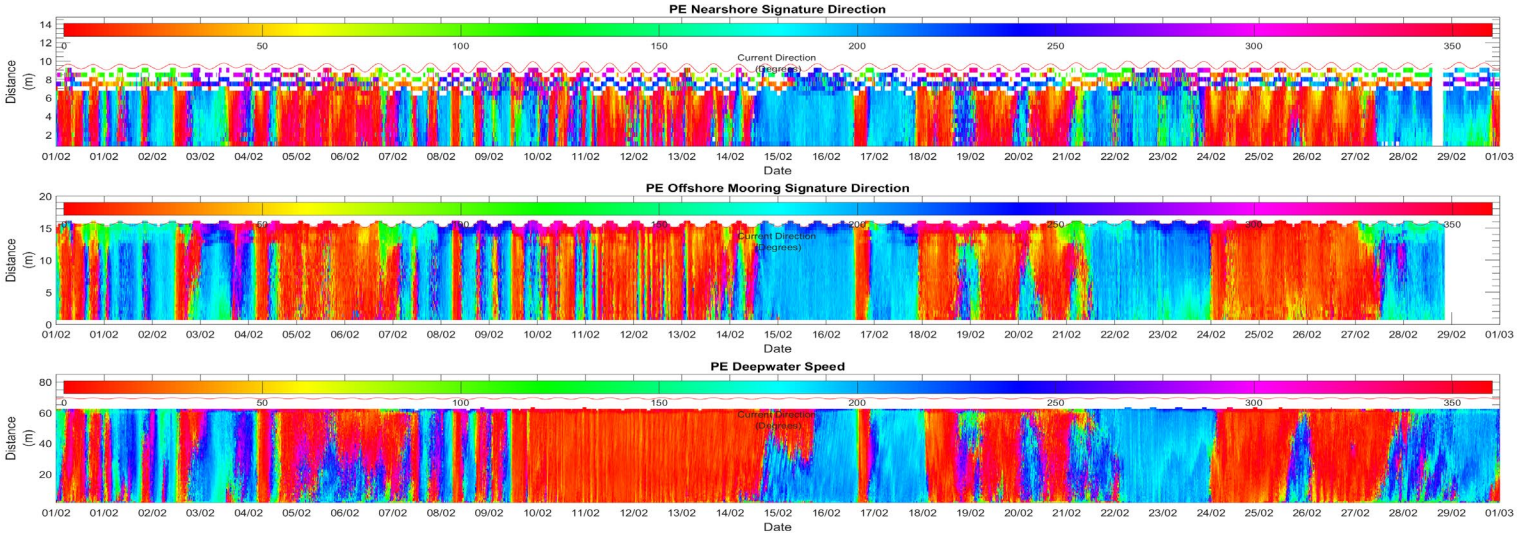


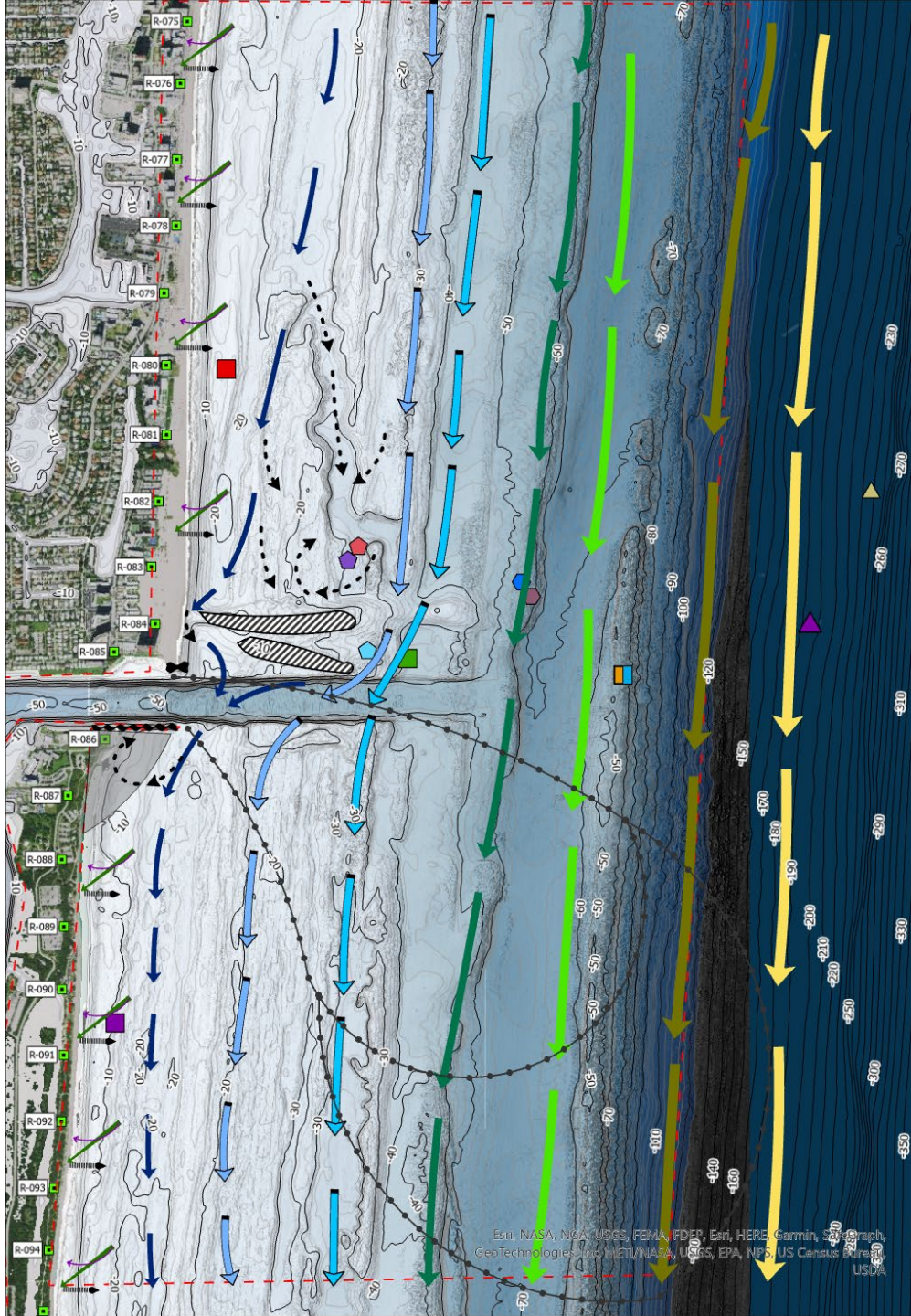
SEFMOD – PORT EVERGLADES:
Key metocean and sediment transport processes

- **Wind and wave-driven circulation** oblique to shore. N'Easters veer to SE & Summer SE Trade winds.
- **Florida Current**: Approx. 50% north & south varies from hours to days Stronger in summer and at LWI

<u>Flow to South (Blue) (Nth (Red):</u> South FC and/or N'Easters.
<u>VARIES significantly Nearshore, Offshore & Deepwater</u>

- Wind & waves oblique to shore. Deflected around spoil bank (before removal) with shadowing effect, deposition of silts to the north
- Deflected ebb (& freshwater) jet to SE if emerging



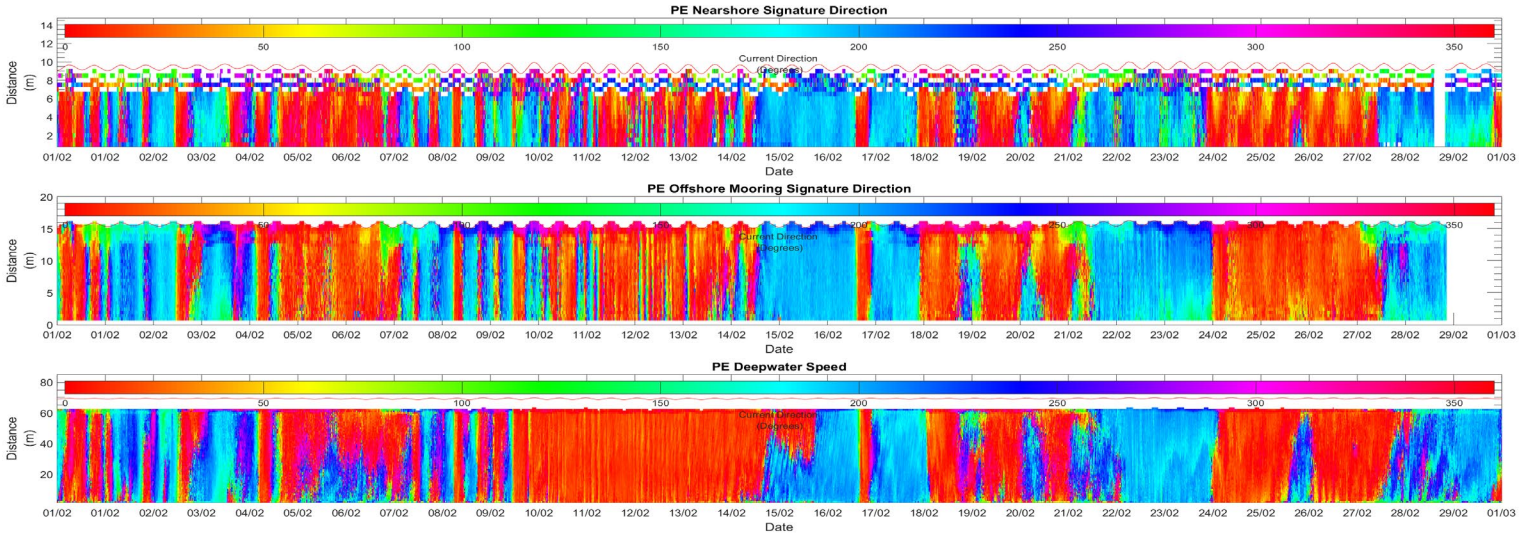


SEFMOD – PORT EVERGLADES:
Key metocean and sediment transport processes

- **Wind and wave-driven circulation** oblique to shore. N'Easters veer to SE & Summer SE Trade winds.
- **Florida Current**: Approx. 50% north & south varies from hours to days Stronger in summer and at LWI

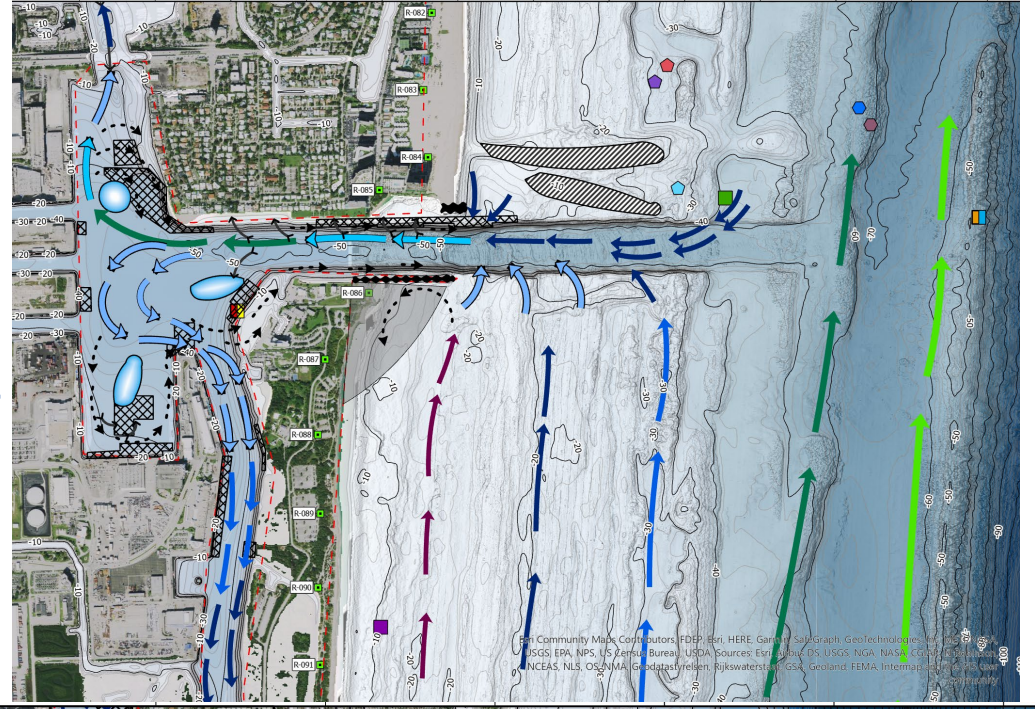
<u>Flow to North (Red):</u> North-running FC & summer Trade winds
VARIES significantly cross-shore

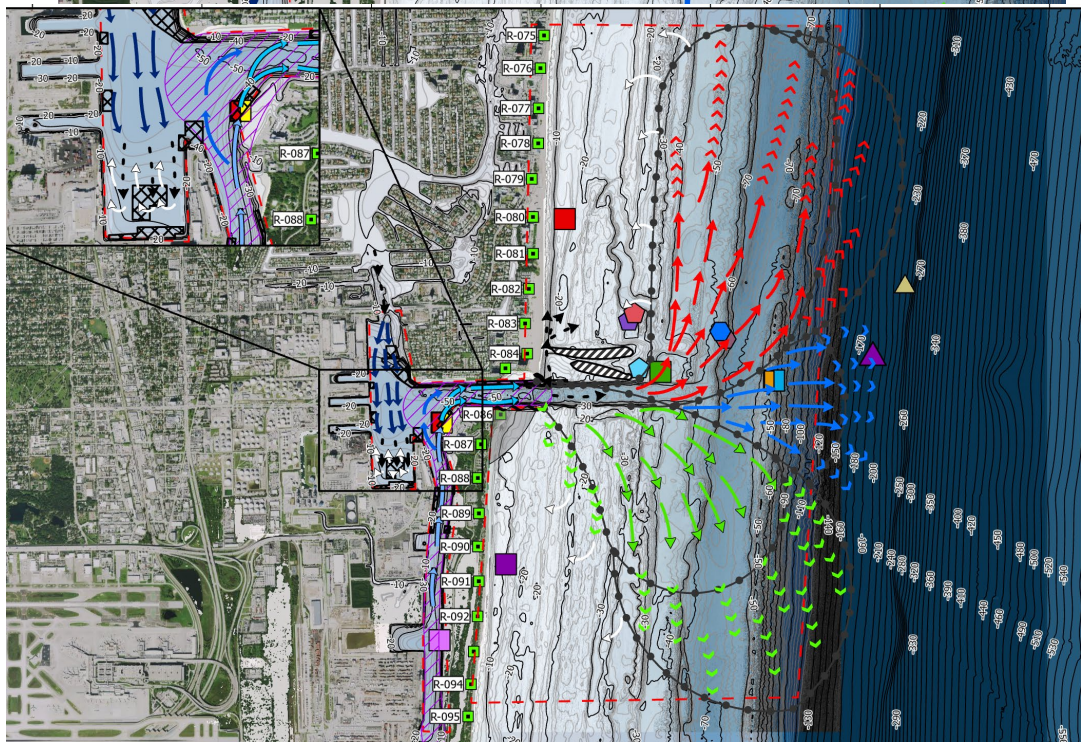
- Deflected around spoil bank (before removal) with shadowing effect, deposition of silts to north
- Deflected ebb (& freshwater) jet to NE if emerging



SEFMOD – PORT EVERGLADES:
Key metocean and sediment transport processes

- **Wind and wave-driven circulation** oblique to shore. N'Easters veer to SE & Summer SE Trade winds.
- **Florida Current**: Approx. 50% north & south varies from hours to days Stronger in summer and at LWI
- **Tidal inlet flow**: tidal dominance varies. Ebb jet combines with freshwater during storms. Can displace or weaken the flood tide



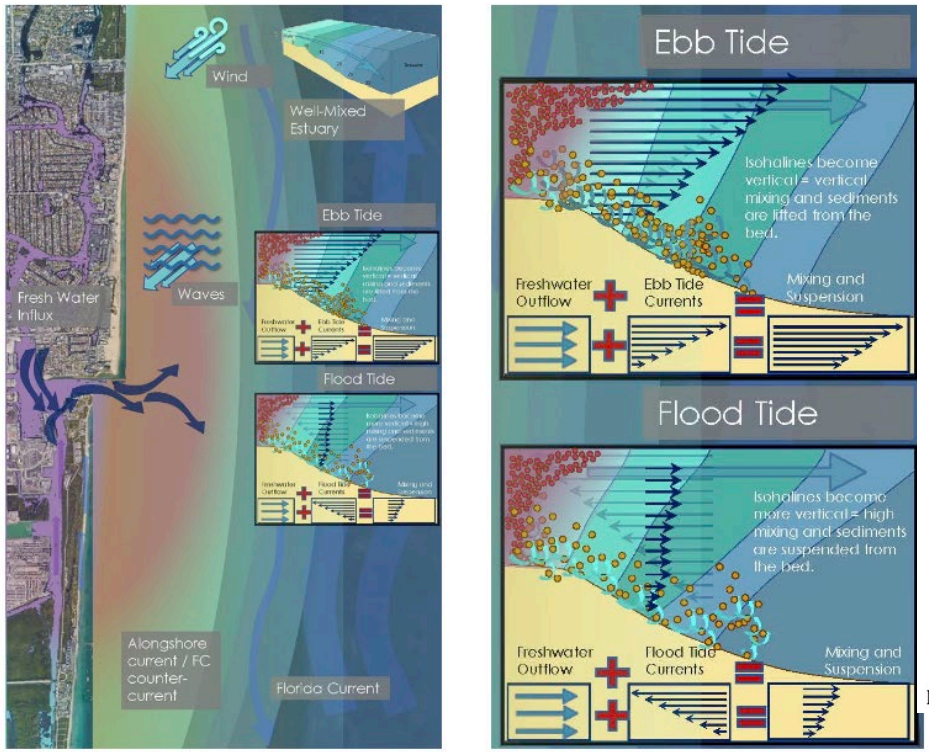


Flood flow
- enhanced by north flowing FC near-bed with tidal pumping into harbor
- Divergence creates return flows, gyres & depositional requiring O&M dredging as per silt/sand tracers

Ebb tide (and freshwater flow)
Deflection & strength of ebb jet function of nearshore circulation (FC, N'Easters and Coriolis forces)
Red – strong Nth FC
Blue – no FC or NE
Green – strong South FC and/or NE

SEFMOD – PORT EVERGLADES:
Key metocean and sediment transport processes

- **Wind and wave-driven circulation** oblique to shore.
- **Florida Current**: Approx. 50% north & south varies from hours to days
- **Tidal inlet flow**: tidal dominance varies. Ebb jet combines with freshwater. Can displace or weaken the flood tide
- **Very low near-bed currents** due to bedform, v. irregular bed and bed roughness (coral/hard-bottom). Increase >0.1 m/s in N'Easters. Higher near-bed velocities are a continental shelf feature not measured in deepwater. Lead to settling, deposition and accumulation of (dredged) sediments, other than larger waves/storms.
- **Tropical storms, hurricanes, surges**



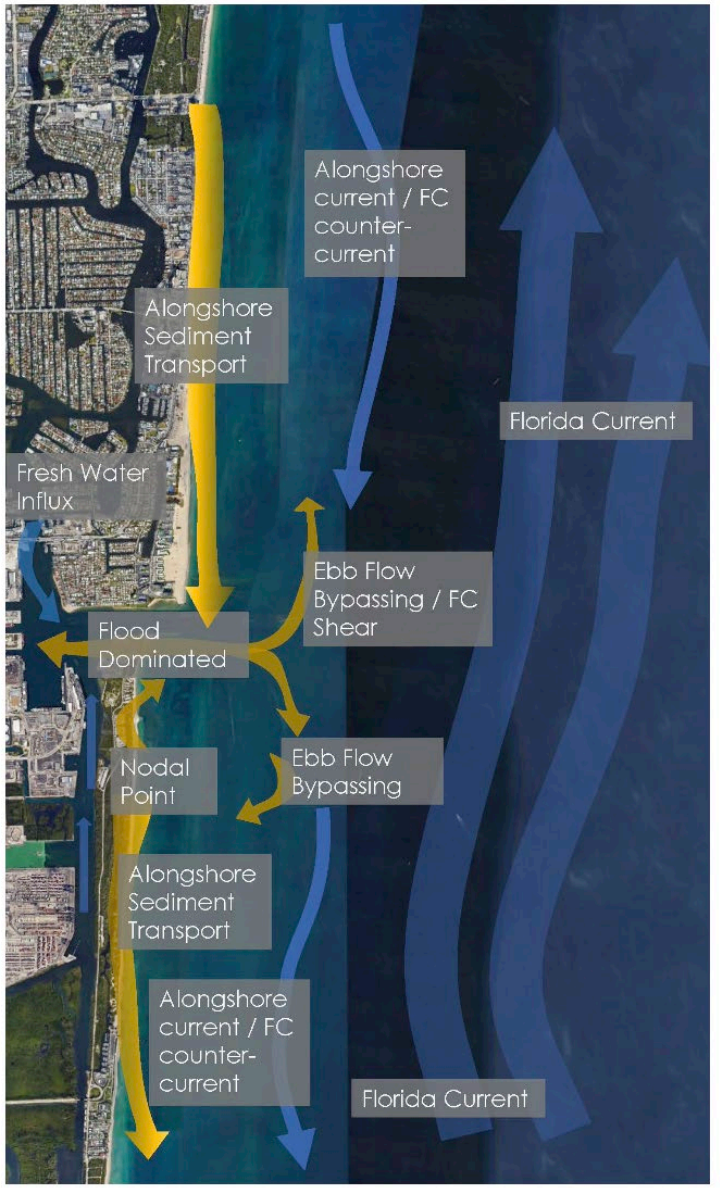


Figure 4: Predominant Nearshore Currents and Sediment Transport Pathways

: High Energy Well-Mixed System with large rainfall event / canal release, sediment resuspension (brown) and freshwater plume (pink) at Port Everglades

Conclusions - PE

1. Complex, opposing & dynamic metocean processes drives suspended sediment plumes & sediment transport.
2. Smaller back-basin & very high freshwater flows creates more subtle hydrodynamics vs M-D & LWI.
3. PE behaves as an estuary, flood-tidal pumping, highly stratified – not incorporated in data & modelling to date.
4. Natural storms & wind-wave events create SSC (mg/L) nearshore and bed level changes 3-4” in NE storms. (*NTU is not accurate or standard. Data collected previously (DCA, O&M) comparable, but not calibrated. NOT biofouling*).
5. Storm events is acute event (hard-bottom survives?). Dredge ops.: chronic load even in H/M/L impact zones = mortality.
6. Fines (silt tracers) remain in study area, settle & deposit despite FC, N’Easters due to bedform. Same as MHIII.
7. Fines (silt tracers) remain in harbor, emerge in high freshwater flow & disperse and deposit as far as Middle/Outer Reef
8. Now have a clear system-understanding of hydraulics & sediment transport: recommend detailed review of all dredging and disposal operations, capital dredging, sand transfer plant & removal of spoil bank; a new equilibrium will develop if removed
9. Complexity of site: not possible to accurately predict, model or use AI for dredging ops. Model not reflect key features in 3D.
10. Dredging ops: proposed deployment of real-time mooring sites without understanding will lead to environmental impact, dredge down-time, costly monitoring and dredging contract (unbiddable?). Recommend Corps retains full control.

SEFMOD - Miami-Dade

(Historic) Problem

- *1937: little inter-tidal beach, groins*
- *1970 NYT: Corps propose 15 million cubic yd. (cy)*
- *2018: 97% of 15 miles 'critically eroded' (FDEP)*
- *O&M dredging at Govt. Cut : 16,000 – 25,000 cy/yr.*
- *~21.9 million cy placed 1955 – 2020**
- *SAND (2014) & SAD/TE (2021) 20 million cy next 50 years*
- *Both concluded offshore sand in M-D County limits depleted; sand from counties north (St. Lucie, Martin etc.), Bahamas?*
- *2022: Based on assumptions, CSRM (USACE) Recommended Plan concluded Main Segment R27 – R74 (Bakers Haulover to Govt. Cut) needed 10 million cy for 2025 - 2075*
- ***Spent $87.9M to nourish Miami Beach, Sunny Isles $58.4M & BAL/SURFSIDE $28.2M = $174.5M***

**(Source: FDEP, SBMP, SE Atlantic SBMP, 2020 – excludes county/hotels)*

Figure 2: Miami Beach 1937. (Romer, G. W.(Gleason Waite), 1887-1971. Aerial photograph looking north over Miami Beach. 1937-04. State Archives of Florida, Florida Memory. Accessed 12 Sep. 2023. https://www.floridamemory.com/items/show/35543)

The Sands of Time Are Running Out for Miami Beach

THE NEW YORK TIMES, SUNDAY, MAY 10, 1970

The Corps of Engineers proposes to pump 15 million cubic yards of sand onto the stretch of oceanfront running from Government Cut to Baker's Haulover Cut. This would create a beach about 200 feet wide, backed by a hurricane berm two and one-half feet high and placed about 20 feet out from the present shoreline. Hurricane protection is the chief reason for the engineers' proposal. An additional 200,000 cubic yards of fill would be required annually to maintain the beach.

$30-Million Project

Figure 3: Miami Beach 1970. (Aerial view of the Fontainebleau Hotel - Miami Beach, Florida. 1970. State Archives of Florida, Florida Memory.

https://www.floridamemory.com/items/show/55330

SEFMOD - Miami-Dade

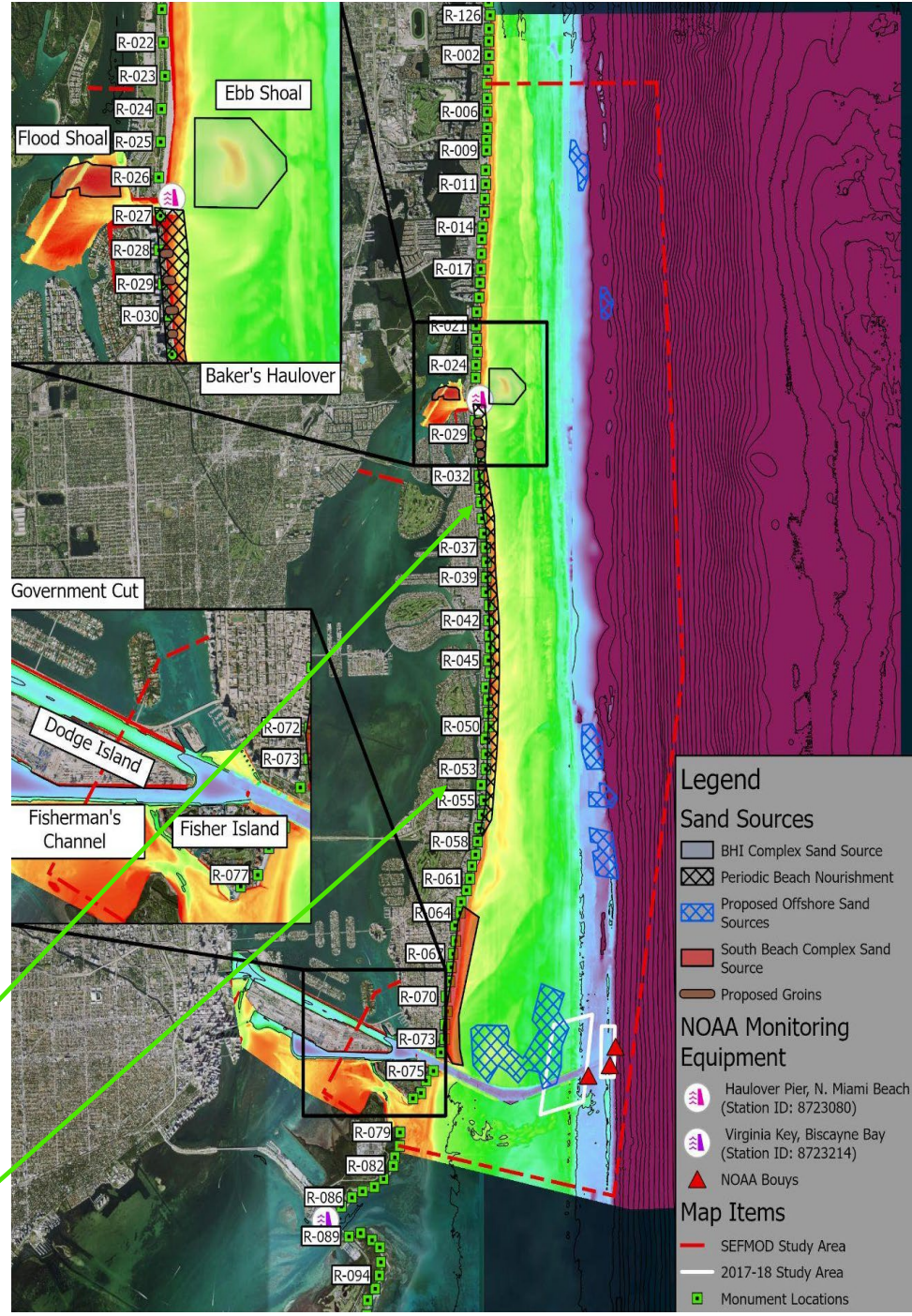
Goal

- *Identify sediment sources*
- *Can sand be recycled?*
- *Can erosion be slowed down (i.e. for high erosion areas/hotspots?)*
- *Produce M-D County-wide sediment transport and resource atlas*

Objective

Use county-wide metocean and RSM study & system-understanding:

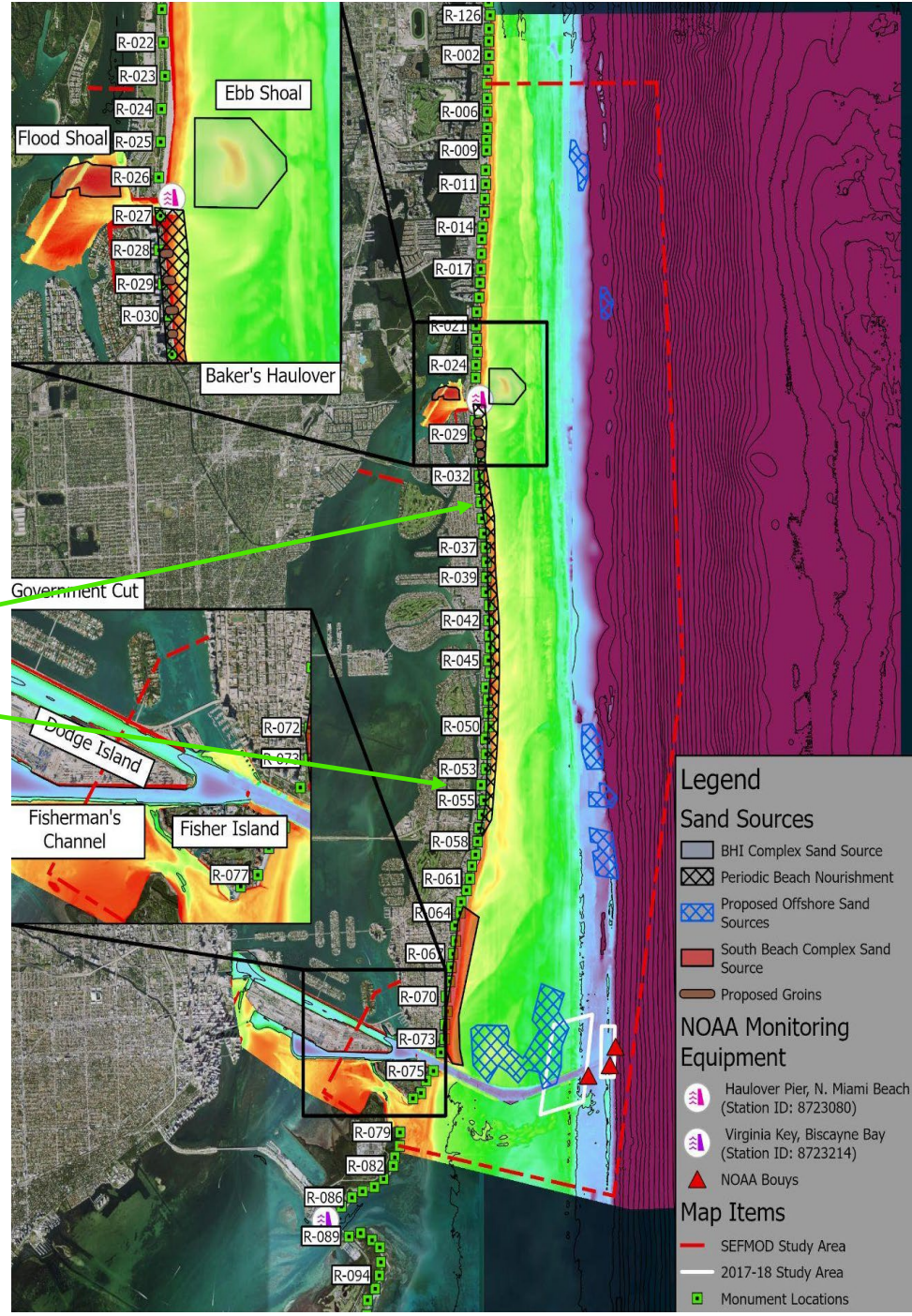
- *Improve sediment availability for CSRM projects for long-term resiliency*
- *Reduce future nourishment needs, interval & costs including nearshore berms*
- *Improve inlet and sediment management.*



SEFMOD - Miami-Dade

Study:
Circulation: ADCP surveys
Sand tracing: 7 sites to determine longshore transport, pathways, fate, difference between beach and nearshore placement
Silt tracing: at 4 sites to assess fate of fines for beach vs. nearshore
8 Inshore, Nearshore & Deepwater moorings: currents, waves, wind, turbidity over 7 – 10 months
>4000 beach & seabed samples: 7 months, 4 – 6 sampling rounds & PSD
2 x multibeam bathy >40km2 (16sqmi.): bed level change over ~6 months
1 x Geophysical & sidescan survey for sediment thickness & bedform

USACE nourished:
- 330,000 yd3 at Surfside (~R31 to R36) in Fall '19 prior to Bathy 1st survey
- 4 Hotspots between R43 to R61: 305,000 yd3 Jan - Jun. '20 between Bathy 1st and 2nd survey

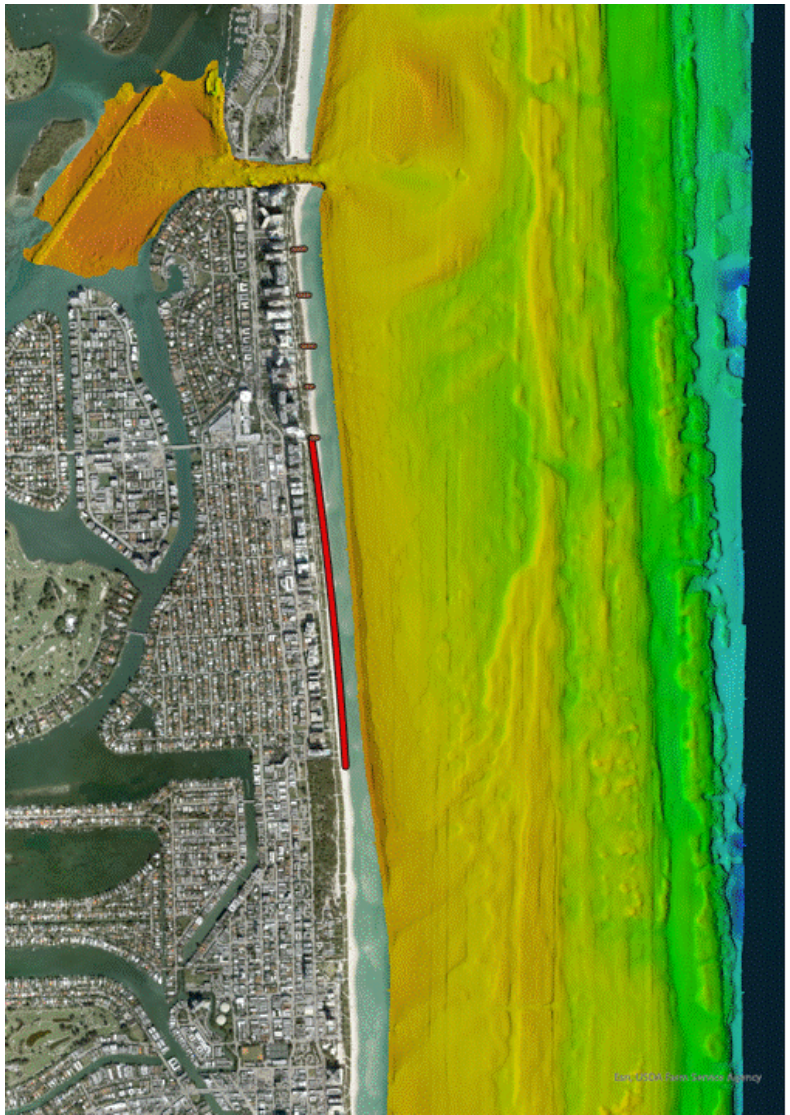


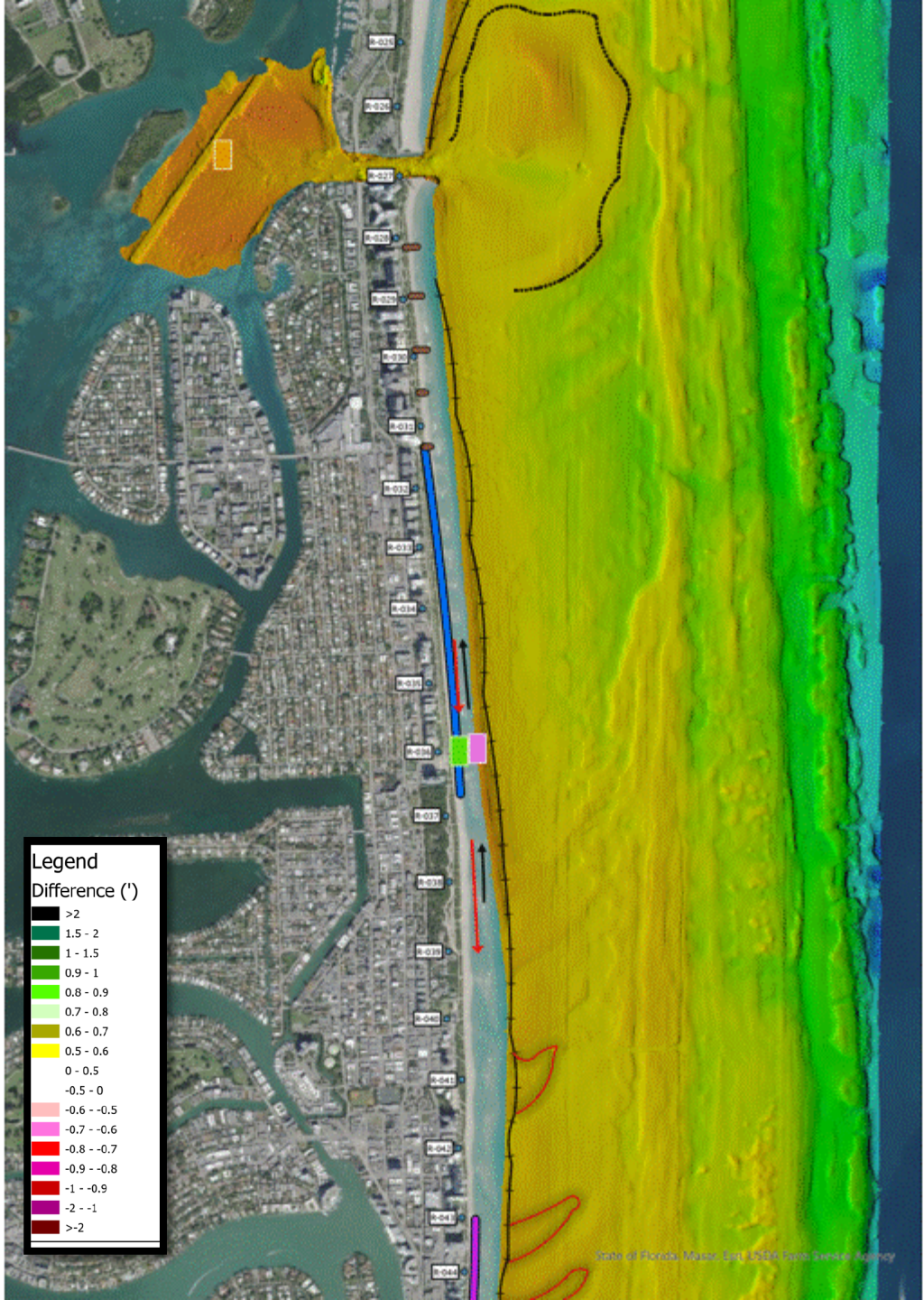
SEFMOD - Miami-Dade

Surfside nourishment:

Sand tracing results & bathy change (*yellow/green = deposition*) to develop:

- Key metocean processes
- Conceptual model for sediment transport
- Silt and sand tracers placed on beach & nearshore: very little difference.

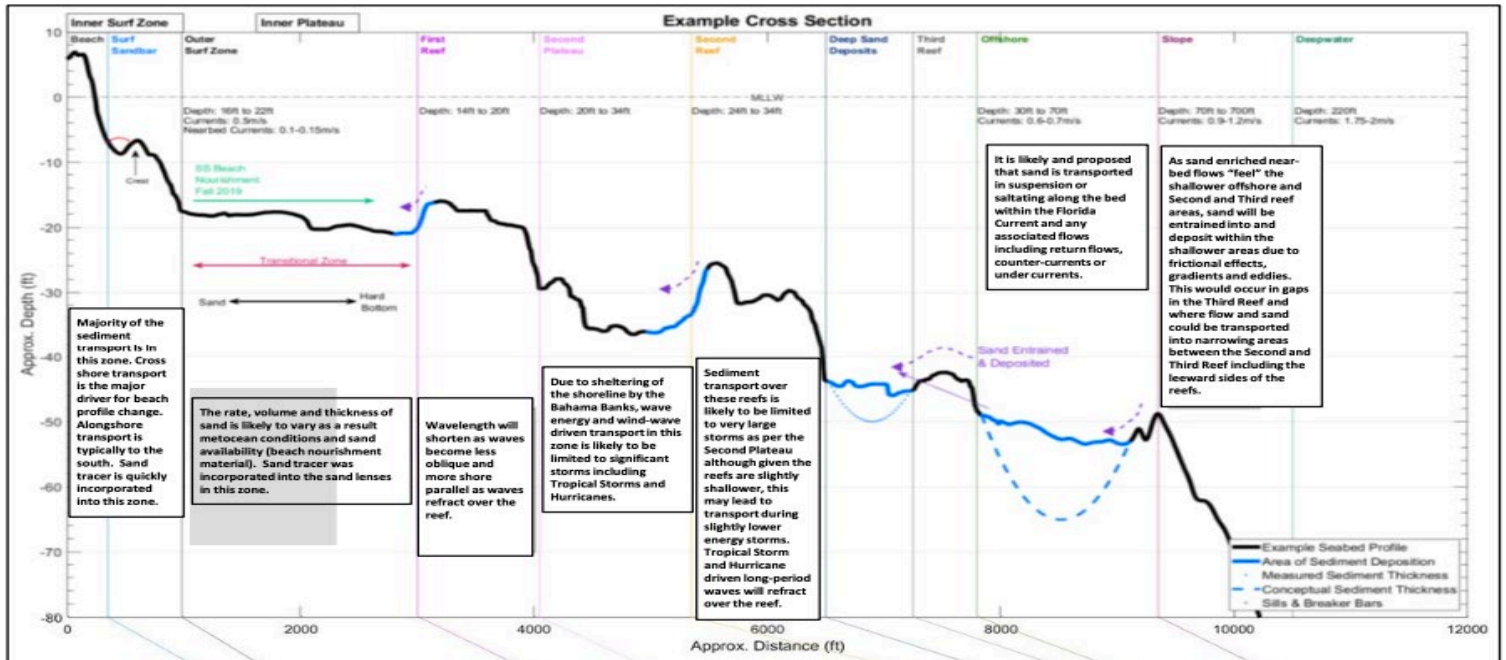


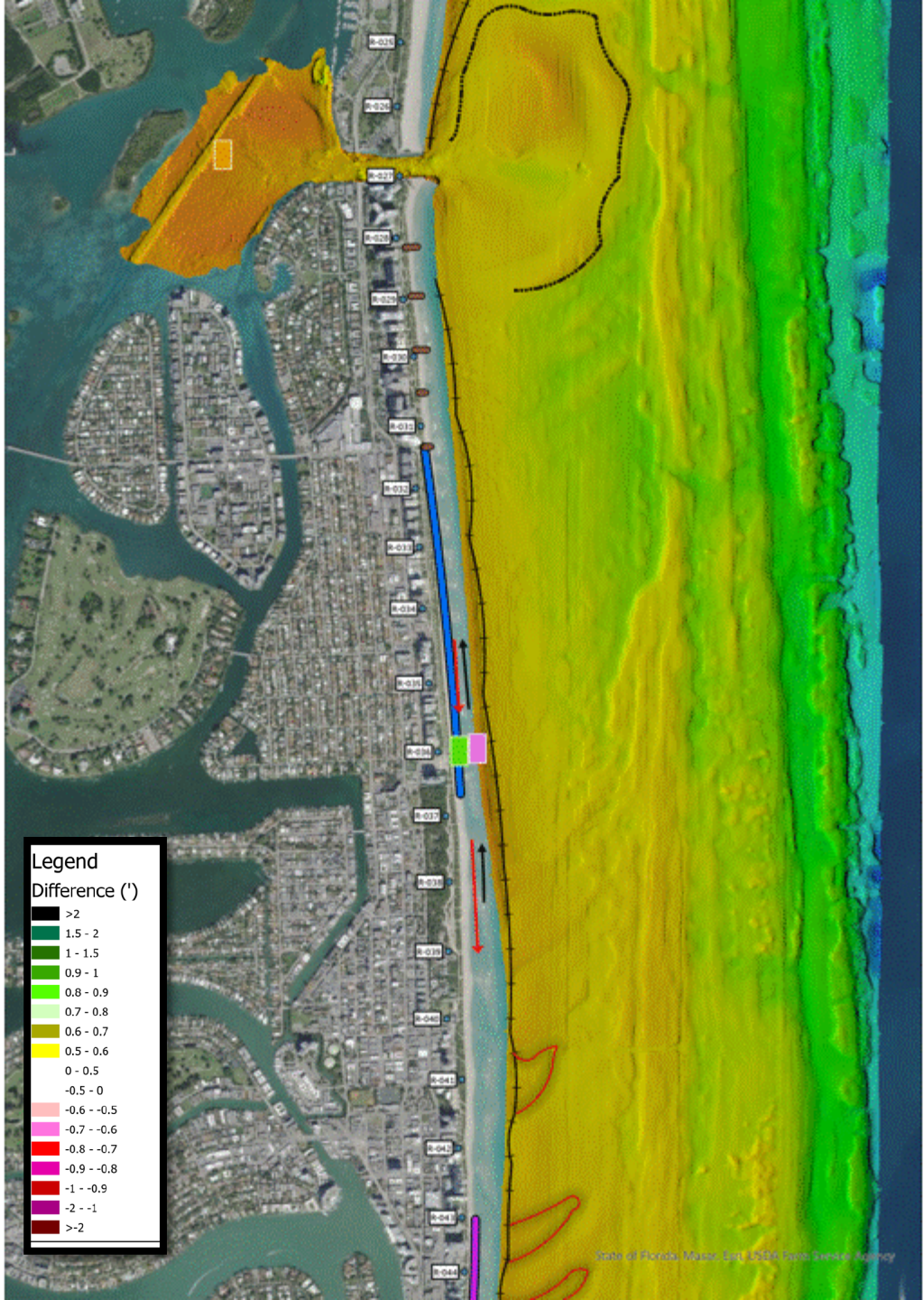


SEFMOD - Miami-Dade

Surfside nourishment & metocean/sediment transport data:

Define sediment transport zones: *Beach, Inner Surf zone, Outer Surf zone (Inner Plateau), Reef (1st and 2nd and 3rd) and The Slope*



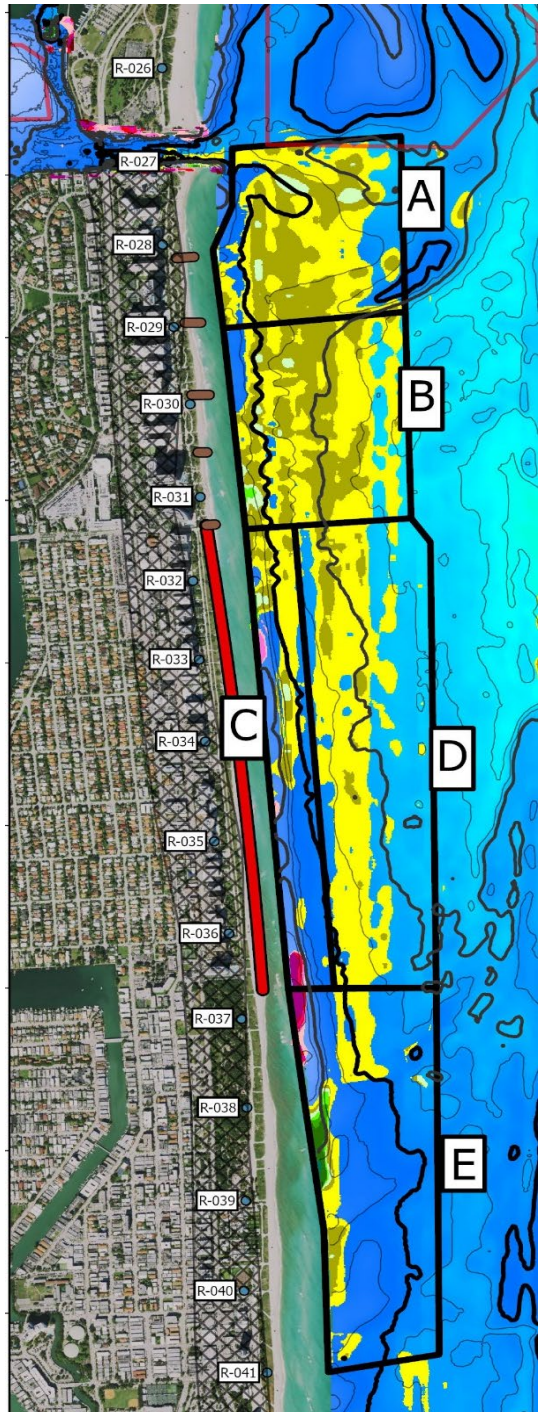


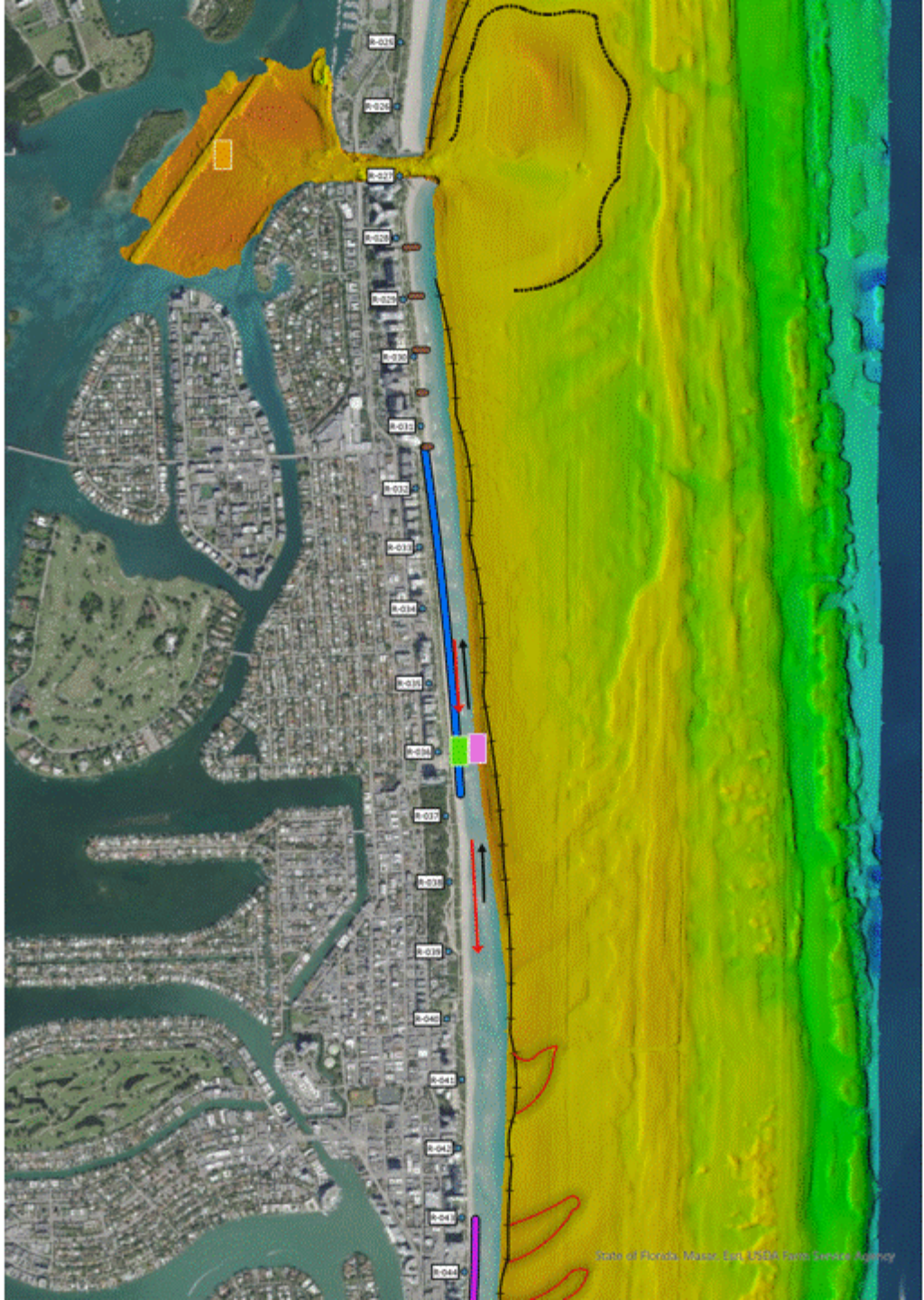
SEFMOD - Miami-Dade

Surfside nourishment:

- 83% of sand accounted for (excl. beach)
- No fines deposited medium/long-term in any hard-bottom/reef areas
- Used different metocean, sediment transport, tracers, bathy & geophysics to corroborate & cross-reference

Area	Percentage in area
A	21.7%
B	27.1%
C	6.5%
D	20.8%
E	7.3%

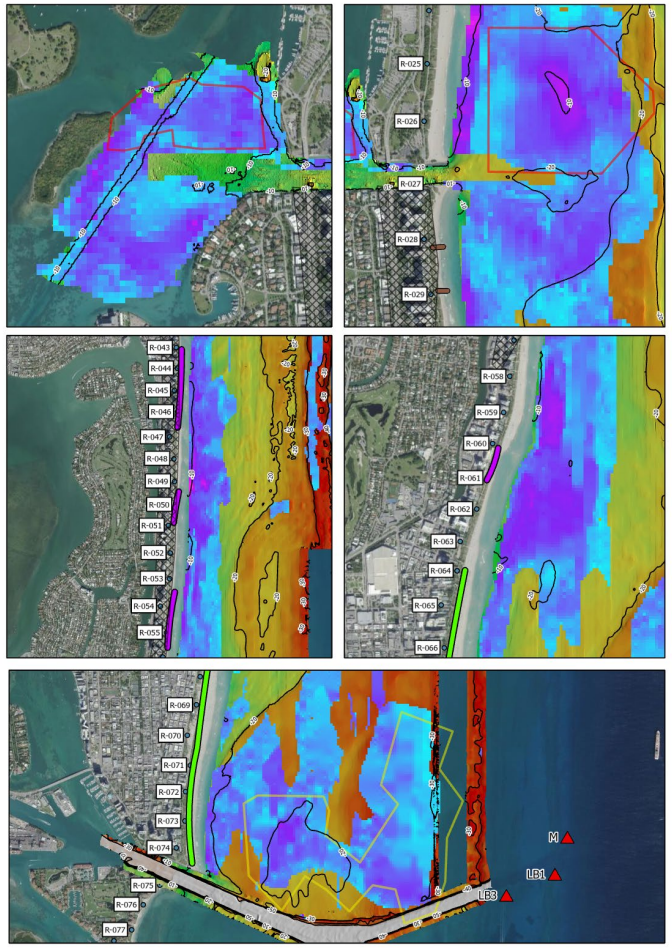




SEFMOD - Miami-Dade

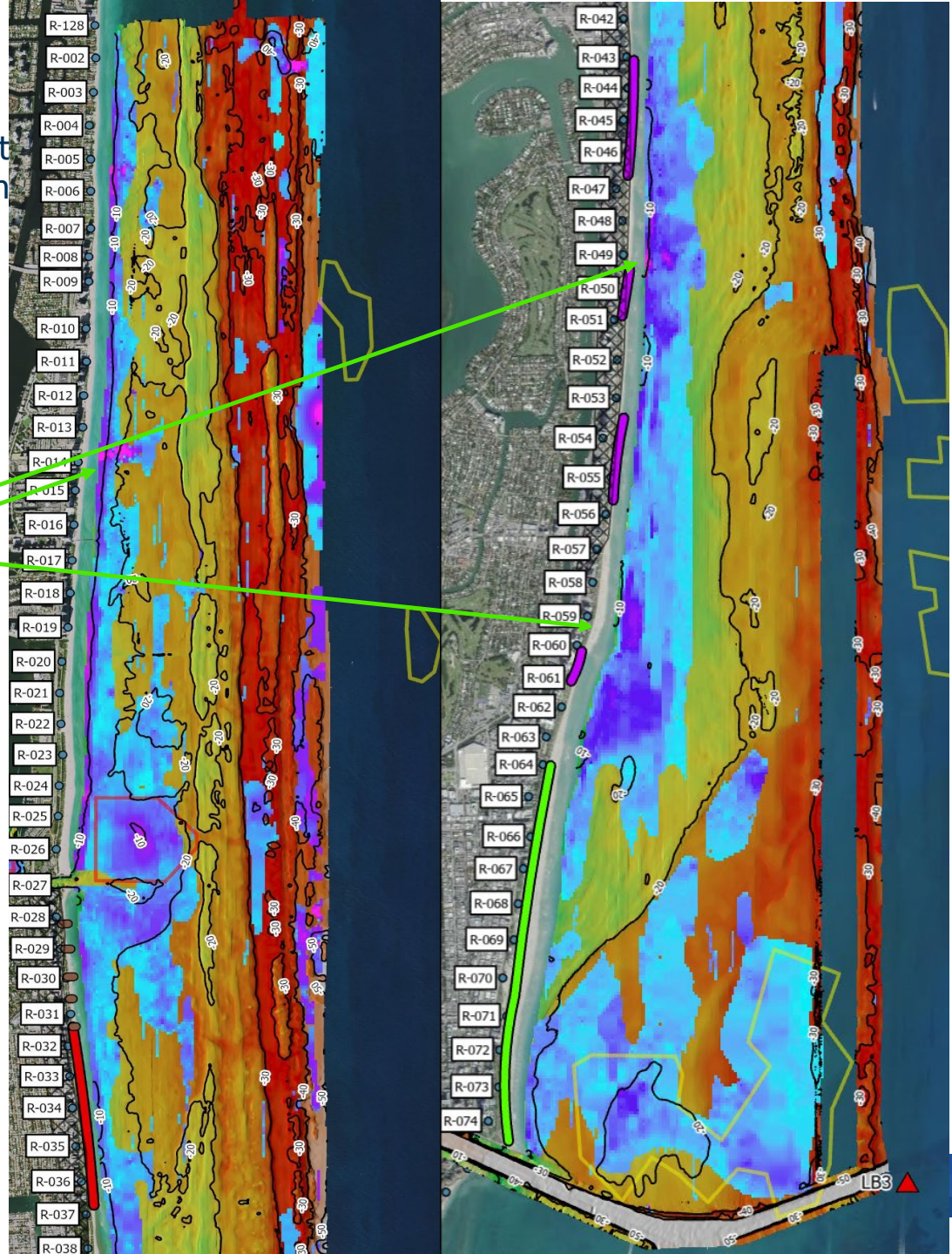
Geophysical data – sediment thickness in key areas

Sand tracers, bathy & geophysics data showed nourished sediment integrated into active surf zone landward of 20’ contour and deposited in areas of high deposition (sand lenses) & not on hard-bottom.



Existing sand lenses found from Geophysical data

SOME v. nearby to ‘Hotspots’



SEFMOD - Miami-Dade

Location FDEP R-Monument	Volume Placed (1955 – 2020) CY	Calculated from SEFMOD geophysical survey 2020 CY
Golden Beach Sunny Isles & Bakers Haulover Park R1 - 26	3,656,286	5,393,175
Bal Harbour R27 – 31	3,112,857	2,336,848
Surfside R31 – 38	3,572,800	954,884
Miami Beach R38 – 74	11,538,477	9,475,723
Miami Dade Total	21,880,420	25,503,740

**Source - Volume Placed 1955 – 2020: FDEP, SBMP, SE Atlantic SBMP, 2020*

Calculated: inshore areas (black polygons) not 2nd plateau or 2nd/3rd reef (extra deposits in outer from FC?)

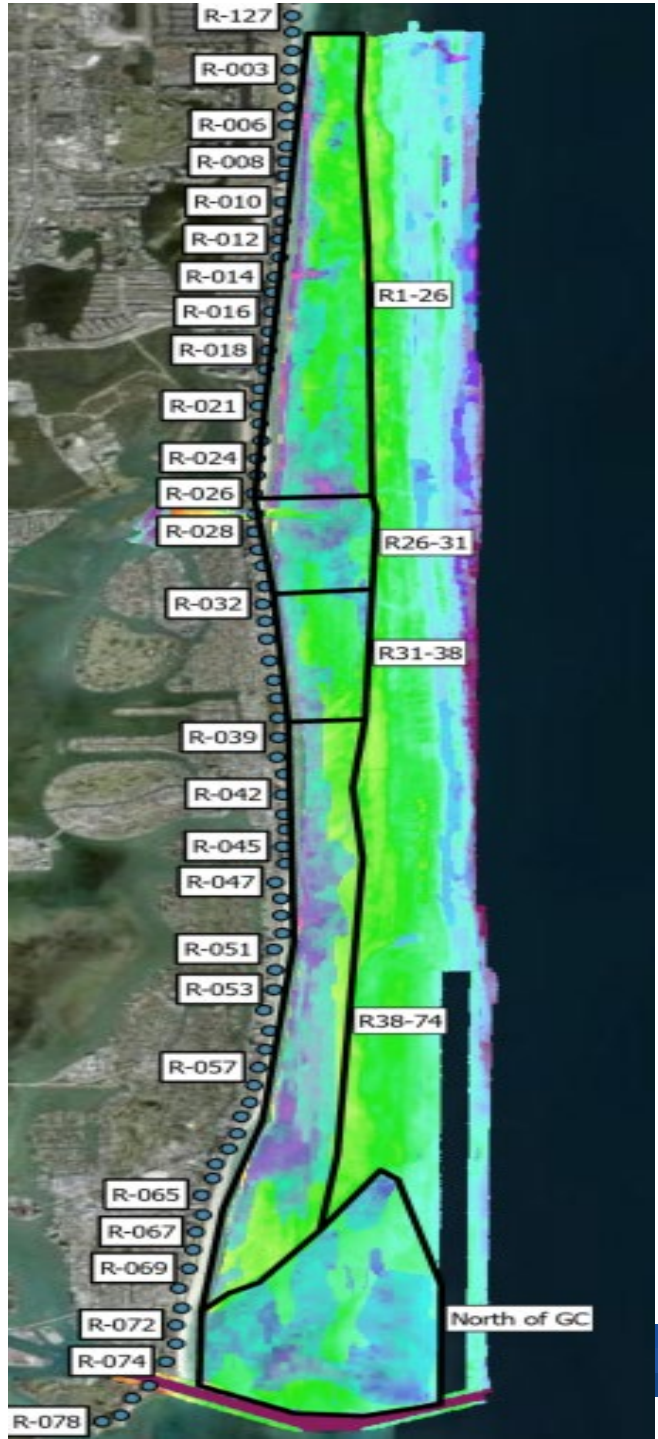
Difference: 3.6 million cy (16.5% additional)

Over 65 years = ~55,700 cy/yr. extra. From Broward?.
Assumes minimal loss (O&M dredge Govt. Cut 16 – 25,000 CY/yr. Some influx from river & bay?)

Sediment budget for BH area (M&N, 2019) 47,000 cy/yr. (existing) conditions.

Corroborates with sediment tracer data & 83% of Surfside nourishment remaining within Inner/Outer Surf zone to Nth and Sth.

Geophysical data for larger NEARSHORE deposits account for approx. 11.1 million cy.
More than CSRM requirements for 2025 – 2075 for Main Segment of 10 million cy.



SEFMOD - Miami-Dade

Metocean, sediment transport and sediment tracing allowed development of
i) Conceptual models
ii) Sediment resource and transport atlas
iii) A System-understanding and RSM of SEFMOD sites
(Recommendations made. Work in progress RSM RCX, Legault & Reichold, 2023)

Q: Has the majority of nourished sand remained within M-D? YES – **See Figure**
Q: Can the sand be recycled (back-passed)? YES
Q: Can erosion be slowed down? YES
Q: Is there enough sand to meet CSRM excluding outer (FC-derived) sources? YES
Q: Could higher fines be placed nearshore (on the beach) without impact: YES
Q: Do hotspots/high erosion areas exist – NO *if include surf zone/whole beach*
Q: Has M-D run out of sand? NO
Q: Is current renourishment and coastal protection sustainable (per BOEM): NO
Q: Is there an elephant (still) in the room: DEFINITELY

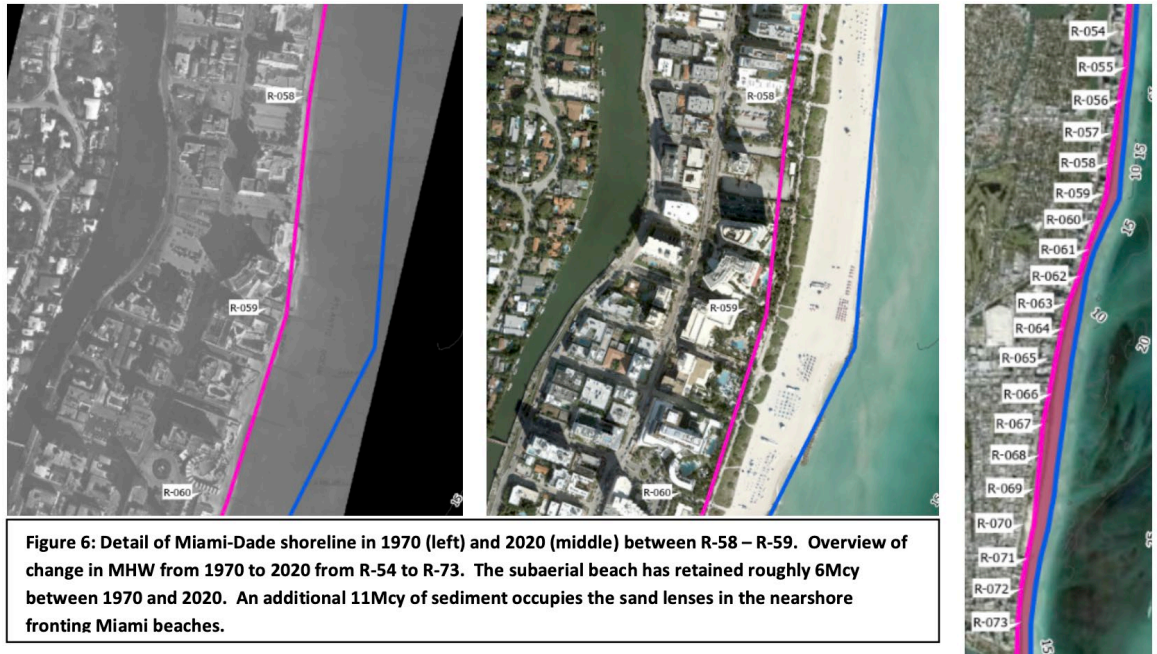
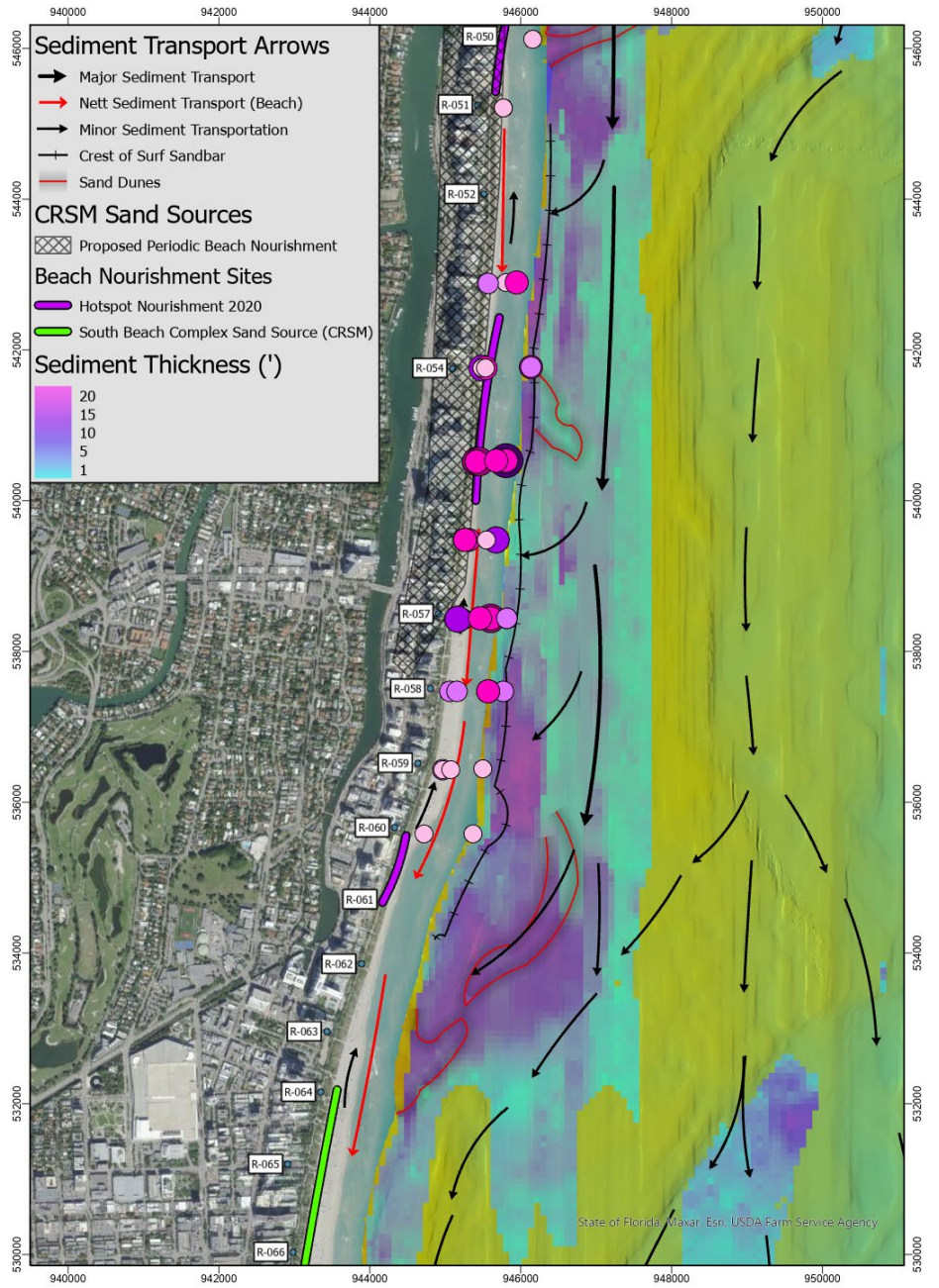


Figure 6: Detail of Miami-Dade shoreline in 1970 (left) and 2020 (middle) between R-58 – R-59. Overview of change in MHW from 1970 to 2020 from R-54 to R-73. The subaerial beach has retained roughly 6Mcy between 1970 and 2020. An additional 11Mcy of sediment occupies the sand lenses in the nearshore fronting Miami beaches.



Questions?


Las Olas Blvd
Harbor Beach
S Ocean Dr
Seabreeze Blvd
NTB
MTB
STB
IEC
West OEC
Widener Shoal
North SAC
South SAC
Port Everglades-Midport
Port Everglades-Southport
Dr. Von D. Mizell-Hahula Johnson State Park
Inner Reef
Middle Reef
Outer Reef
Spoil Shoal
Nearshore Ridge Complex
Legend
South Port Everglades, FL - Station ID: 872295
Recorded Shoaling
Study Area
Monument Lines
Port Areas
Inner Entrance Channel
Outer Entrance Channel
North Turning Basin
Mid Turning Basin
South Turning Basin
North Southport Access Channel
South Southport Access Channel
Widener Shoal