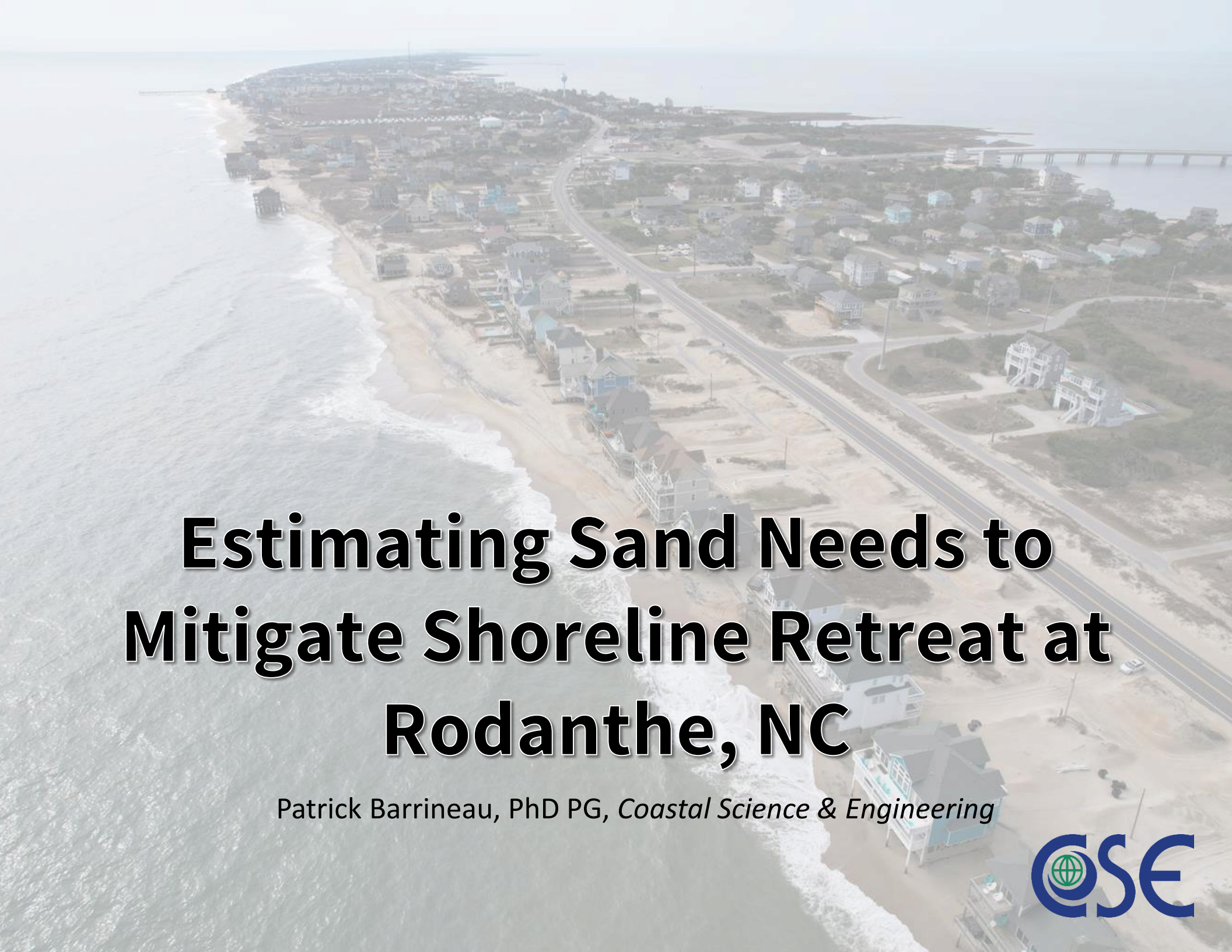


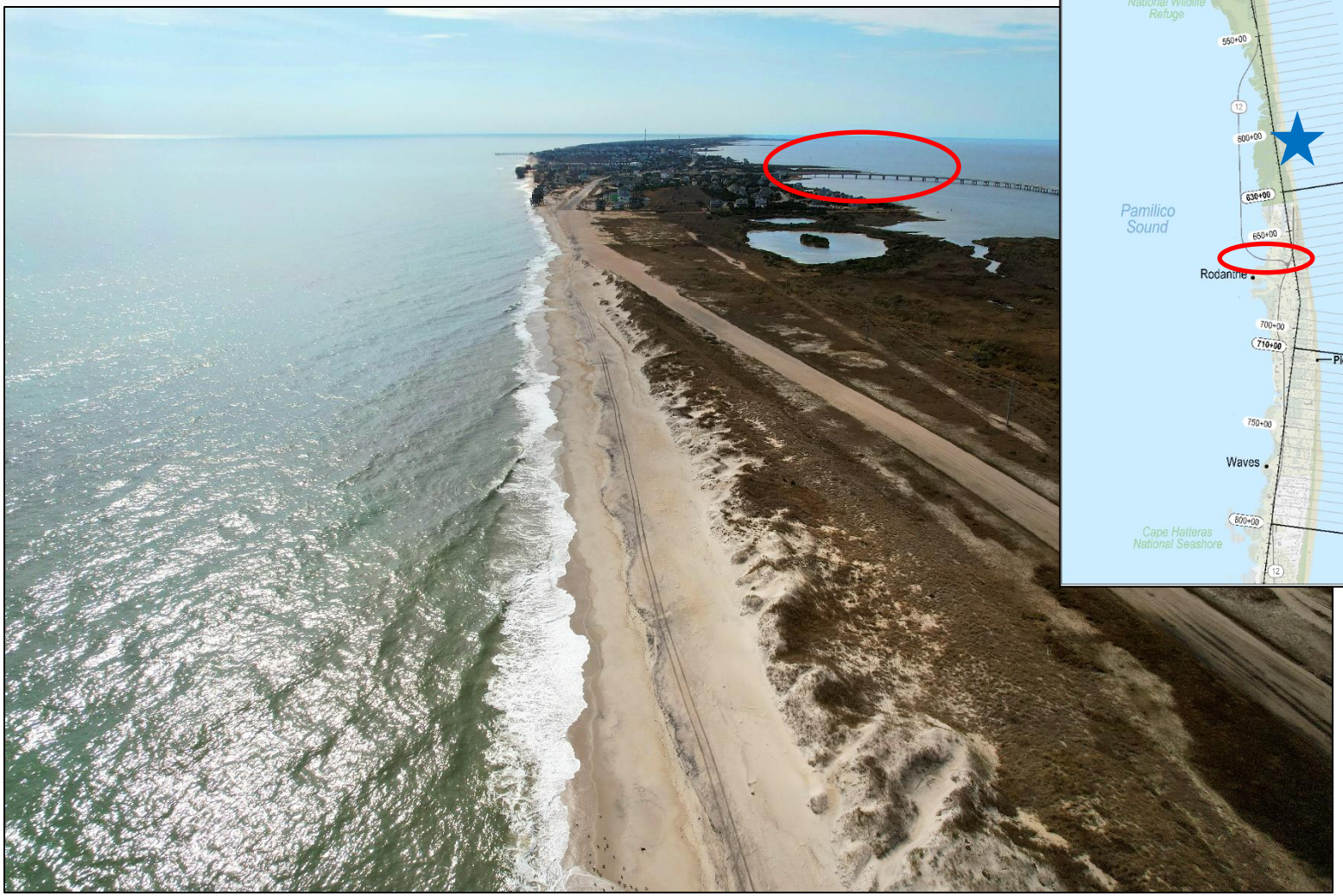
Estimating Sand Needs to Mitigate Shoreline Retreat at Rodanthe, NC

Patrick Barrineau, PhD PG, *Coastal Science & Engineering*

Background

- First National Seashore in the United States
  - Averaging ~2.5 Million Visitors per year since 2018
- NC 12 Connecting Ocracoke, Hatteras, Buxton, Avon, Rodanthe, Nags Head, Others
- Erosion Hot Spots Within Developed Areas Near **Rodanthe**, Avon, Buxton

Background



Looking south from PINWR towards Rodanthe, February 2023

Background

Reach 1 “PINWR”: *looking north from Mirlo Beach towards PINWR, February 2023*

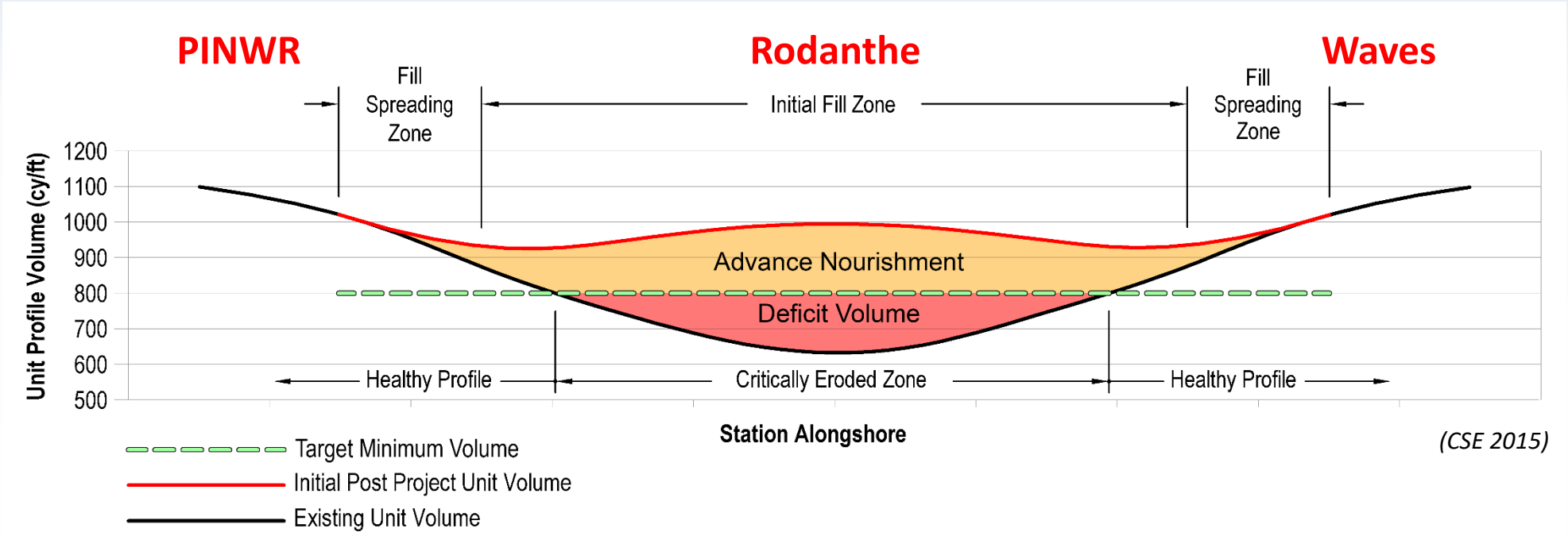
Background

Reach 2 “Rodanthe”: *looking south from Mirlo Beach towards Rodanthe Pier, February 2023*

Background

Reach 3 “Waves”: *looking north from Waves towards Rodanthe Pier, February 2023*

Determining Sand Needs



(CSE 2015)

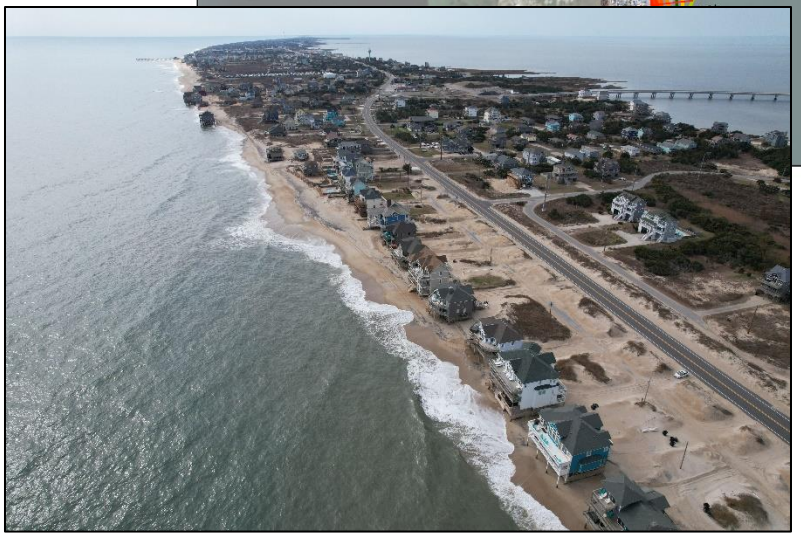
ASSUMPTIONS:

- Erosion Hot Spots Result From Volume Deficit in Active Beach System
- Nourishment can be Used to Fill that Deficit Over Time
  - Particularly if Fill Volumes Divided by Project Lifetime Exceed Annual Erosion

CSE, 2015. *Beach Restoration to Protect NC Highway 12,Clean Water Act 404 and NPS Special Use Permits at Buxton, Dare County, North Carolina Environmental Assessment.* Prepared for the US Army Corps of Engineers and National Park Service. Columbia, SC: CSE.

Determining Sand Needs

- **Landward retreat along PINWR/Rodanthe**
  - -5 to -15 ft/yr
  - Discontinuous/absent foredune
    - ~+10 to +15 ft NAVD
- Stability/advance along Waves-Salvo
  - 0 to +5 ft/yr
  - continuous foredune crest
    - >20 ft NAVD
- *Strong gradient in longshore sediment transport from north to south*



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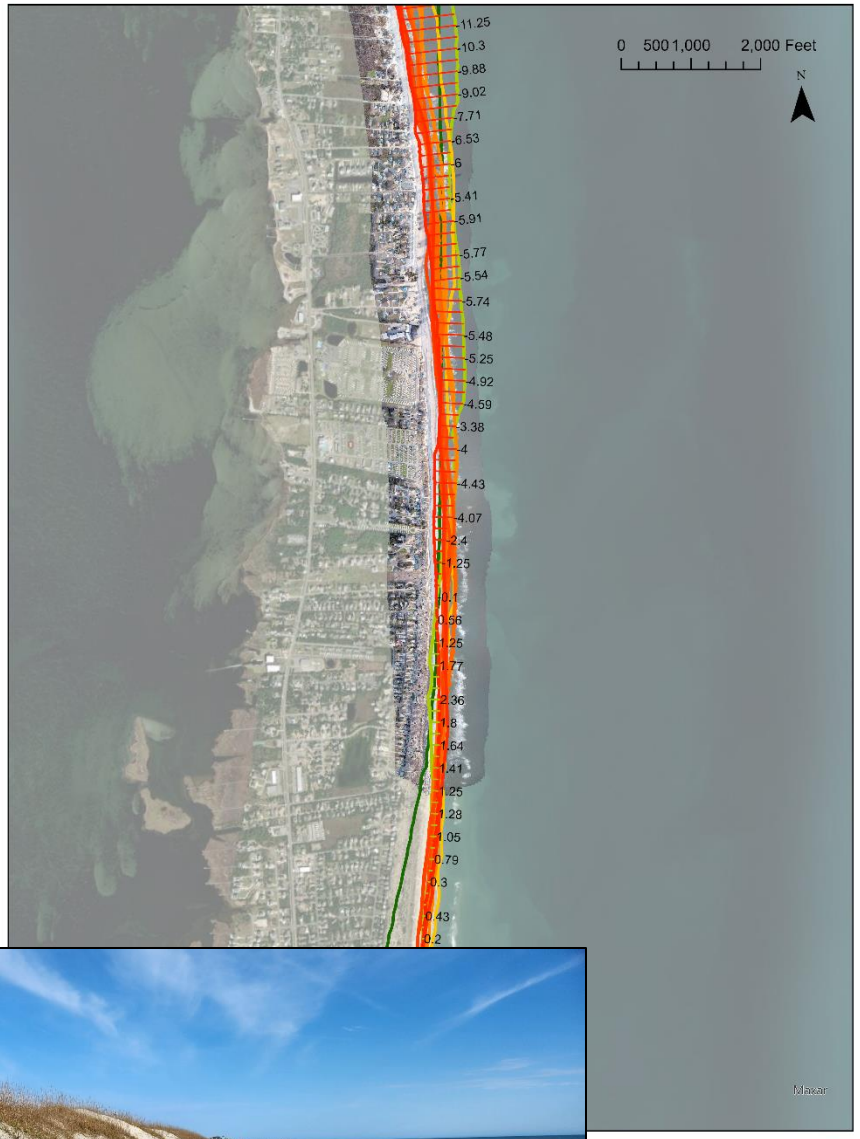
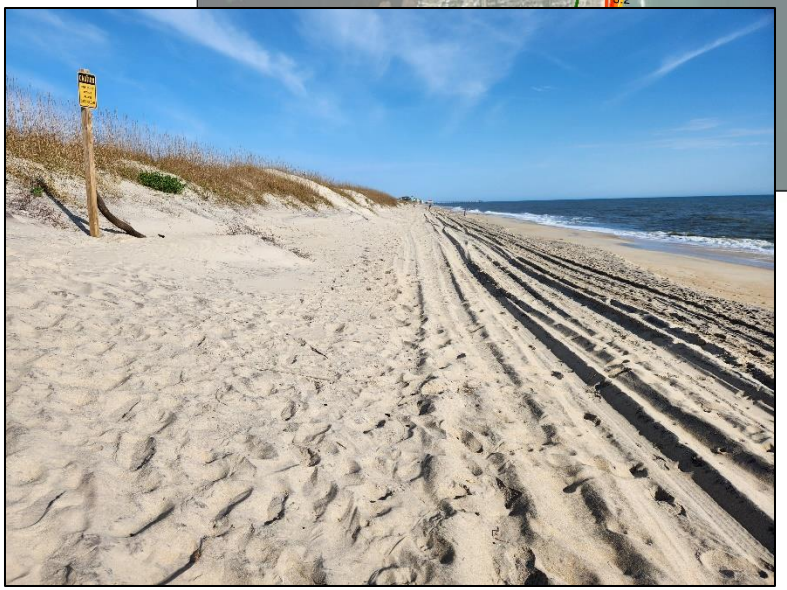
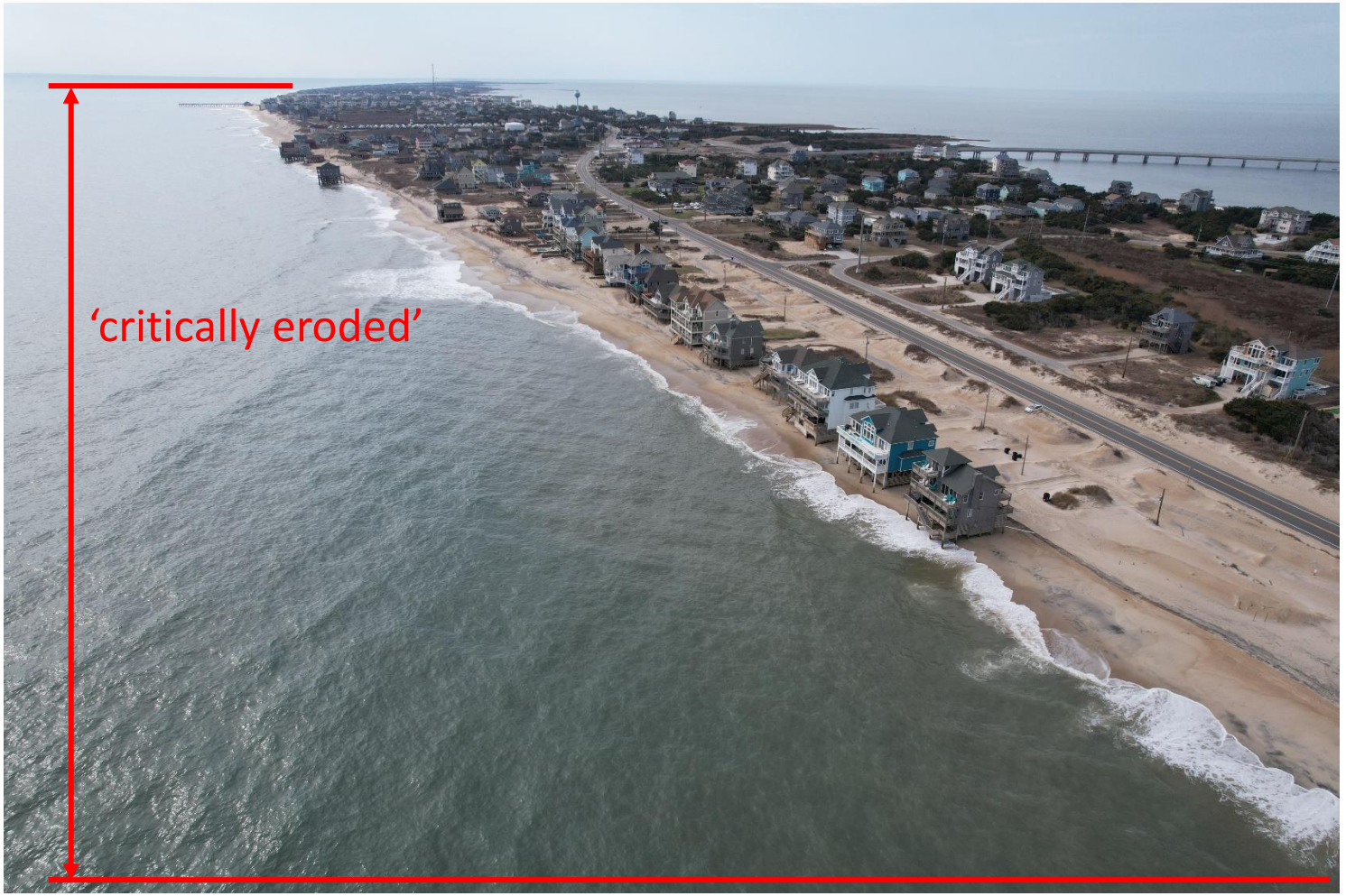




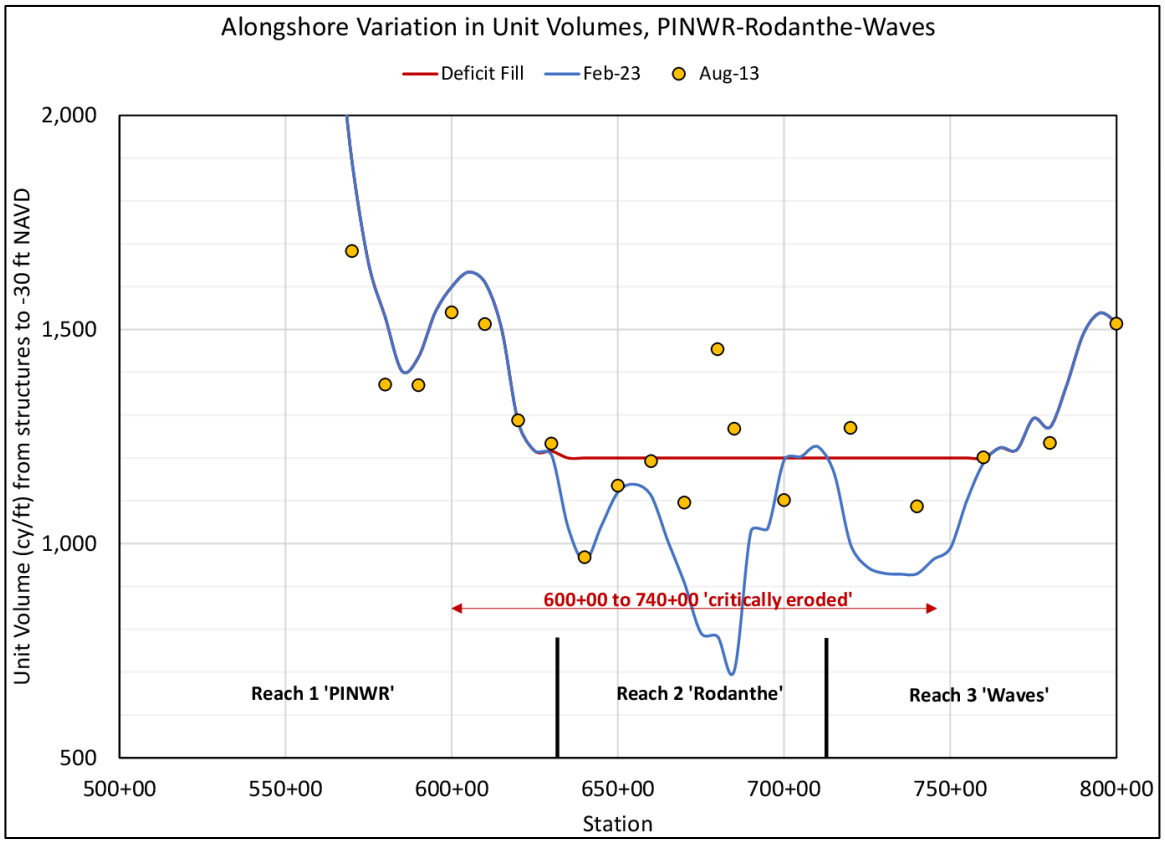
Determining Sand Needs

- ‘critically eroded’ section – 14,000 ft
  - Unit Volume < 1,200 cy/ft
  - No foredune
  - Erosion >10 ft/yr



Determining Sand Needs

- Method 1 – ‘Deficit Volume’
- Compares qualitative beach condition to surveyed volumes
- Foredune to -24 ft NAVD
  - 1,200 cy/ft
- 2023 Conditions
  - 12,000 ft below deficit
  - 2,257,600 cy to meet deficit



(CSE 2023)

CSE, 2023. *Rodanthe Sand Needs Assessment.* Prepared for Dare County NC. Columbia SC: CSE.

Determining Sand Needs

- Method 2 – ‘CSE profiles’
- Compares 2013 and 2023 survey data to estimate annualized erosion*

  **accounts for 2014 USACE volume*

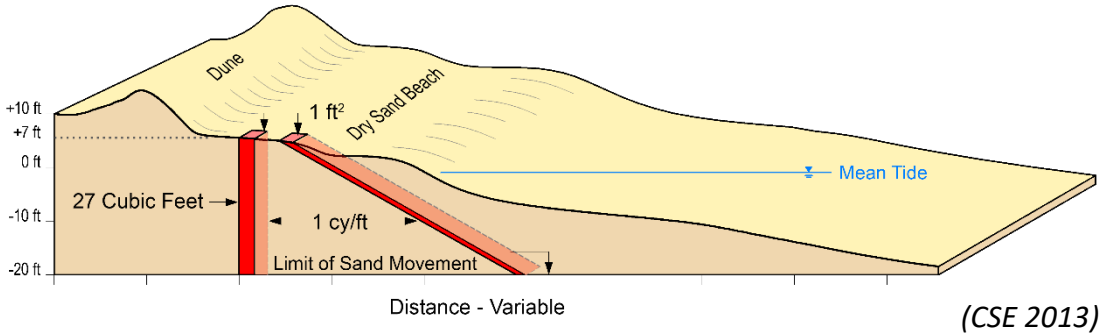
- Foredune to -24 ft NAVD:
  - -22 cy/ft/yr
  - 14,000 ft
  - ~308,000 cy/yr
  - ‘5-year’ project
    - 1,539,771 cy

Station	Reach		Unit Volume (cy/ft)		Unit Volume Change since last survey (cy/ft)		Annualized Unit Volume Change since last survey (cy/ft/yr)	
			Aug-13	Feb-23	Feb-23	Feb-23 (minus USACE)	Feb-23	Feb-23 (minus USACE)
500	PINWR		1411.9	1484.5	72.6	72.6	7.6	7.6
520			1417.7	1405.8	-11.9	-11.9	-1.3	-1.3
540			1316.4	1310.9	-5.4	-5.4	-0.6	-0.6
550			1293.9	1328.8	34.9	34.9	3.7	3.7
560			1335.7	1416.4	80.7	80.7	8.5	8.5
570			1277.0	1336.6	59.6	59.6	6.3	6.3
580			1262.2	1360.7	98.5	98.5	10.3	10.3
590			1291.7	1327.1	35.3	35.3	3.7	3.7
600		'Critically Eroded'	1243.2	1251.0	7.7	-152.3	0.8	-16.0
610			1236.0	1257.2	21.2	-138.8	2.2	-14.6
620			1191.5	1176.6	-14.9	-174.9	-1.6	-18.4
630	Rodanthe		1065.4	1014.0	-51.4	-211.4	-5.4	-22.2
640			946.9	940.2	-6.7	-166.7	-0.7	-17.5
650			1035.1	1027.9	-7.2	-167.2	-0.8	-17.5
670			1247.9	1059.6	-188.4	-348.4	-19.8	-36.6
680			1397.4	1090.0	-307.3	-467.3	-32.3	-49.0
700			1195.9	1296.8	100.9	-59.1	10.6	-6.2
720	Waves		1234.2	972.2	-262.1	-262.1	-27.5	-27.5
740			1088.5	931.0	-157.5	-157.5	-16.5	-16.5
760			930.7	890.8	-39.8	-39.8	-4.2	-4.2
780			923.2	845.2	-77.9	-77.9	-8.2	-8.2
800			956.6	810.3	-146.3	-146.3	-15.3	-15.3

From Sta 600+00 to Sta 740+00:	Feb-23	Feb-23 (minus USACE)
cy/ft/yr	-8.3	**-22.0**
cy/yr	115,618	**307,954**
cy per 5 years	578,089	**1,539,771**

Determining Sand Needs

- Method 3 – ‘DENR rates’
- Uses state-adopted erosion rates
- As of 2020:
  - -18.2 cy/ft/yr
    - 1 ft = 1.7 cy/ft
  - 14,000 ft
  - ~246,000 cy/yr
  - ‘5-year’ project
    - 1,232,112 cy



(CSE 2013)

Erosion Rates from NCDENR Study (1946-2020)

Reach	PINWR	Rodanthe	Waves	Critically Eroded
ft/yr	-5.5	-11.6	-2.7	-10.3
cy/ft/yr	-9.7	-20.5	-4.8	-18.2
cy/yr	-116,261	-154,674	-41,002	-246,422
			5-yr losses>	1,232,112

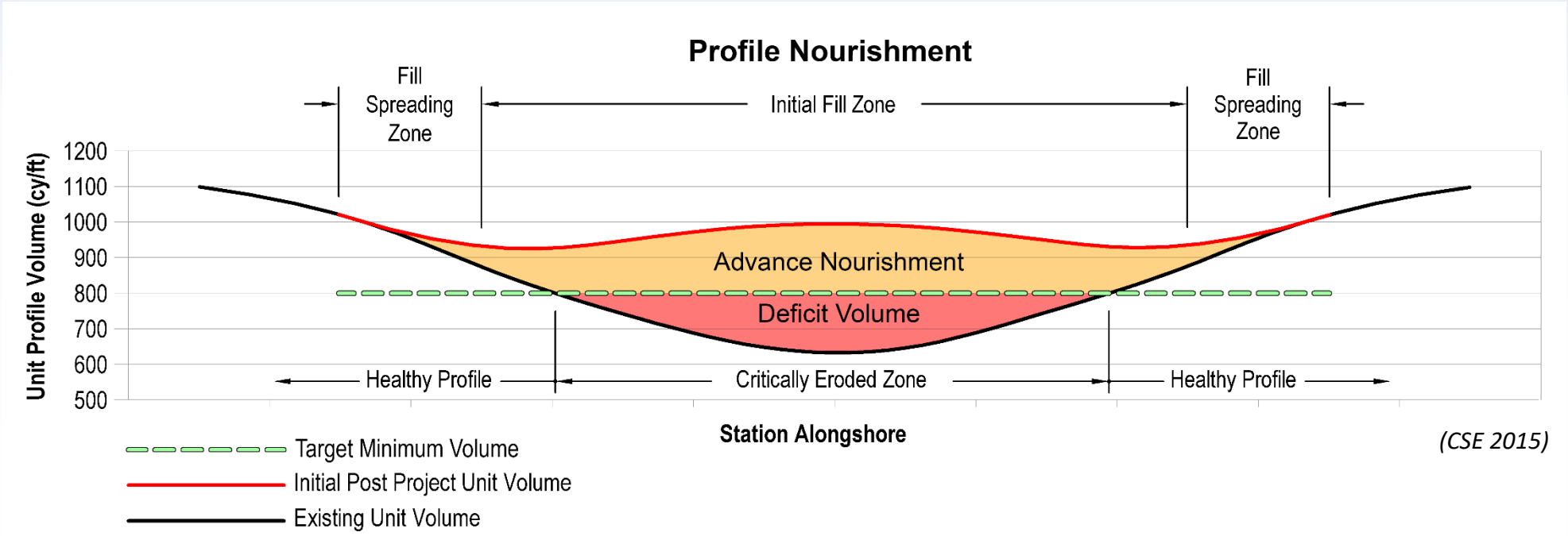
CSE, 2013. *Shoreline erosion assessment and plan for beach restoration Rodanthe and Buxton areas Dare County, North Carolina.* Prepared for Dare County NC. Columbia SC: CSE.

Determining Sand Needs

		Mob/Demob	Base Bid Quantity (cy)	Total Pumping Cost	Total Base	Total + Permit
Unit cost (per cy)	$ 8.00	$ 4,500,000	3,800,000	$ 30,400,000	$ 34,900,000	$ 40,135,000
	$ 8.50	$ 4,500,000	3,500,000	$ 29,750,000	$ 34,250,000	$ 39,387,500
	$ 9.00	$ 4,500,000	2,300,000	$ 20,700,000	$ 25,200,000	$ 28,980,000
	$ 9.50	$ 4,500,000	2,000,000	$ 19,000,000	$ 23,500,000	$ 27,025,000
	$ 10.00	$ 4,500,000	1,500,000	$ 15,000,000	$ 19,500,000	$ 22,425,000

- Estimated costs (one-time)
  - 1.5 – 3.8 Mcy along 14,000 lf
    - ~100 to 270 cy/ft
    - 3 to 9 years' worth erosion
  - $4.5 million mob/demob
  - $8 to $10/cy unit cost
  - $22.4 to $40.1 million
- Estimated costs (through 2053)
  - $120 to $200 million

Determining Sand Needs



(CSE 2015)

ASSUMPTIONS:

- **Erosion Hot Spots Result From Volume Deficit in Active Beach System**
- **Nourishment can be Used to Fill that Deficit Over Time**

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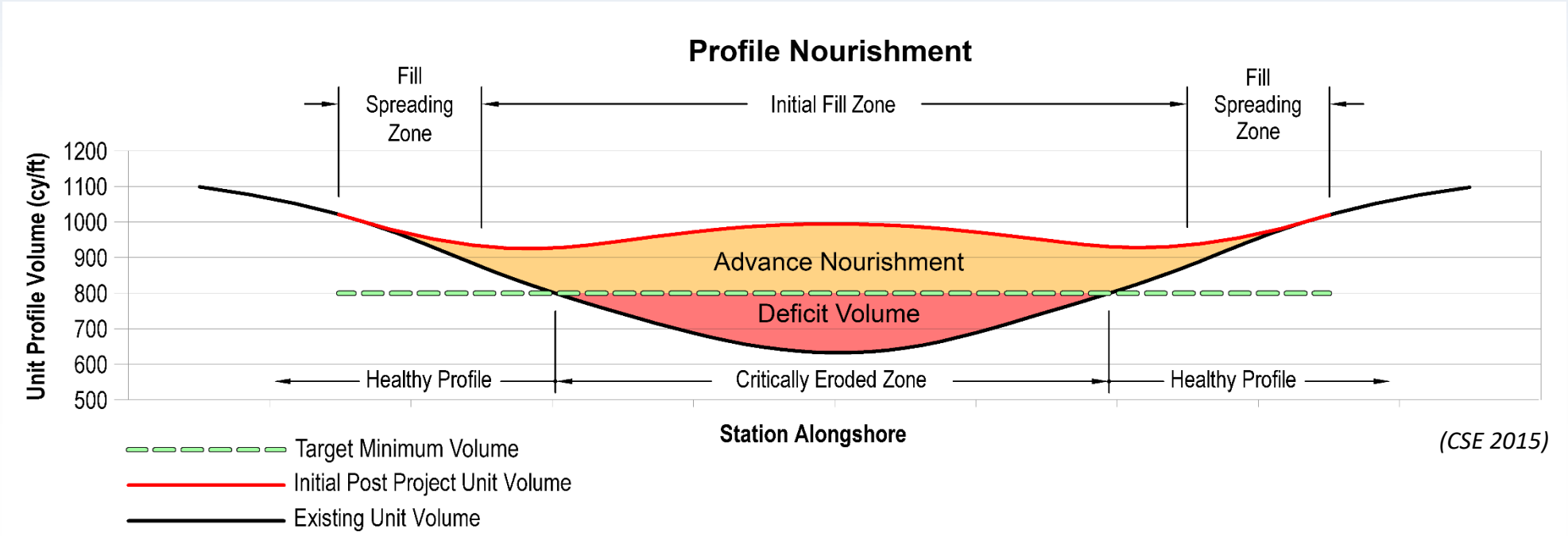
Determining Sand Needs



(CSE 2015)

ASSUMPTIONS:

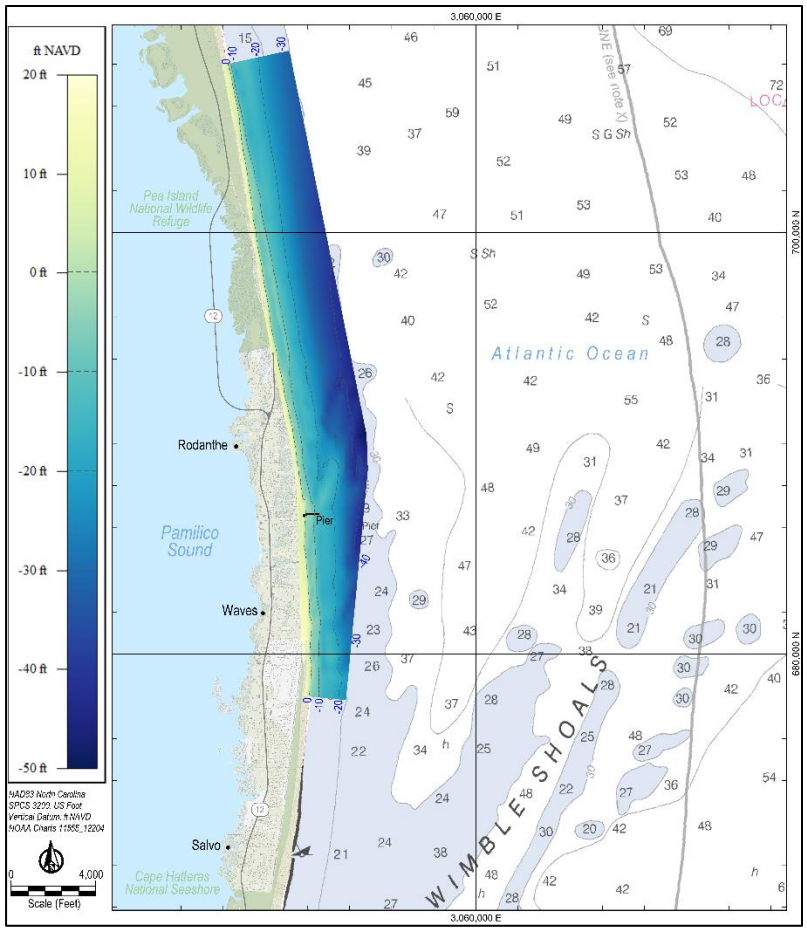
- **Erosion Hot Spots Result From Volume Deficit in Active Beach System**
- **Nourishment can be Used to Fill that Deficit Over Time**

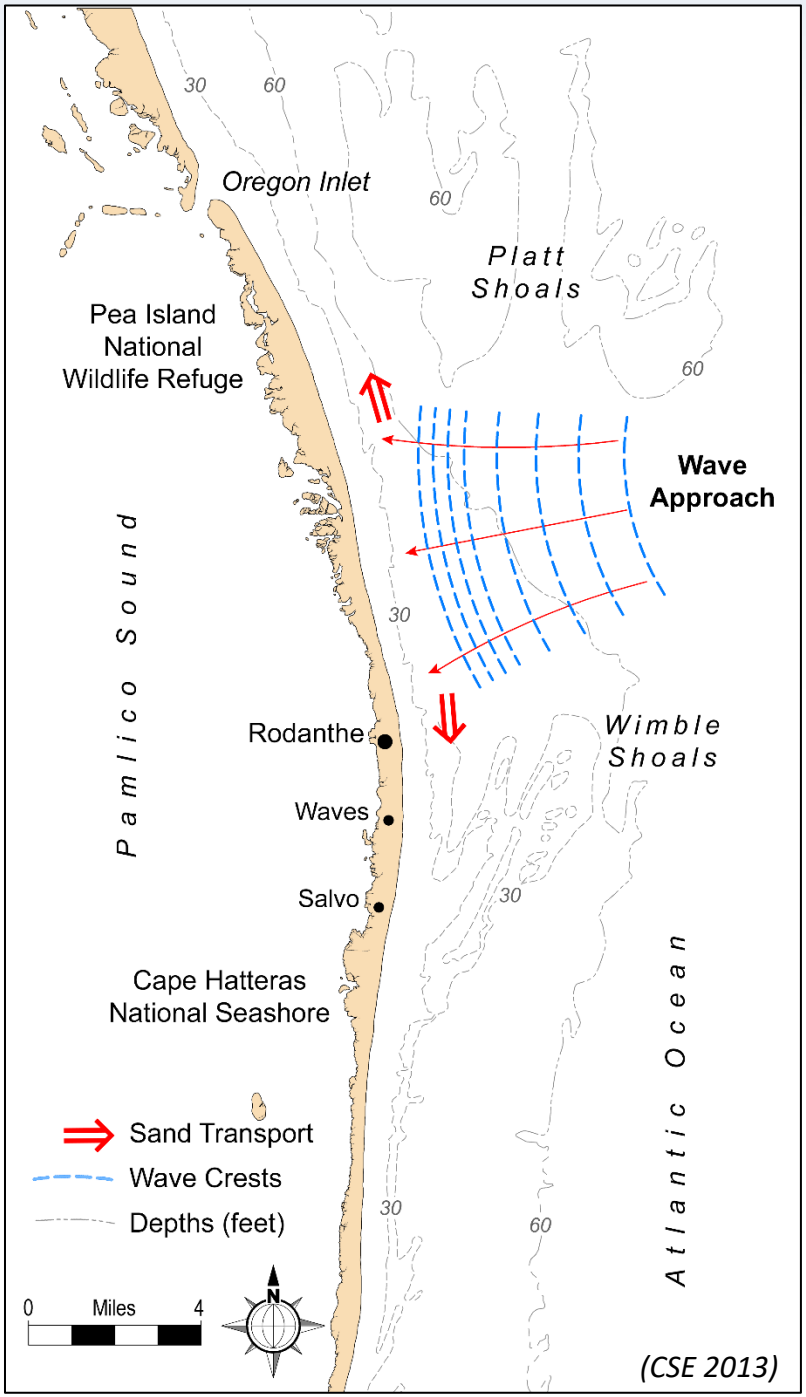
What about when the background rates of erosion are changing?

CSE, 2015. *Beach Restoration to Protect NC Highway 12,Clean Water Act 404 and NPS Special Use Permits at Buxton, Dare County, North Carolina Environmental Assessment.* Prepared for the US Army Corps of Engineers and National Park Service. Columbia, SC: CSE.

Determining Sand Needs

- Why?
  - Shoreline azimuth
  - Shoal geometry
  - *Overwash?*

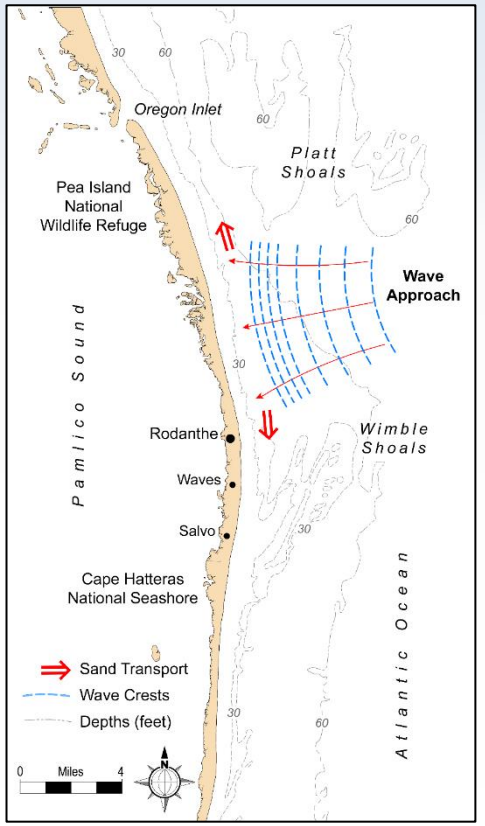


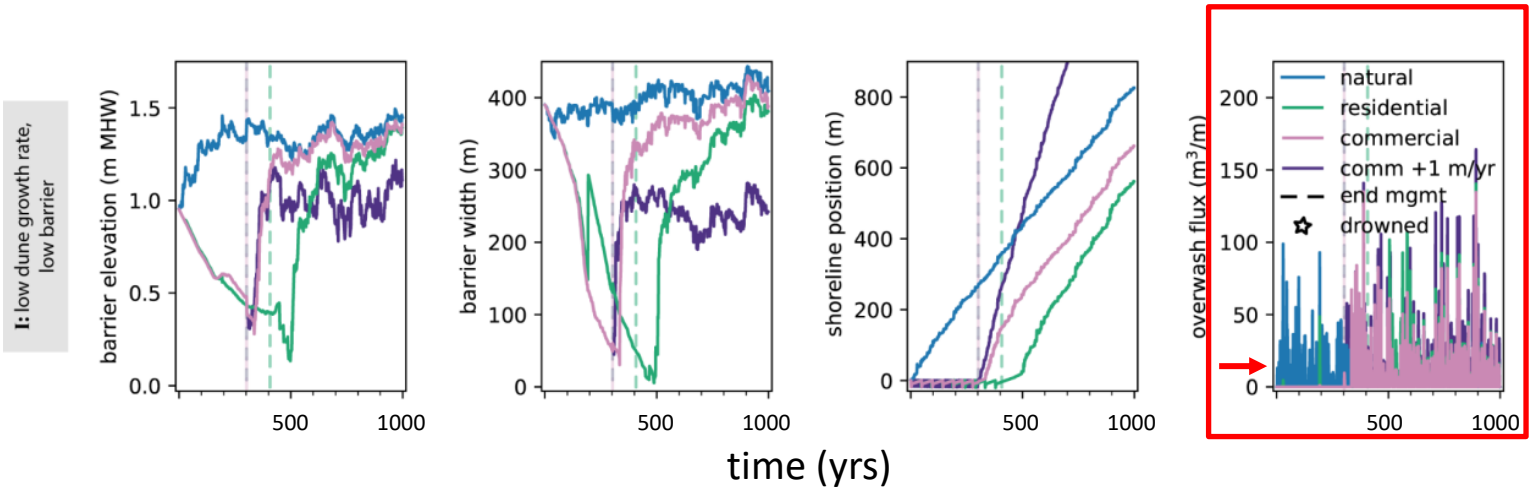


CSE, 2013. *Shoreline erosion assessment and plan for beach restoration Rodanthe and Buxton areas Dare County, North Carolina.* Prepared for Dare County NC. Columbia SC: CSE.

Determining Sand Needs

- Landward Transgression of Hatteras Island
  - Facilitated by overwash at Pea Island, just north of Rodanthe
  - How to quantify future losses under SLR?
    - **~10 m³/m/yr lost to overwash** *(Anarde et al 2023)*
    - ~5 cy/ft/yr
    - ~150 cy/ft over 30-year period





Anarde, Moore, Murray, Reeves, 2023 (preprint). *The future of developed barrier systems – Part 1: pathways toward uninhabitability, drowning and rebound*. Earth's Future.

Determining Sand Needs

- Volumes needed through 2053:
  - Overwash (SLR) + Volume Deficit + Annual Erosion
  - 150 cy/ft + 150 cy/ft + 600 cy/ft = **900 cy/ft**
  - **900 cy/ft ≈ 600 horizontal feet**
- Total project volume through 2053:
  - 900 cy/ft along 14,000 ft = 12,600,000 cy x $9/cy = $113,400,000
  - $4,500,000 mob/demob x 4 projects
  - $131,400,000

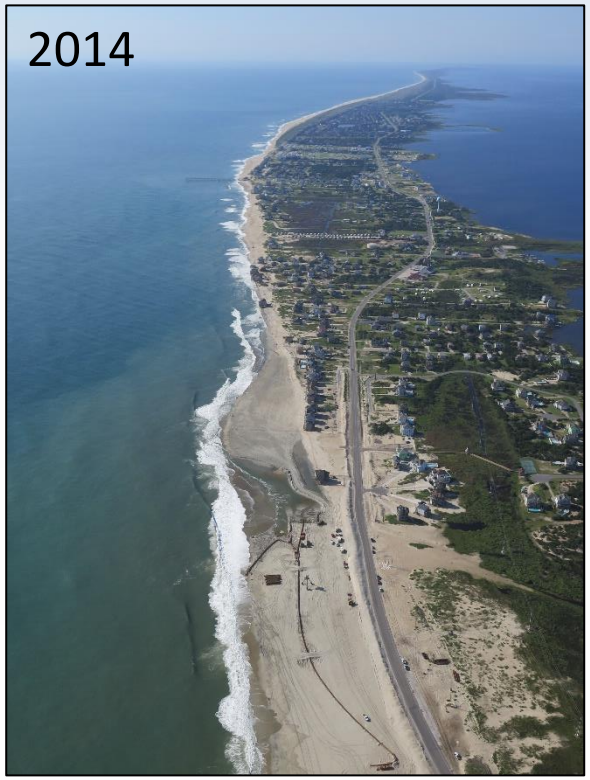
Comparing Costs

- 80 properties within 300 ft of MHHW *(WCU 2023)*
  - Net Value $42,713,600
  - Relocation/removal costs ($20,000,000 @ $250,000 per structure)
  - Plus ~$10,000,000 lost tax revenue
  - Total cost ~$72,713,000*
- 170 properties within 600 ft of MHHW *(Dare County GIS, 2023)*
  - Net Value $88,735,000
  - Relocation/removal costs ($42,500,000 @ $250,000 per structure)
  - Plus ~$20,000,000 lost tax revenue
  - Total cost ~$151,235,000*

**does not include infrastructure removal costs*

Comparing Costs

- 14.7 million cy = $131,400,000 for nourishment alone (covers base fill, erosion, and SLR)
- $151,235,000 (+ ?) for ‘unmanaged retreat’
- What if immediately at-risk properties are removed, and nourishment was used to re-establish a functional beach-dune system?
  - Eliminates ‘ideal volume’ component, reduces 30-year need to ~750 cy/ft over 14,000 ft = 10,500,000 cy



Comparing Costs

- What if immediately at-risk properties are removed, and nourishment was used to re-establish a functional beach-dune system?
- $112,500,000 for nourishment alone
  - 10,500,000 cy @$9/cy
  - 4,500,000 mob/demob, 4 projects
  - restores continuous dune crest
  - mitigates structure line offset
- $39,093,100 for ‘managed retreat’ from ~2 dozen homes (‘critically eroded’ condition e.g. <100 ft from MHHW, no dune) *(Dare County GIS, 2023)*

		Mob/Demob	Base Bid Quantity (cy)	Total Pumping Cost	Total Base	Total + Permit
Unit cost (per cy)	$ 8.00	$ 4,500,000	3,800,000	$ 30,400,000	$ 34,900,000	$ 40,135,000
	$ 8.50	$ 4,500,000	3,500,000	$ 29,750,000	$ 34,250,000	$ 39,387,500
	$ 9.00	$ 4,500,000	2,300,000	$ 20,700,000	$ 25,200,000	$ 28,980,000
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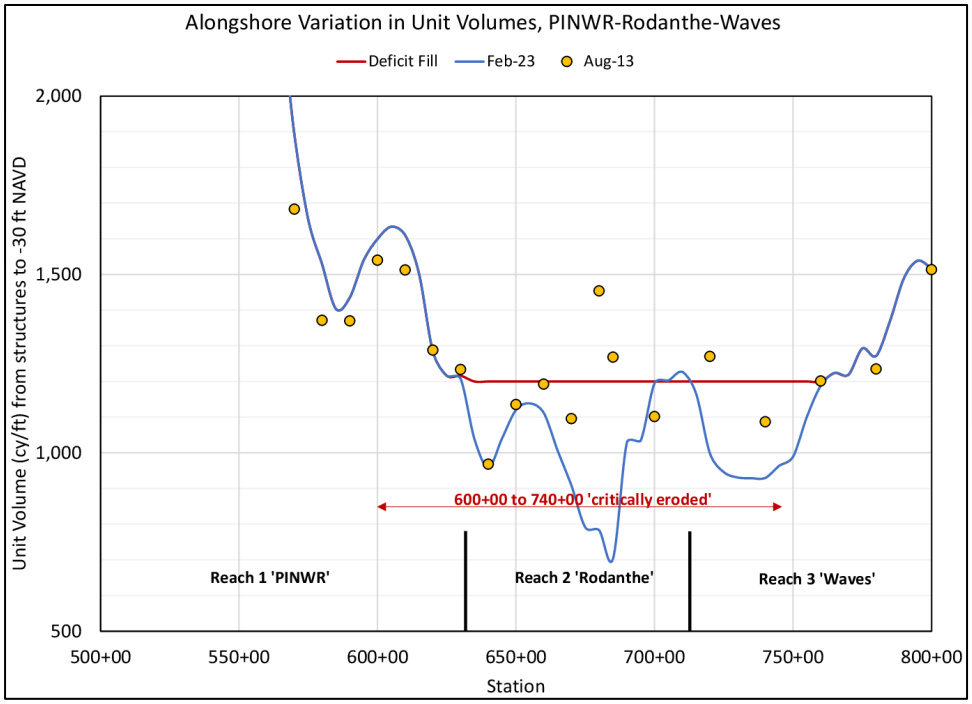


(CSE 2023)

CSE, 2023. *Rodanthe Sand Needs Assessment.* Prepared for Dare County NC. Columbia SC: CSE.

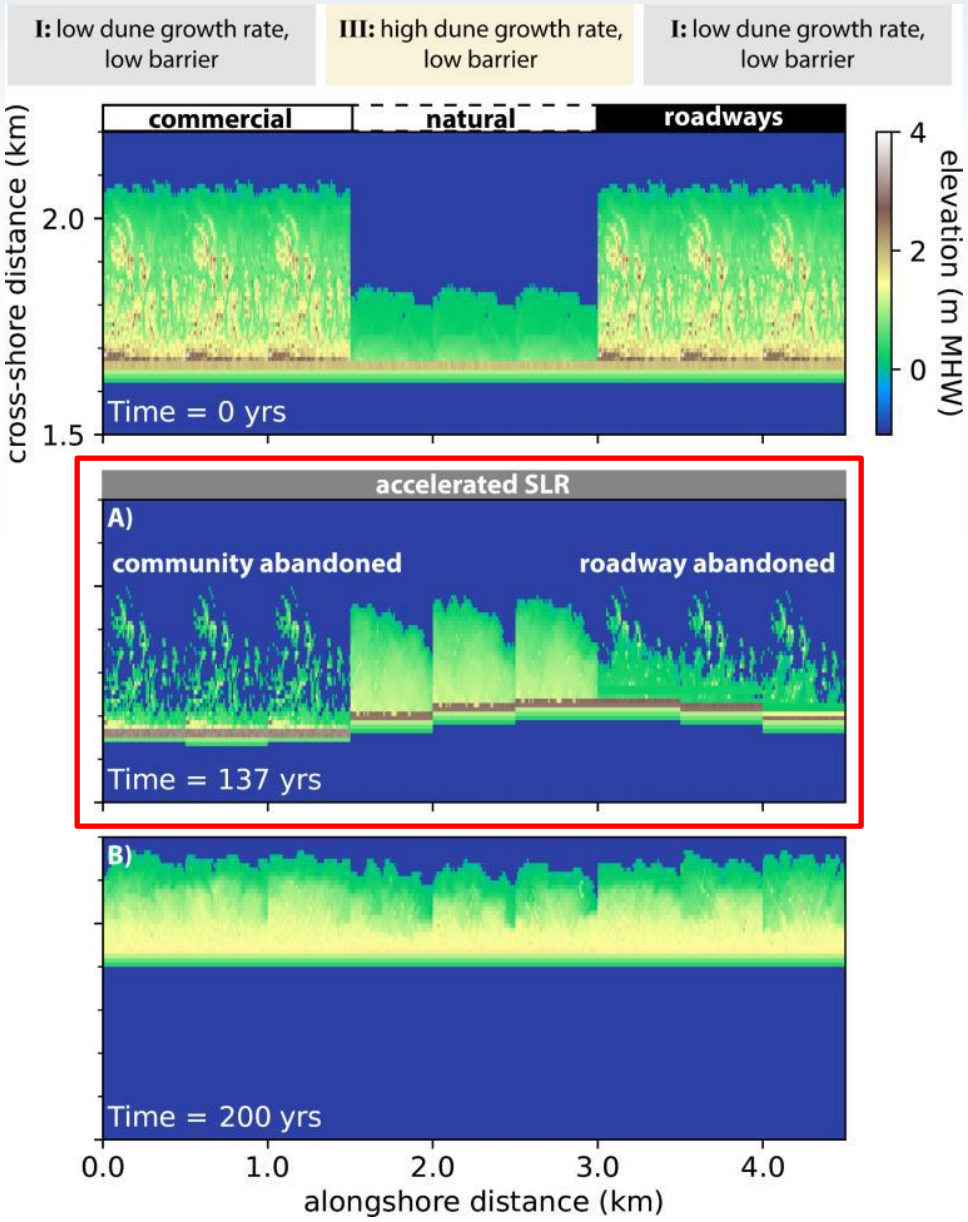
Comparing Costs

- Three options
- Nourishment Alone
  - $131,400,000 + ?
  - Pros: balances sand budget, minimizes litigation
  - Cons: more susceptible to future losses related to SLR, offshore sand sources needed, sound side flooding remains a problem
- Unmanaged Retreat
  - $151,235,000 + ?
  - Pros: mitigates current hazards (houses/septic in surf), reduces losses from inundation including sound side flooding
  - Cons: doesn’t restore foredune crest, mitigate future overwash
- Managed Retreat
  - $151,593,100 + ?
  - Pros: removes properties in immediate danger, balances sand budget
  - Cons: more susceptible to future losses related to SLR, offshore sand sources needed, sound side flooding remains a problem

Lingering Questions

Technically speaking:

- How can we account for future changes in background erosion using a sediment budget approach?
- How should we valuate costs of infrastructure removal and/or litigation involving private properties?



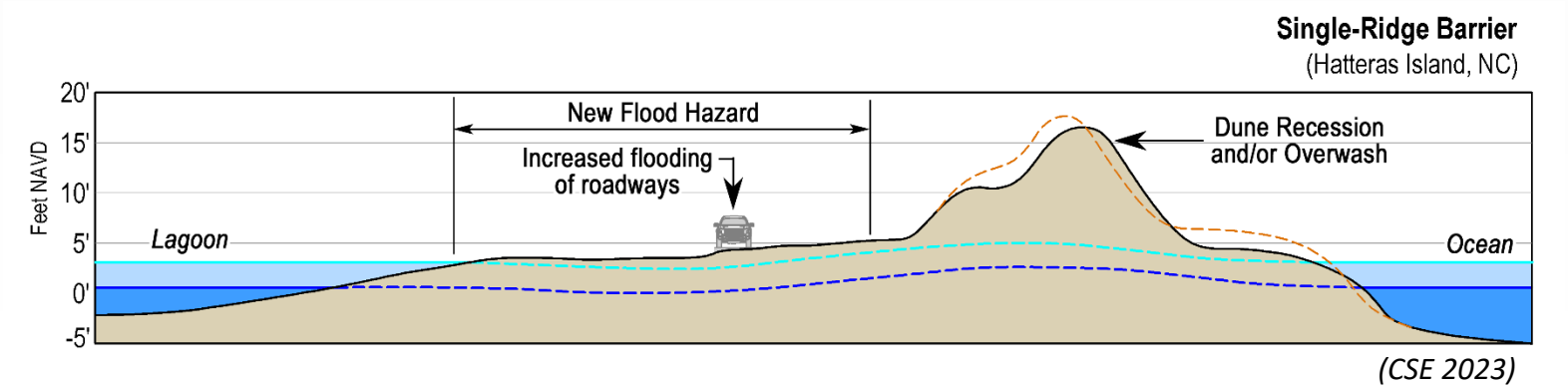
Anarde et al. 2023

Anarde, Moore, Murray, Reeves, 2023 (preprint). The future of developed barrier systems – Part 2: alongshore complexities and emergent climate change dynamics. Earth's Future

Lingering Questions

More generally:

- What about the sound side of the islands?



- Who pays for all of this?

CSE, 2023. *Rodanthe Sand Needs Assessment.* Prepared for Dare County NC. Columbia SC: CSE.


Thank you!