When Shoreline Rates Change:

Using change-point detection to reveal shifting shoreline trajectories in Virginia's Chesapeake Bay

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Adding temporal context to shoreline change rates.

ASBPA 2026

Shoreline Change Rate Methods

Three rates answer three different questions.

EPR End Point Rate

How far did the shoreline move between the first and last observations?

→

LRR Linear Regression Rate

What single trend best summarizes all observed shorelines?

→

CPR Change-Point Rate

Did the trend change — and when?

Use together — not as competing answers.
EPR and LRR remain useful, but the long-term rate can obscure a change point.

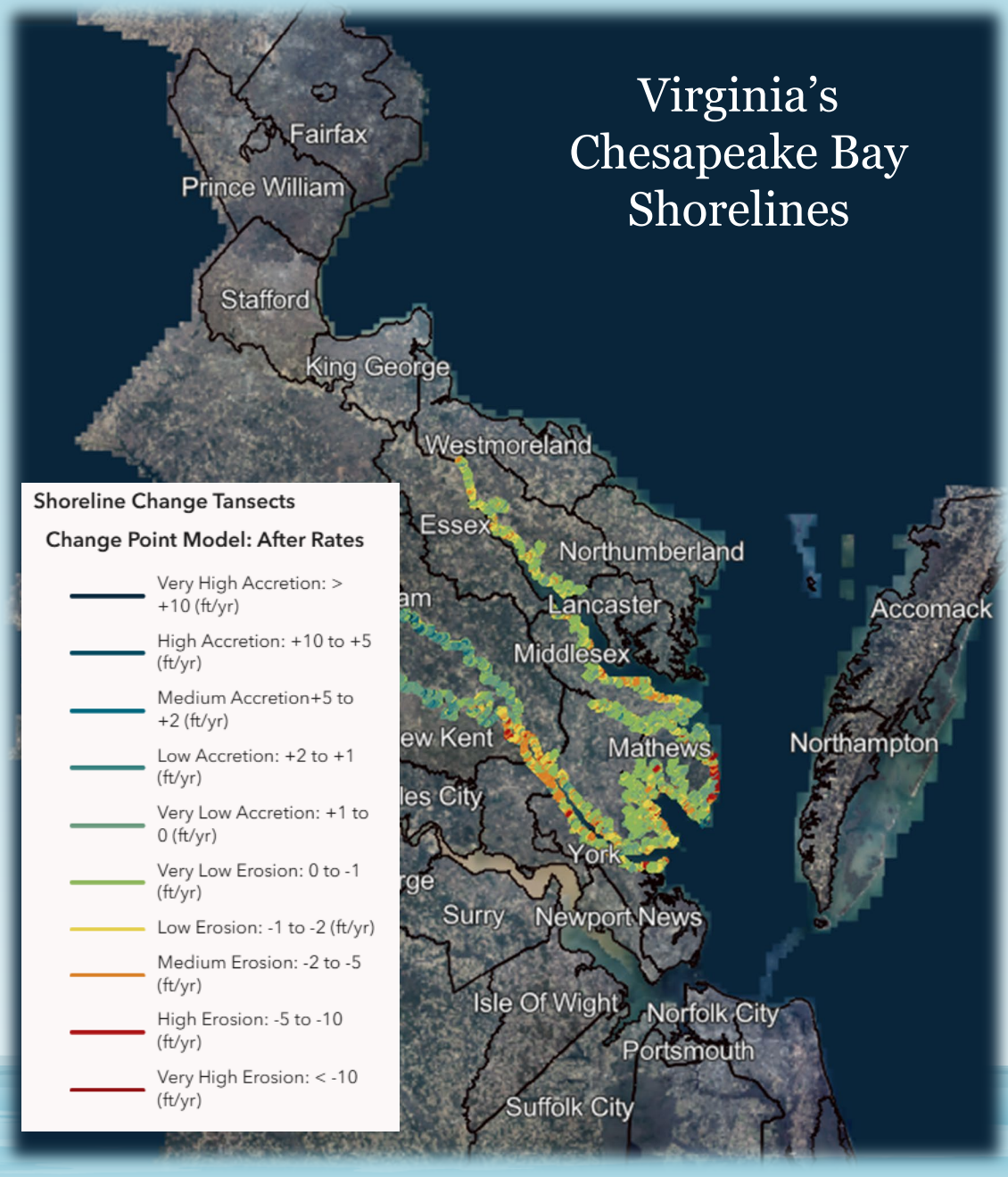
A long-term EPR/LRR may average across decades that include very different physical conditions, storms, sea-level trends, or shoreline interventions.

A custom Python script was used to model the information, plot results, and export, for each transect, the shoreline change rates, the time frame when rates change, and the magnitude of the change in rate.

Location

Virginia's Chesapeake Bay and Ocean Shorelines





DATA

The model utilizes a consistent shoreline record.

Historic + recent shorelines

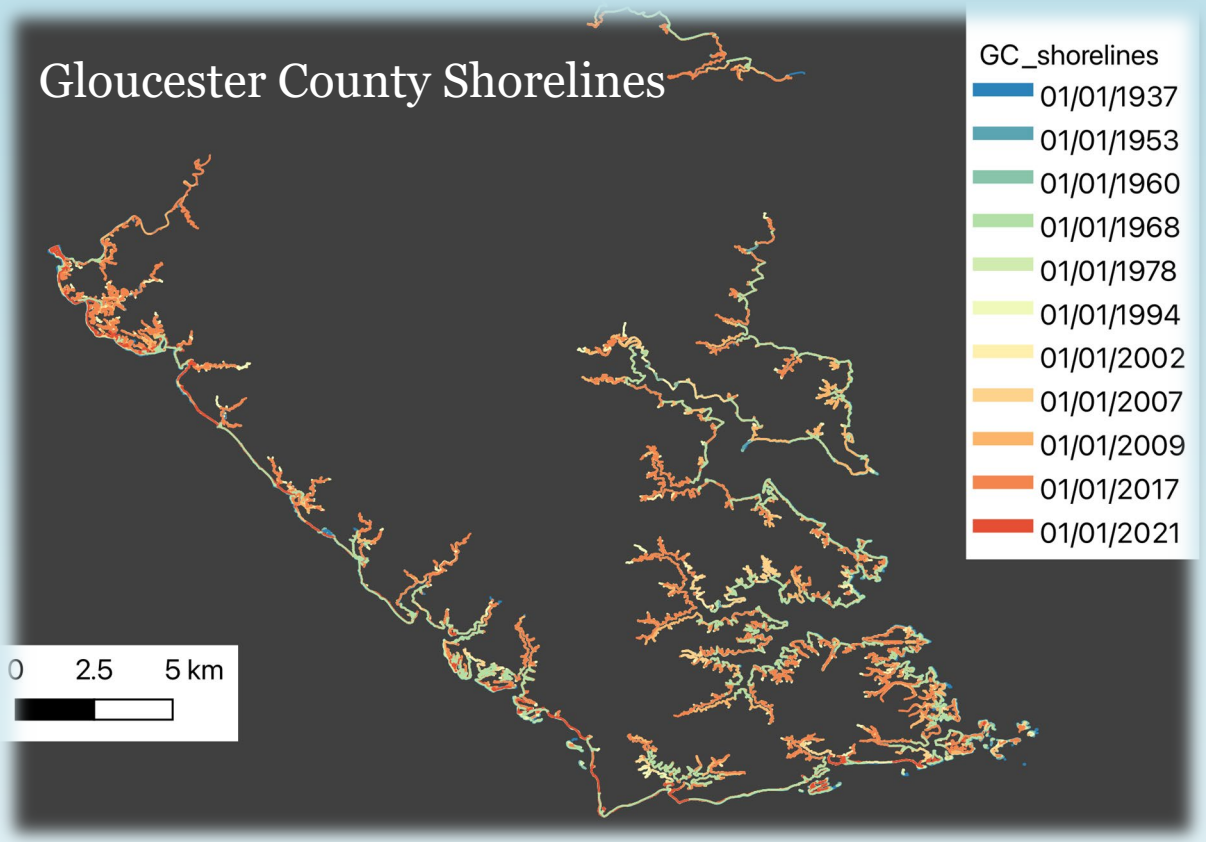
Aerial imagery from 1937 through 2025; the SSP database has been maintained for more than 25 years.

DSAS framework

Transects and long-term shoreline metrics are generated with the Digital Shoreline Analysis System.

The CPR Model

Developed in QGIS – provides recent vs. early change rates, timing, and magnitude

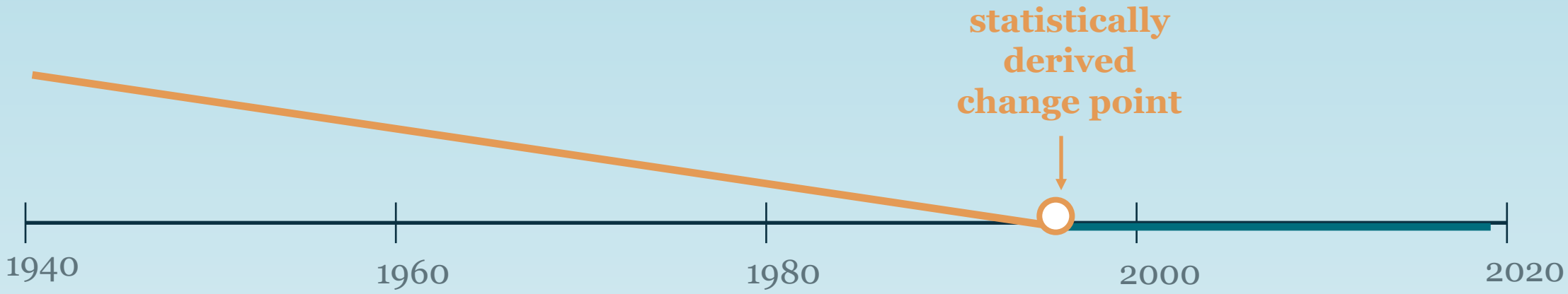


TAKEAWAY

A common baseline lets CPR be compared directly with EPR and LRR on the same transects.

METHOD

CPR turns the shoreline record into an “early vs. late” story.



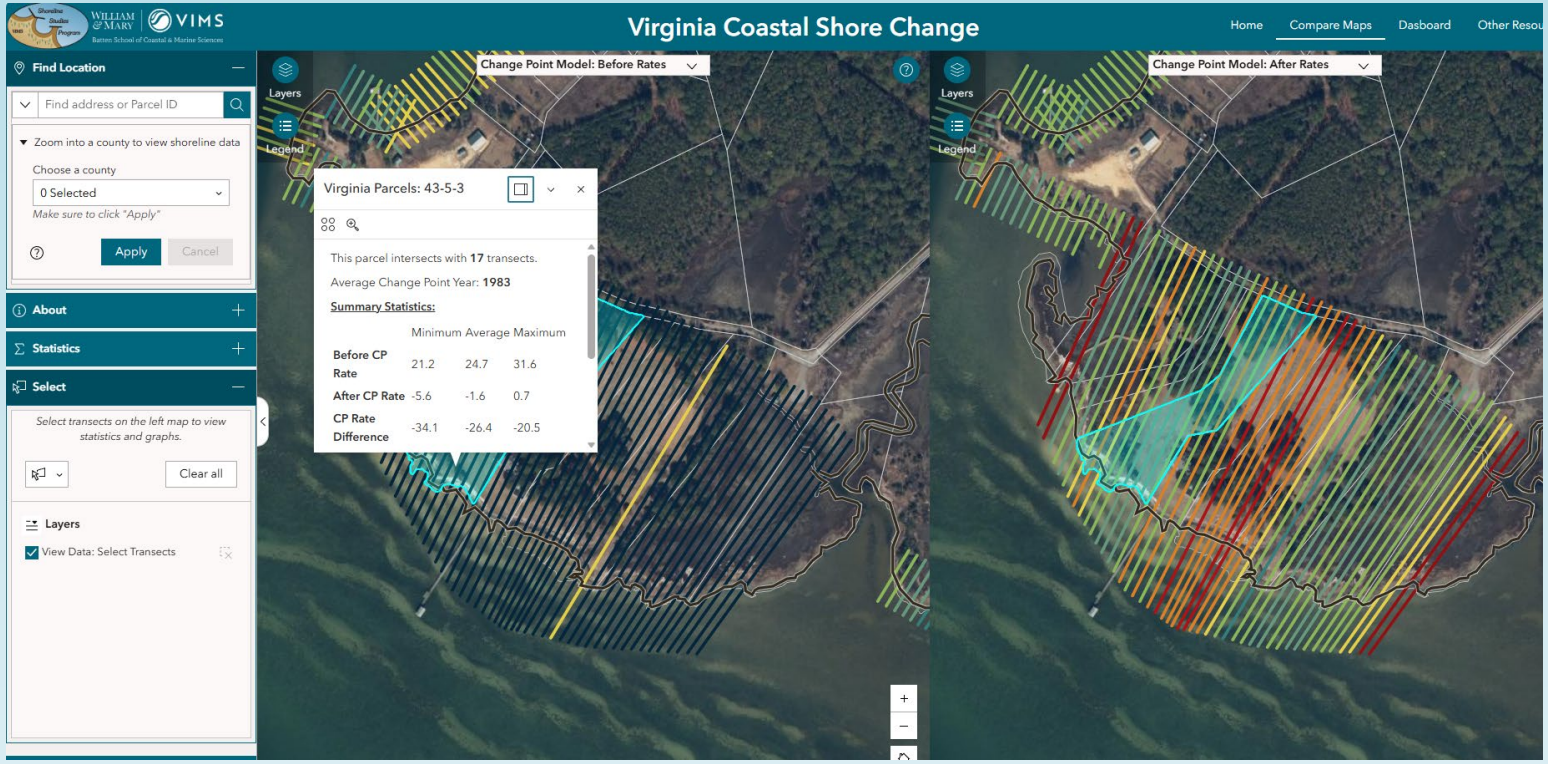
1. **Build transects from the DSAS shoreline framework**
2. **Fit piecewise regression to each transect and digitized shorelines.**
3. **Estimate transition year + early slope + late slope**
4. **Compare CPR with EPR and LRR and other GIS spatial/statistical analysis**

TAKEAWAY

The key new output is not just a rate — it is a transition year and the magnitude/direction of the rate change.

EXAMPLE

Example: Dredge material placement create a change point.



Gloucester parcel example

17 transects
average change point: 1983

Summary statistics shown in the viewer

Before CP rate	**21.2 to 31.6 ft/yr**
After CP rate	**−5.6 to +0.7 ft/yr**
CP rate difference	**−34.1 to −20.5 ft/yr**

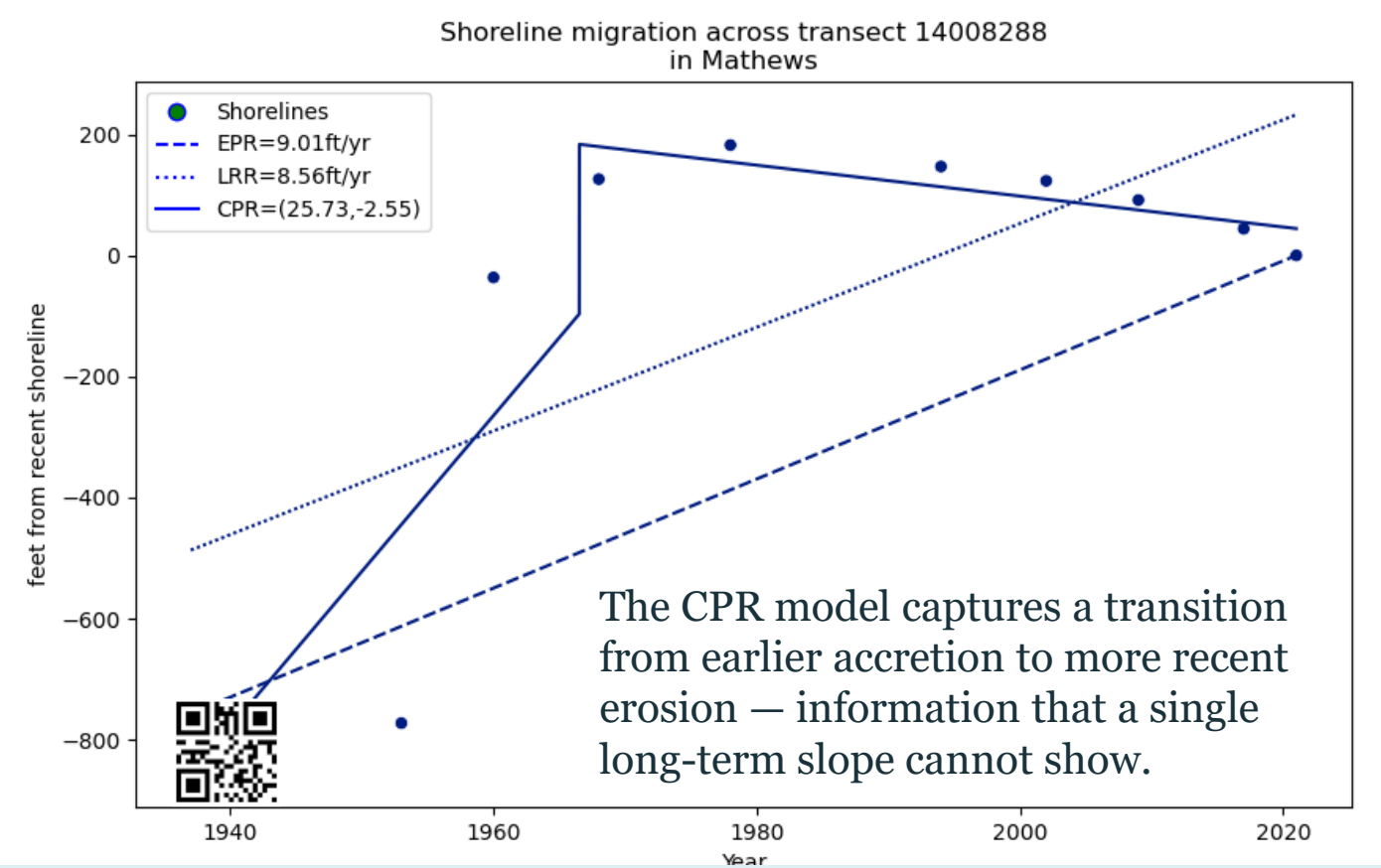
This illustrates how a localized intervention or geomorphic change can produce a large shift in the recent rate.

TAKEAWAY

A large CP-rate shift is a clue to investigate what changed in the physical or human system.

EXAMPLE

Example: the long-term trend can point the wrong way for today.



+8.6 ft/yr

Linear Regression Rate (LRR)

+9.0 ft/yr

End Point Rate (EPR)

−2.6 ft/yr

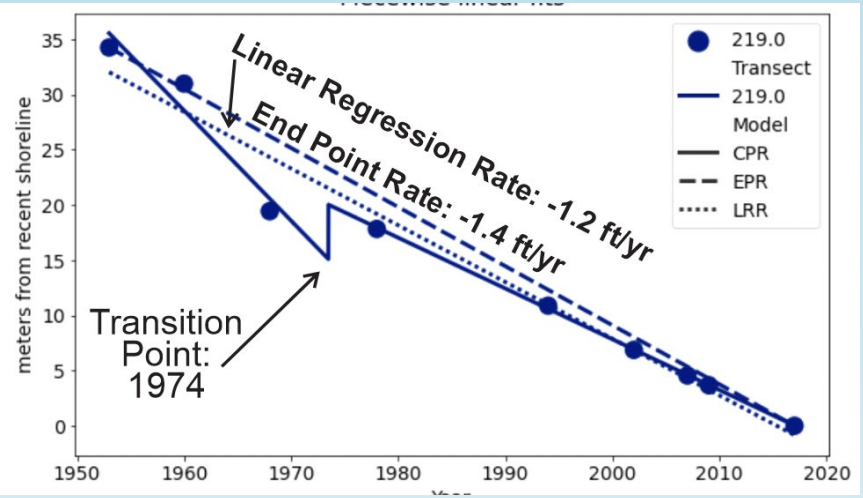
CPR late slope shown in the piecewise model

TAKEAWAY

Divergence is the diagnostic: EPR/LRR summarize the full record; CPR tells us that the recent trajectory has changed.

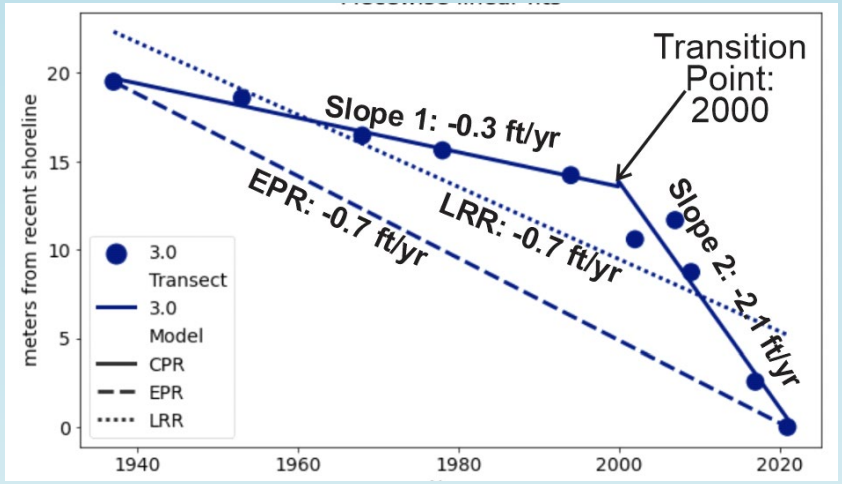
TYPICAL EXAMPLES

Shore condition information can help determine why rates are changing.



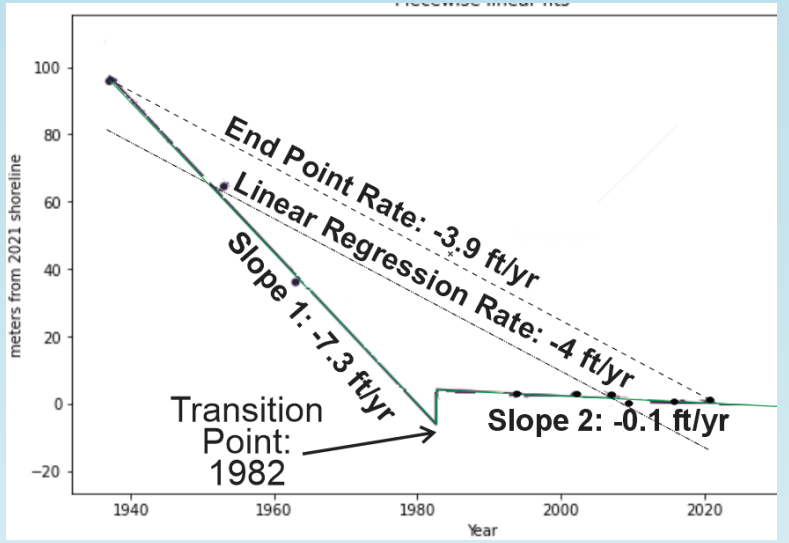
Low Interior Creek Marsh Shoreline
No Structure

Very little difference in the 3 rates of change



Low Wooded Open Shoreline
No Structures

Increased recent rate of erosion due to increased storms and sea-level rise.



Low Park Open Shoreline
Revetment on Shore

Recent rate of change is nearly zero due to revetment construction

YEAR 1 RESULTS

Year 1: erosion is widespread, and many reaches are accelerating.

York River and Mobjack Bay

5 counties
Detailed statistical evaluation completed for York River counties

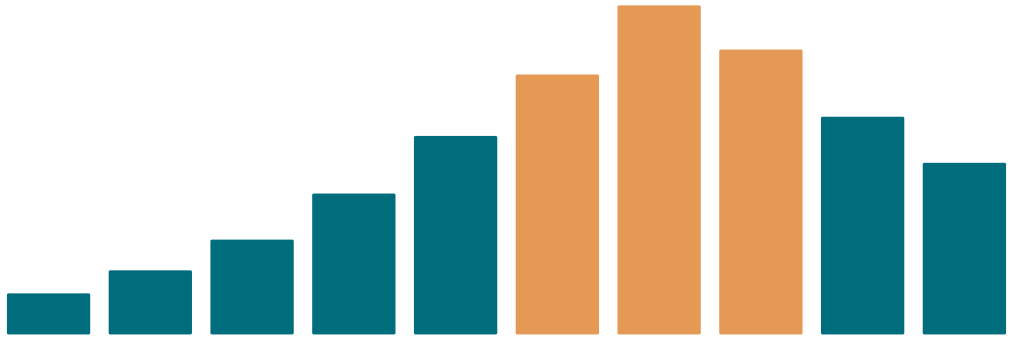
4 of 5
Counties showed measurable acceleration in erosion rates

late 1980s–1990s
Median change points clustered in this period

Change-point timing is not random

Median change-point years clustered in the late 1980s to early 1990s.

All five counties had net long-term shoreline erosion; four exhibited measurable acceleration.



illustrative distribution of change-point years

RESULTS

The strongest acceleration occurs on lower-elevation and wetland shores.

ELEVATION

< 10 ft NAVD88

experienced the greatest increases in erosion rates

SHORE / LAND USE

Wetland + open water

showed stronger erosion acceleration than other land-use categories.

Land-use categories are agriculture, developed, forested, wetland, and water.

DEVELOPED SHORES

Localized stabilization

often showed reduced erosion acceleration or localized accretion

Interpretation ≠ attribution

The current results identify patterns associated with shoreline elevation, shore type, land use, and stabilization. The next step is to test physical and anthropogenic controls together.

RESULTS

County-wide results

County	EPR	Before CPR	After CPR	Change
Gloucester	-0.6	-0.6	-0.7	-0.1
James City	-1.6	-1.3	-2.1	-0.8
King & Queen	-0.7	-0.4	-0.8	-0.4
New Kent	-1.5	-0.4	-2.3	-1.9
York	-0.8	-0.8	-1.1	-0.4
		Units in ft/yr		

Though erosion increased overall, Gloucester, York, and King & Queen had the smallest increases.

- Gloucester and York County shorelines are heavily protected.
- King & Queen shorelines have lower fetches and some high banks, which are more erosion-resistant.

New Kent County has the greatest acceleration of shore erosion rates because of its extensive tidal marshes and low floodplain shoreline.

NEXT STEP:

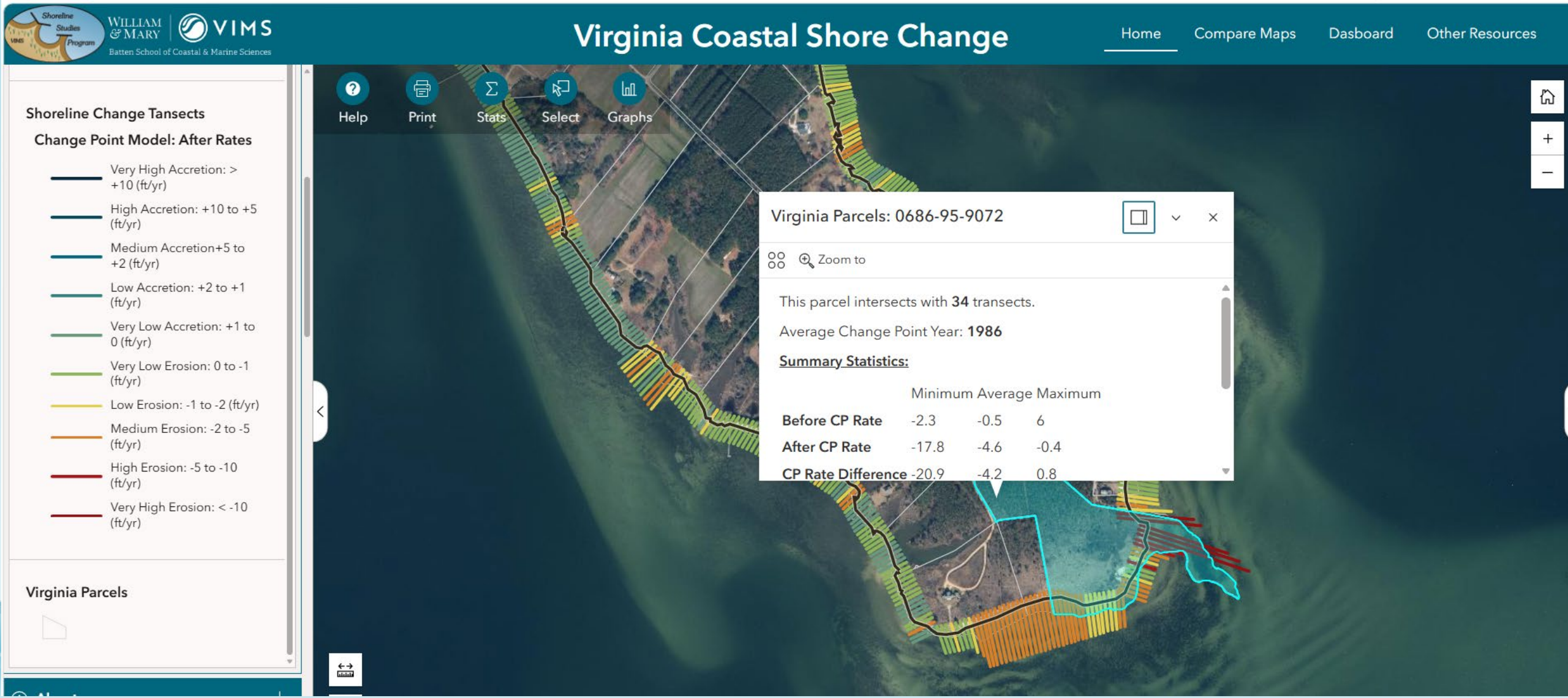
Break shorelines into reaches for analysis based on physical characteristics.



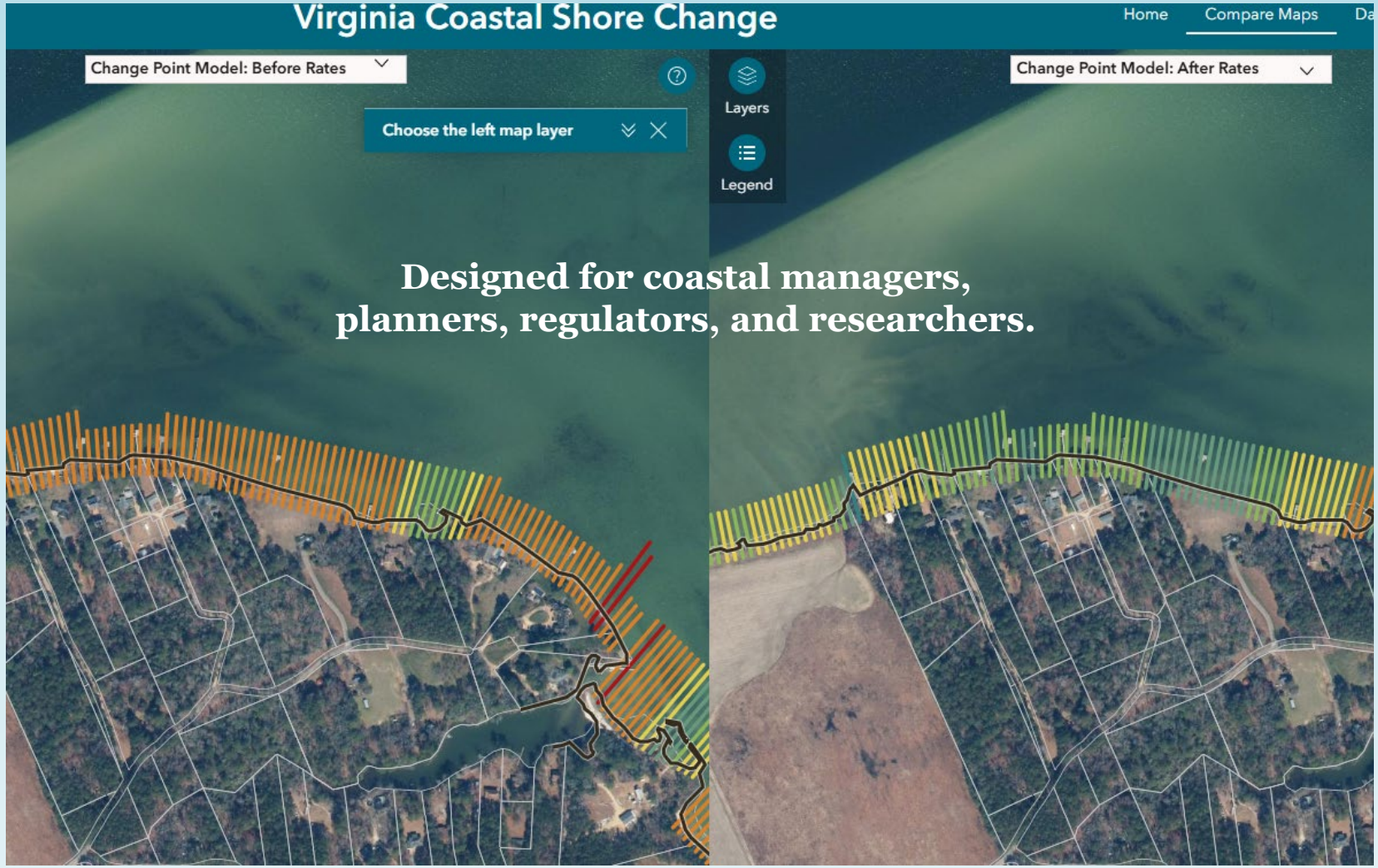
Gloucester County has long stretches of bulkheads and revetments

APPLICATION

The interactive viewer puts the change-point results where managers can use them.



APPLICATION



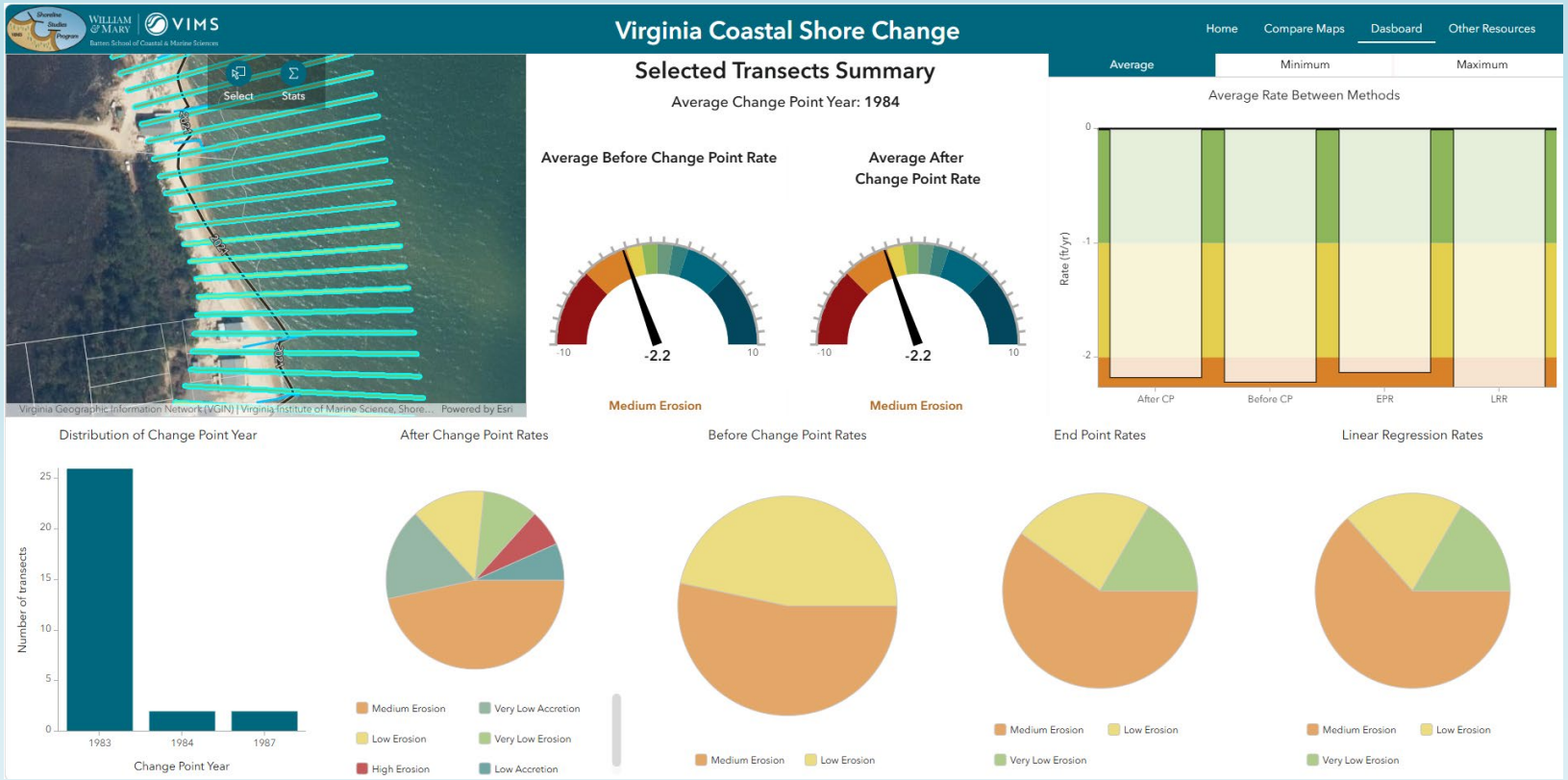
- **Compare maps**
  View before- and after-change-point rates side by side.
- **Select a parcel / reach**
  Summarize the transects that intersect a site.
- **Dashboard**
  See average, minimum, and maximum behavior across EPR, LRR, end-point, and CPR outputs.

TAKEAWAY

A map-based viewer turns a statistical result into a site-specific management conversation.

APPLICATION

The dashboard makes agreement — and divergence — visible.



How to read the comparison

Agreement — Methods cluster together → behavior is comparatively consistent.

Divergence — CPR differs from EPR/LRR → investigate timing, acceleration, deceleration, or intervention.

Spatial pattern — Neighboring transects behave similarly → the shift may reflect a reach-scale control.

TAKEAWAY

The viewer is most powerful when users ask “What changed?” and then inspect the shoreline, structure, and local context.

WHAT COMES NEXT

CPR opens the door to more site-specific resilience questions.

1. **Are rates changing with recent sea-level-rise acceleration?**
2. **How do bank height, fetch, morphology, shore type, and habitat affect the rate shift?**
3. **How do different shoreline protection structures alter trajectories?**
4. **Which rate is most appropriate for planning and design at a specific reach?**
5. **Can CPR support future shoreline projections tied to sea-level-rise scenarios?**

Why this matters for coastal resilience

Shoreline management planning and design should be based on the trajectory that is likely to govern future conditions - not automatically on the full historical average.

TAKEAWAY

The goal is adaptive management: detect emerging hotspots, understand their trajectory, and choose a rate that matches the planning horizon.

Four things to remember...

1. **EPR and LRR still matter.**
   They provide the long-term context and common DSAS baseline.

2. **CPR adds time.**
   It identifies when the shoreline began behaving differently and how much the rate changed.

3. **Divergence is informative.**
   Differences among methods can flag emerging hotspots and reaches that need investigation.

4. **Reach-based planning is instructive**
   Determining how the shoreline is changing on adjacent shorelines and similar vs. different physical conditions is important for planning and design.

Questions?

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Change-point detection adds temporal context to shoreline change rates which is needed for shoreline management planning and design.

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Virginia Institute of Marine Science

Virginia Coastal Zone Management Program

DEQ Virginia Department of Environmental Quality

NOAA National Oceanic and Atmospheric Administration U.S. Department of Commerce