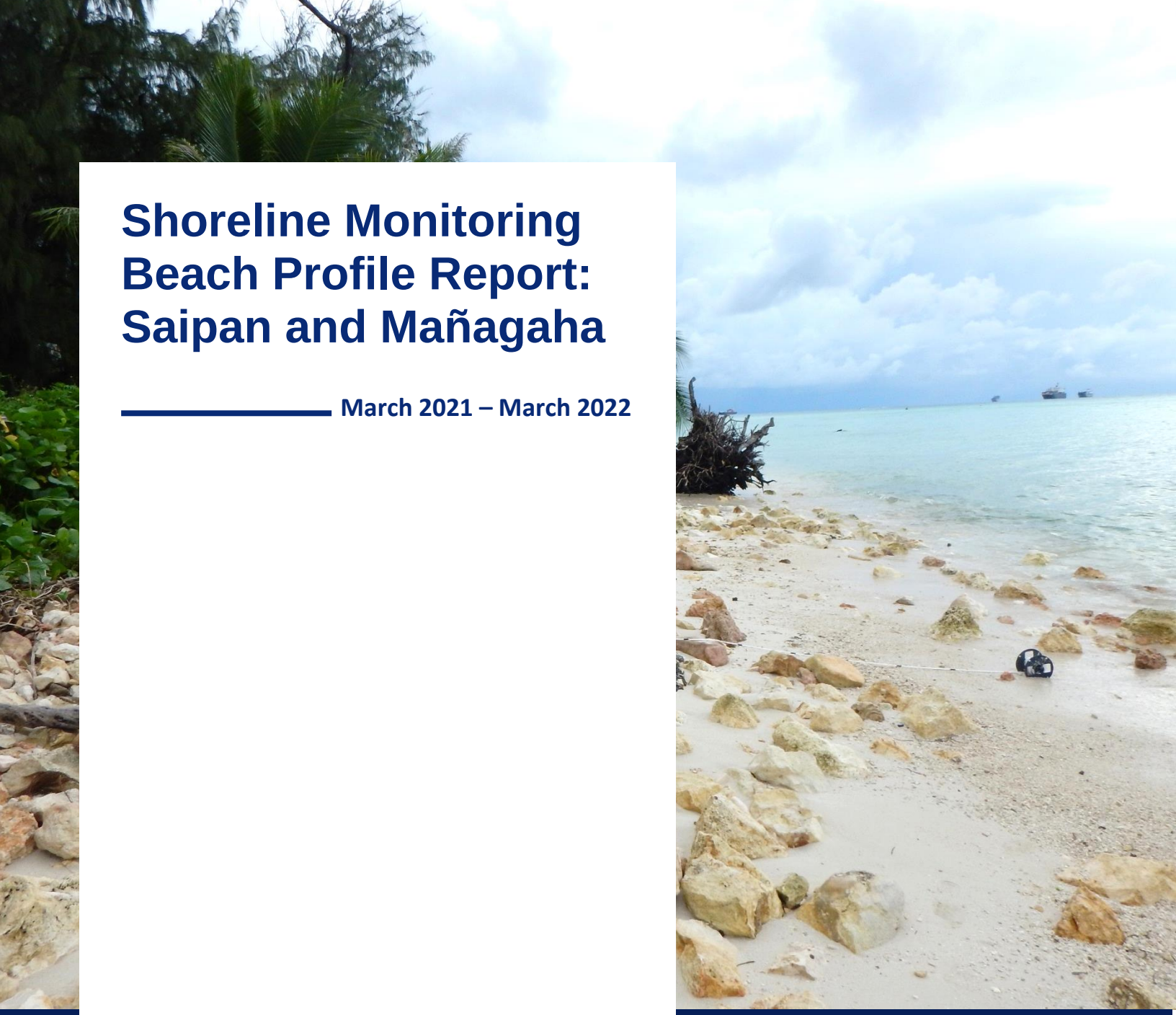

Shoreline Monitoring Beach Profile Report: Saipan and Mañagaha

March 2021 – March 2022

Division of Coastal Resources Management
CNMI Bureau of Environmental Coastal Quality
Award No.: NA20NOS4190179

About the Report

This report is released annually to inform the findings from field data collected under DCRM's Shoreline Profile Monitoring Program between June 2016 - March 2022. An update from the August 2018 - February 2021 report, this document builds from the previous findings. Monitoring efforts are improving with regular field surveying, utilizing the Trimble GPS device, and capturing baseline elevation data with the higher accuracy total station.

This report aims to guide coastal managers and stakeholders in making informed, effective, and adaptive decisions regarding our dynamic shoreline.

Cover photo is the eroded shoreline of American Memorial Park Point 1.

Acknowledgements

The Shoreline Monitoring program is led by the DCRM's Planning Section, with the direction of the Coastal Planner I, and valued assistance from DCRM staff volunteers, dedicated summer interns, and NMC student interns. Interns have greatly contributed numerous hours to data collection and field work and support the program's consistency. The integration of the total station in this program is largely thanks to Seamus Harrison, who served as DCRM's GIS Specialist during this reporting period. Any questions or comments about the program or this report may be directed to shorelines@dcrm.gov.mp.

Financial assistance provided by the Coastal Zone Management Act of 1972, as amended, administered by the Office for Coastal Management, National Oceanic and Atmospheric Administration.

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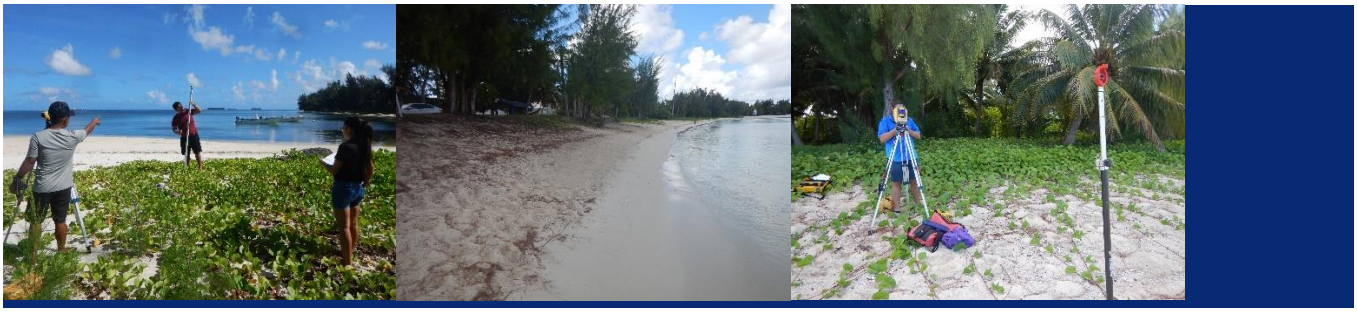
Contents

DCRM Shoreline Monitoring Program

CNMI beaches are dynamic places between the ocean and land providing critical economic, recreational, and cultural services to our island community. Over the years, the loss of sandy shoreline by storm-driven ***erosion*** concerns those who work, live, and play in these spaces.

Every shoreline stretch is unique. Understanding the coastal processes that drive the width of our sandy beaches is key to improving how we manage development along the shoreline. Which ones are eroding or ***accreting*** (gaining sand)? How could the sand be shifting along the coastline?

To understand this change, the Division of Coastal Resources Management (DCRM) implements long-term shoreline monitoring to track changes of sandy beaches in Saipan, Mañagaha, Tinian, and Rota over time. Timing is a critical factor to how a shoreline appears, given how tides reduce or increase dry beach and how currents shift sand. Data is visualized into ***beach profiles***, which are used to interpret any short-term and long-term trends. These findings are published in this annual document-type report and into an interactive **"Climate Impact Viewer"** map. (See page 5, Online Interactive Map.)



Methods

Since 2016, staff have been using on-the-ground transect surveys at designated starting points along the coast, we call ***headstakes***. We use survey-grade equipment to record elevation and distance data from the ***backshore***, where waves usually do not reach, to the ***beach toe***, where the shoreline is usually exposed at high tide. We rely on the ***Berger Level method***, which requires manual readings on a measured rod through a leveled telescope instrument. The above photo on top left displays this two to three-person survey method. In 2021, we integrated the one-person higher accuracy electronic method, known as the ***Total Station*** method (shown in the right photo). Using data from both, we graph out ***beach profiles*** to compare the shoreline contours over time. (See page 7, How to Read the Beach Profile).

In addition, we capture damages or remnants after a strong storm by walking the ***wrackline*** or ***scarp*** with the ***Trimble GNSS.***

Web Resources

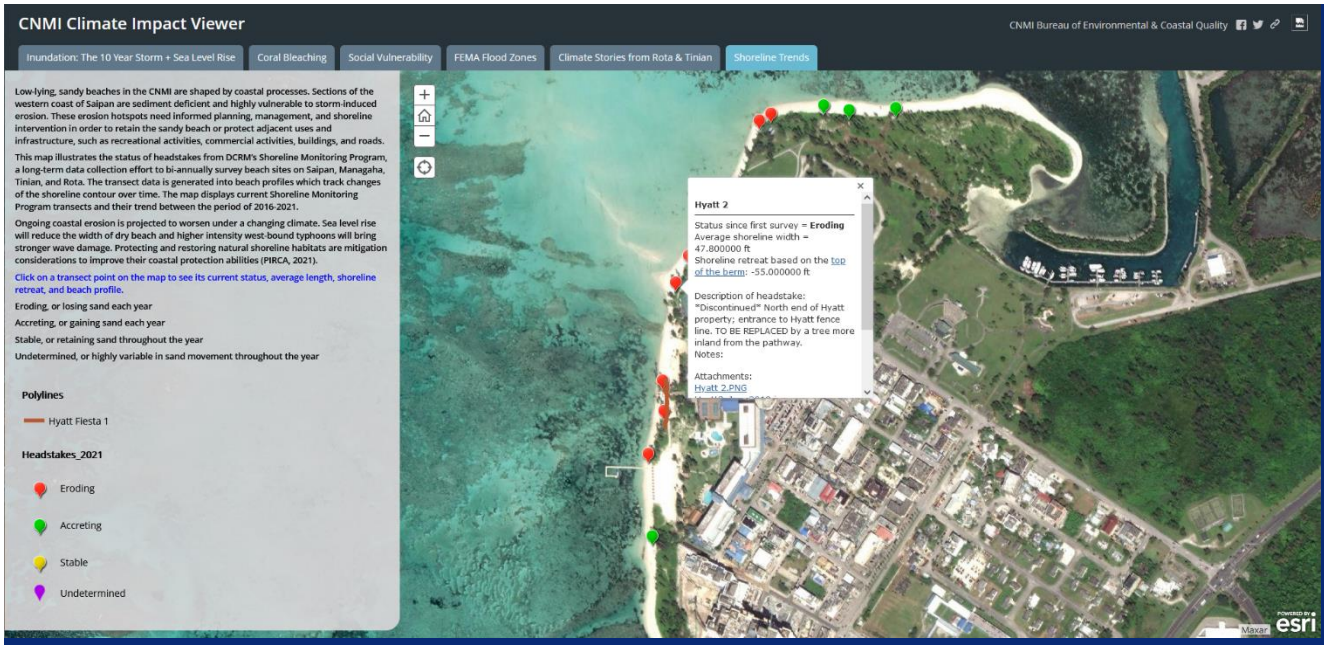
Shoreline Monitoring Interactive Map

Shoreline Monitoring has an interactive map available for viewing on the DCRM website. The map illustrates the status of the headstakes on Saipan, Tinian, Mañagaha, and Rota, along with its beach profiles and picture comparison.

It is expected to be updated more frequently than the annual report. It also includes the polylines of the wracklines or scarp captured by the GPS.

To access the map:

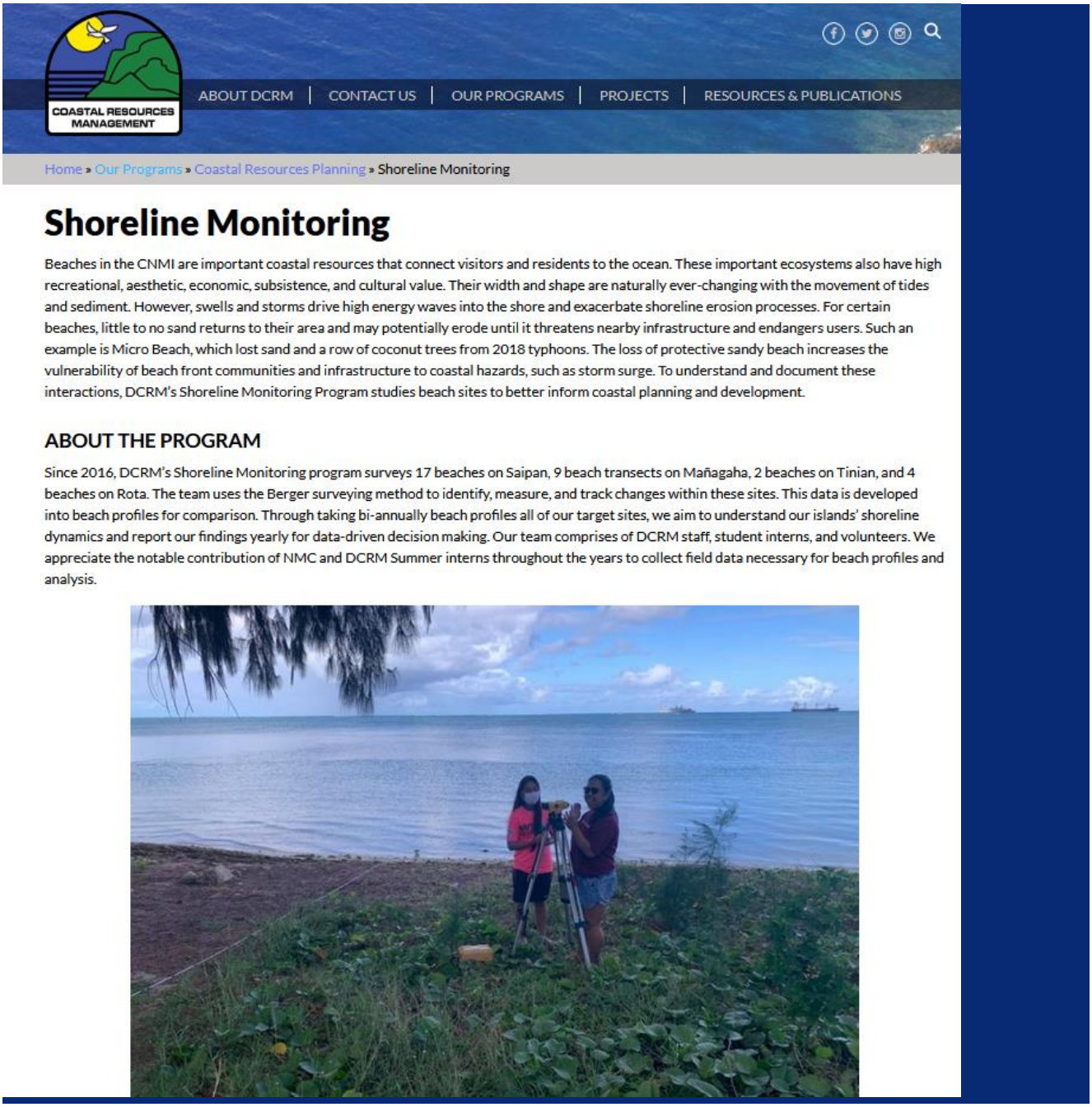
1. Click on this link: https://dcrm.maps.arcgis.com/apps/MapSeries/index.html?appid=3b8d1a4b46d64586b39047f5732621cd **OR**
   On, www.dcrm.gov.mp, hover over “Resources & Publications” then “Tools and Apps.” Click on “Open Data Access.” On the “Open
2. Go to “Shoreline Trends.”
3. Zoom into the area of interest.
4. The bubbles marked in red, green, yellow, or purple are the headstakes surveyed.
   - Red indicates that the beach profile is eroding (losing sand).
   - Green indicates that the beach profile is accreting (gaining sand).
   - Yellow indicates that the beach profile is stable (no significant change).
   - Purple indicates that the beach profile is undetermined, likely due to its moderately dynamic nature.



Shoreline Monitoring Web Page

Shoreline Monitoring webpage on the DCRM website is the information hub of the shoreline surveying work along. All resources developed by the Shoreline Monitoring team are published into this page for public use.

Access the website: https://dcrm.gov.mp/our-programs/coastal-resources-planning/shoreline-monitoring/



Definitions

Abrasion/abrading **-** the process of scraping or wearing away

Accretion/accreting - the gradual addition of land by deposition of water-borne sedimen

Backshore **-** the generally dry part of the beach lying between the nearshore and inland area, which is only exposed to waves during storm surge and high tide events

Beach nourishment **-** practice of adding sand or sediment into the beach to address erosion

Berm - the nearly horizontal portion of the beach or backshore formed by the deposit of materials by wave action. (In the CNMI, the berm is a vertical drop.)

Berger Level - used to accurately measure the height of an inaccessible object. Takes cross sectional picture of a beach's contour.

Dredging **-** maintenance practice of sand removal for deepening water depths for docks, harbors, or channels

Dynamic - constantly changing

Elevation difference - the height difference of the headstake to the beach toe

Erosion **-** the wearing away of land and the removal of beach (or dune) sediments by wave action, tidal currents, drainage, or high winds.

Foreshore **-** the part of the shore that lies between high and low water mark at ordinary tide.

Headstake **-** the starting point of a transect. Usually marked on a tree in paint.

High waterline **-** The level reached by the sea at high tide

Hydrodynamics **-** science revolving around the motion of fluids acting on solid bodies. For this report, it is the motion of waters surrounding the west coast of Saipan acting on corals and other physical objects in the water during wave conditions.

Incidental erosion **-** takes place mainly by cross-shore processes during extreme events (high waves, high water levels) and produce beach lowering or scouring

Risk - chance that something or someone will experience negative impacts from a coastal hazard

Scarp - a drop formed by erosive forces

Sediment transport - hydrogeological process in which waves currents push sediment into or away from coastal spaces

Shoreline change – change in the shoreline contour by loss or gain of sand volume

Stable/stability - a state in which the shoreline appears to return to its original condition over time even when disturbed

Stabilization measures - known approaches to address coastal erosion, whether structural or nature-based

Storm surge - rising water from the ocean that is pushed towards the shore by the force of winds from a strong storm. Storm surge can damage the shoreline and property.

Toe (beach toe) - the point of a beach that juts out past the waterline. Often this is sand that is covered by water but may be exposed during low tides.

Total Station method - Optical surveying instrument that integrates a leveled electronic movable telescope to measure the slope distance at where the prism rod is placed.

Trade winds – winds that reliably blow east to west just north and south of the equator

Transect - a straight line or narrow section across the earth's surface along which observations are made or measurements are taken.

Trimble GNSS - a Trimble-branded satellite navigation system (GNSS) device that provides global coverage

Vegetation line - the first line of stable and natural vegetation, separate from grass. Also the boundary between the sand beaches.

Waterline - a line that marks the surface of the sea on land.

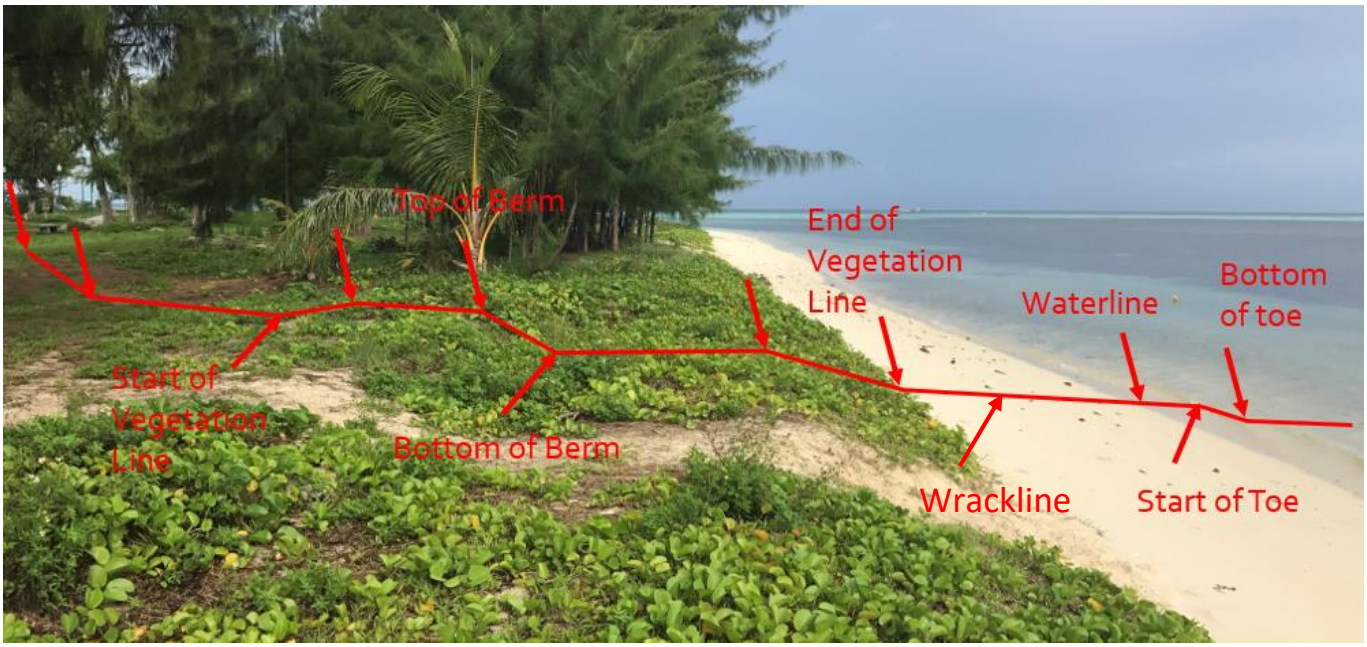
Wave overtopping- when waves meet a submerged reef or structure and overtakes the structure

Wrackline - The line of debris that is left by high tide. Usually made up of eelgrass, pebbles, and litter.

How to Read the Beach Profile

Beach profiles are "excellent evidence of the magnitude and frequency of the cross-shore changes which are experienced by a particular shoreline of any sediment type" (Cooper et al, 2000). They are the contour of the shoreline from the headstake (starting point inland) to the bottom of the moat/toe. It is like a snapshot of the shoreline in time, only measured and plotted into a graph.

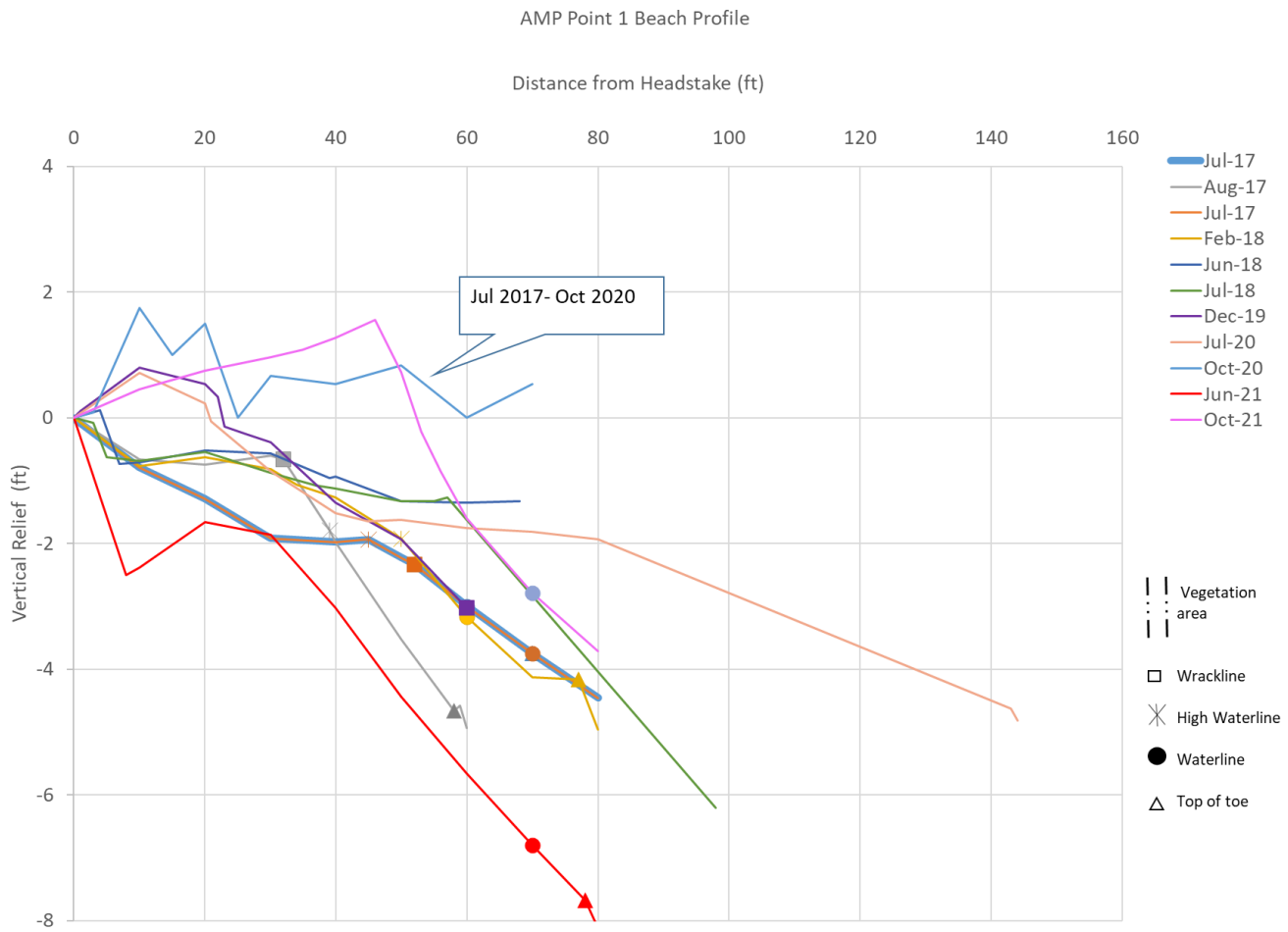
The figure below indicates the common features of a beach profile captured in surveying. Properly identifying these features is a necessary skill for understanding the shoreline condition at the time.



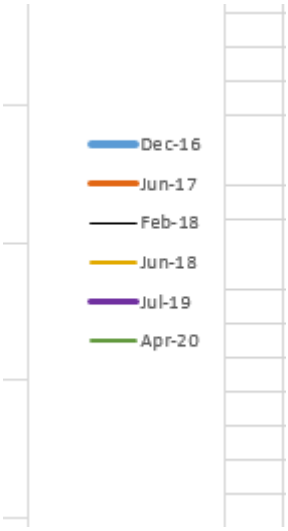
The common features of beach profiles are:

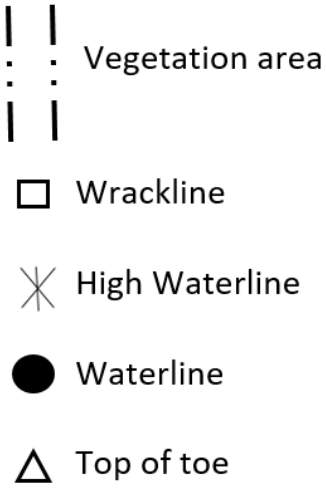
- ***Vegetation line*** – The start and end of stable and natural vegetation that may demonstrate stability of a beach profile
- ***Berm*** - The nearly horizontal portion of the beach or backshore formed by the deposit of materials by wave action. (In the CNMI, the berm is a vertical drop.)
- ***Wrackline*** - The line of debris left by high tide, usually made up of seagrass, pebbles, seashells, and litter
- ***Waterline*** - The line marking the surface of the sea on land
- ***Toe/moat*** – The point of a beach that jut out past the waterline. It is usually exposed during low tide so it is often submerged.

The feature below is the generated beach profile once data has been processed.
The x-axis, horizontal, is the distance from the headstake in feet.
The y-axis, vertical, is the vertical relief in feet. The vertical relief assumes that the headstake is at zero elevation and that the feet is the elevation difference from the headstake.



On the top right hand corner, there are different colored lines followed by dates. Each corresponding color line indicates a data entry captured at that day. For instance, a beach profile taken on Jul-17 is shown in thick blue. Time is an important factor for shoreline monitoring because entries taken at different times will be compared to understand shoreline change.





Symbology is used to label shoreline features and where they have been detected along the transect. These shoreline features have been selected as important and common indicators of change. The color matches the date/time of the transect taken. The symbol matches the beach feature. ***Vegetation*** area has two lines. The left indicates 'Start of Vegetation' while the right indicates the 'End of Vegetation'. '***Wrackline'***, '***high waterline'***, '***waterline'***, and 'top of (beach) ***toe'*** are generally detected as one point. Note that not all beach features may be detected in a single shoreline transect.

- The Berger Level beach profiles are prioritized given that Berger level survey is regularly deployed.
- The Total Station beach profiles generated during this reporting period follow, marked in a dotted outline. The total station surveying is in progress to become more consistent.

Accounting Seasonal Change

Shoreline change is often dictated by seasonal trade winds that drive sediment transport.
In the CNMI, the typical winter easterly and typhoon season winds exhibit the highest wave energies.

- The typical winter easterly conditions usually happen within January to April, bringing swells to the CNMI shoreline.
- The typhoon season wave conditions are anticipated after each storm, usually anticipated within July to October. Intensity and length of disturbance greatly influence sediment transport, with high potential to worsen erosion. Typhoons often approach the CNMI from the east to the west but have the ability to curve from south to north. Two common typhoon types have been observed: southwest (SW) and north-northwest (NNW).

This report considers seasonal change and includes map of the wave directions generated from the **Hydrodynamic Study of Saipan's Western Lagoon (2019).**

Saipan Beach Profiles and Key Findings

Pak Pak

Sheltered by the nearby reef (approximately 500 meters away) and Agingan Point, Pak Pak Beach has exhibited stable shoreline since 2016. In 2018, storm surge damaged vegetation. Compared to last year, Pak Pak beach's vegetation has developed, signifying stability since then.
As observed, southwest typhoon conditions appear to be more damaging than north-northwest especially due to the proximity of the storm. However, the beach may be receiving sediment from the adjacent reef and Agingan Point. Greyish rubble-textured rocks were found along the shoreline after one storm event, potentially from Agingan Point.

Pak Pak 1 Highlights:

- STABLE with a Wrackline that ranges 10 – 40 ft and an elevation difference of 5 ft

Pak Pak 2 Highlights:

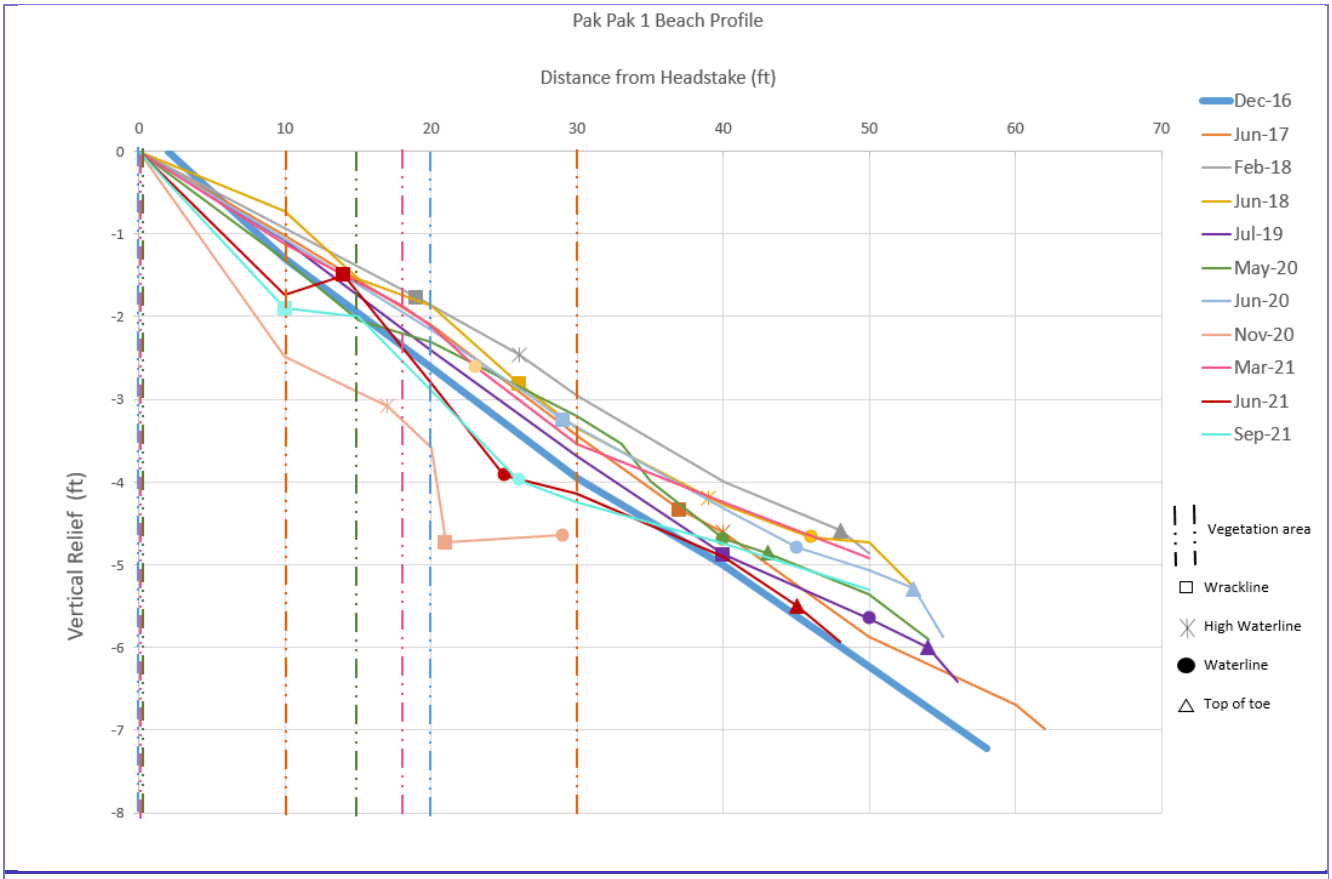
- STABLE with a Wrackline that ranges 45 – 75 ft with an elevation difference of 9 ft

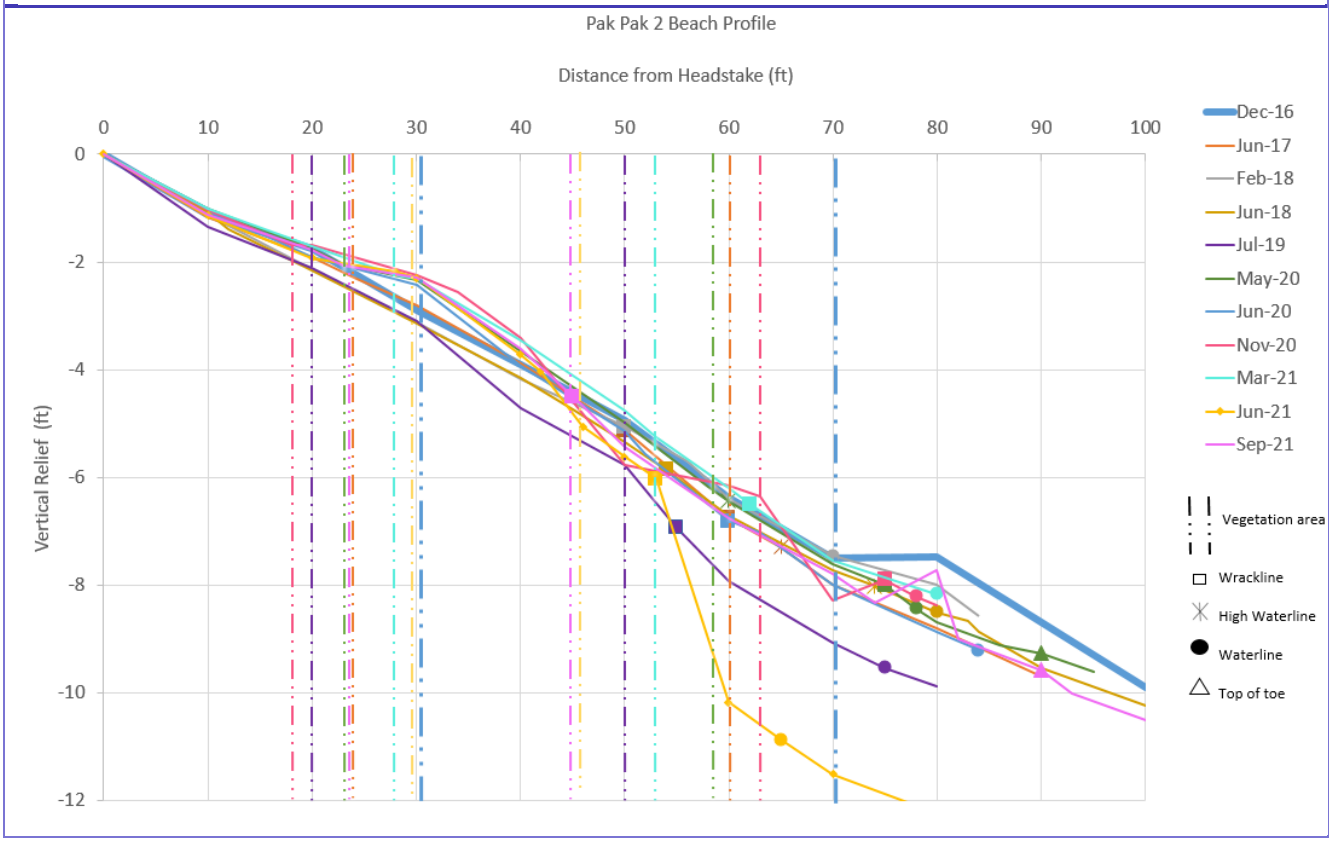
Pak Pak 3 Highlights:

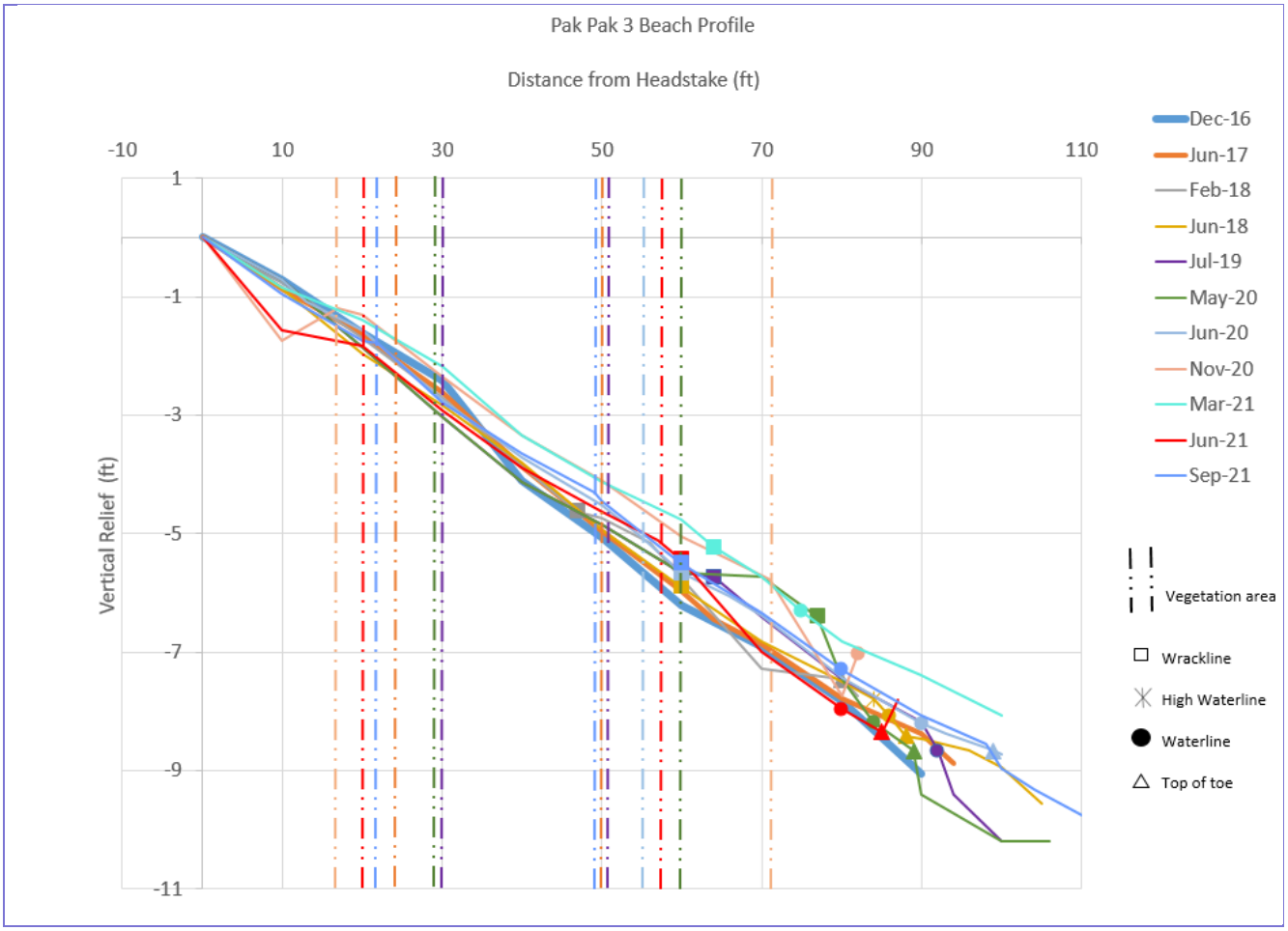
- STABLE with a Wrackline that ranges 47 – 77 ft with an elevation difference of 8 ft
- Seasonal variation may bring some fresh sediment to the shoreline. The nearby outfall northward may have some influence. Vegetation has developed indicating that storm surge has not impacted the area since 2019.


2020
2021
Pak Pak 1
2020
2021
Pak Pak 2
2020
2021
Pak Pak 3

Pak Pak Beach Profiles






Pak Pak 3 Beach Profile
Distance from Headstake (ft)
-10
10
30
50
70
90
110
1
-1
-3
-5
-7
-9
-11
Vertical Relief (ft)
Dec-16
Jun-17
Feb-18
Jun-18
Jul-19
May-20
Jun-20
Nov-20
Mar-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

PIC

PIC is adjacent to the Chalan Kanoa reef, which is 500 meters away from the headstakes. This shoreline is subjected to storm-induced erosion. The storms of 2018 have abraded the shoreline and fell trees located on the berm. As a response, the PIC hotel has placed sand bags and rocks in hopes of stabilizing the highly eroding storm berm. Fortunately, the storms in this period have not damaged the berm. Wild native vegetation has prospered since their settlement, indicating stability for now. Southwest typhoon conditions appear to be more damaging than north-northwest especially due to the proximity of the storm. Intense storm surge events in the future may erode the shoreline further.

PIC 1 Highlights:

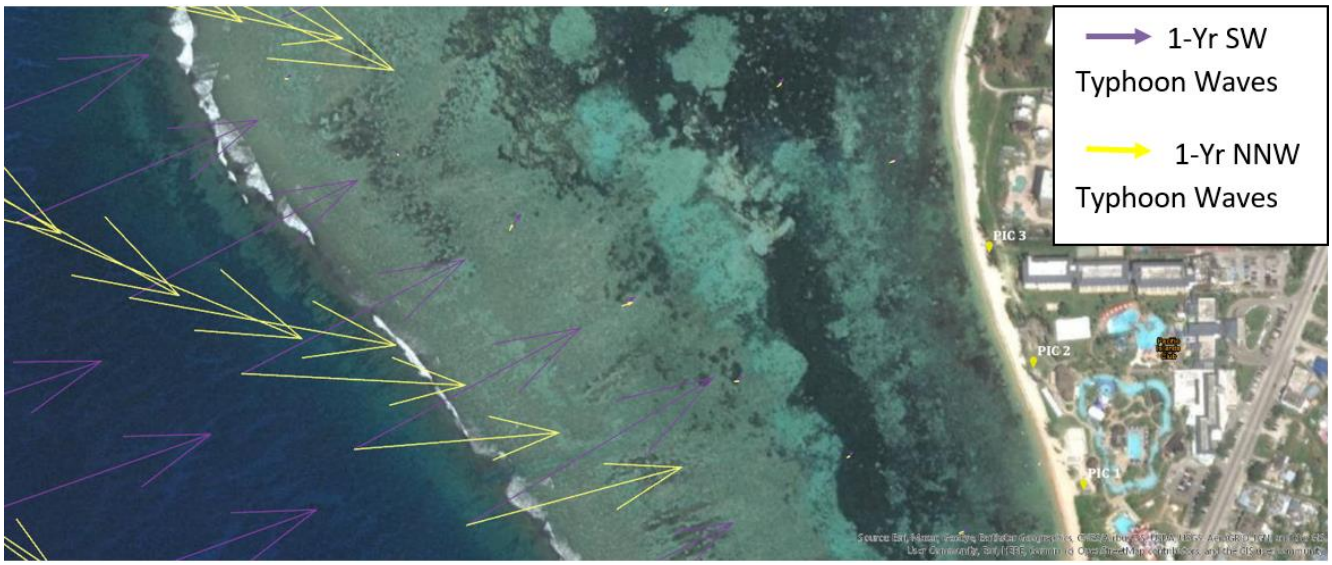
- ERODING with a Wrackline that ranges 37 – 63 ft and an elevation difference of 9 ft
- Erosion to the shoreline occurred in Dec-20 at a 40 ft distance and more.
- Foot traffic continues to discourage vegetation growth.

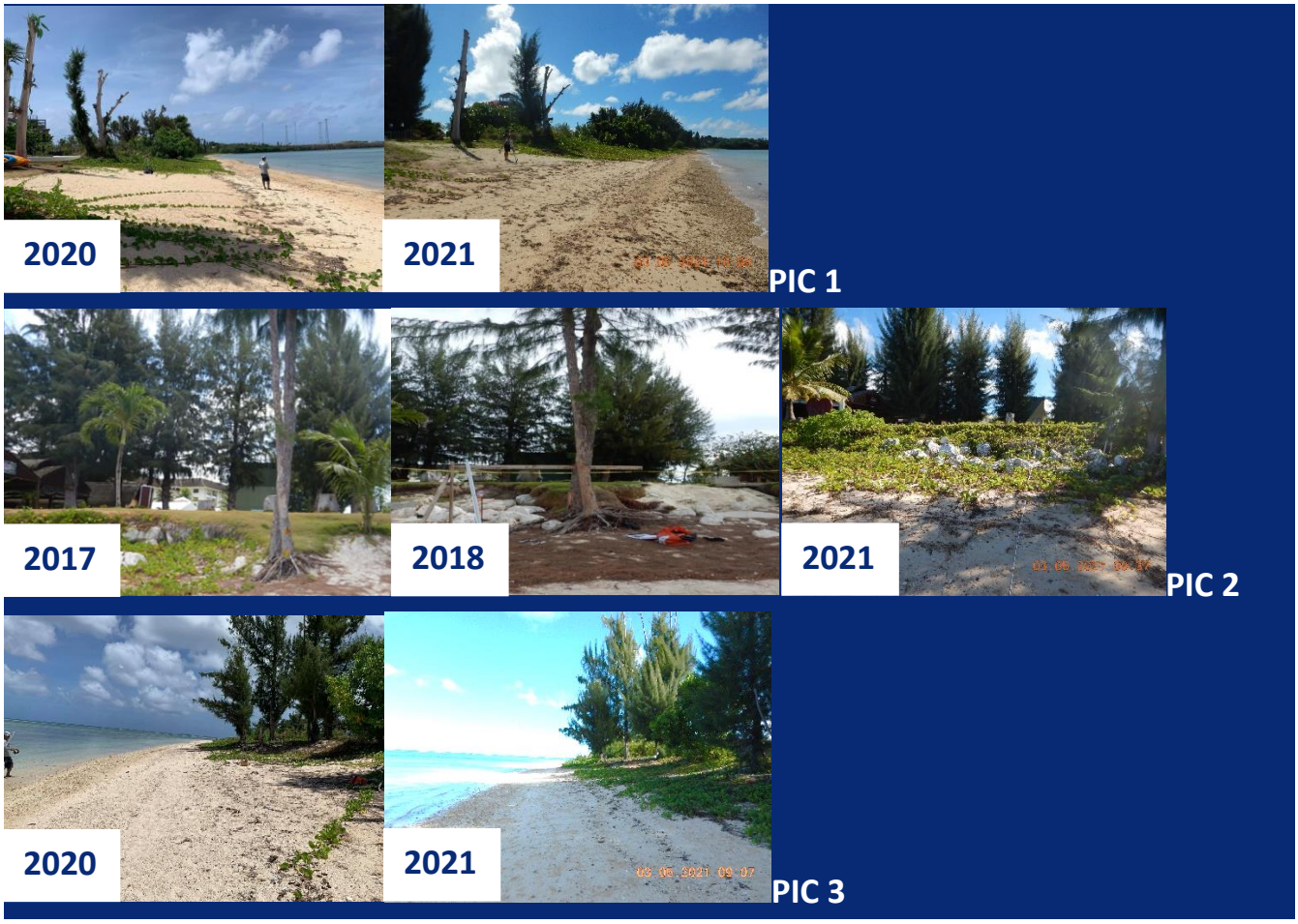
PIC 2 Highlights:

- STABLE in the short-term; ERODING in the long-term
- Wrackline that ranges 35 – 48 ft with an elevation difference of 9 ft
- Stabilizing beach vegetation has grown over the berm. The berm was steepened from an erosion event around June 2017. Rocks were placed to stabilize the berm but Typhoon Yutu (2018) deepened the drop more. The loss of the head stake may indicate if the hotel property is at high risk of shoreline erosion from storm surge.

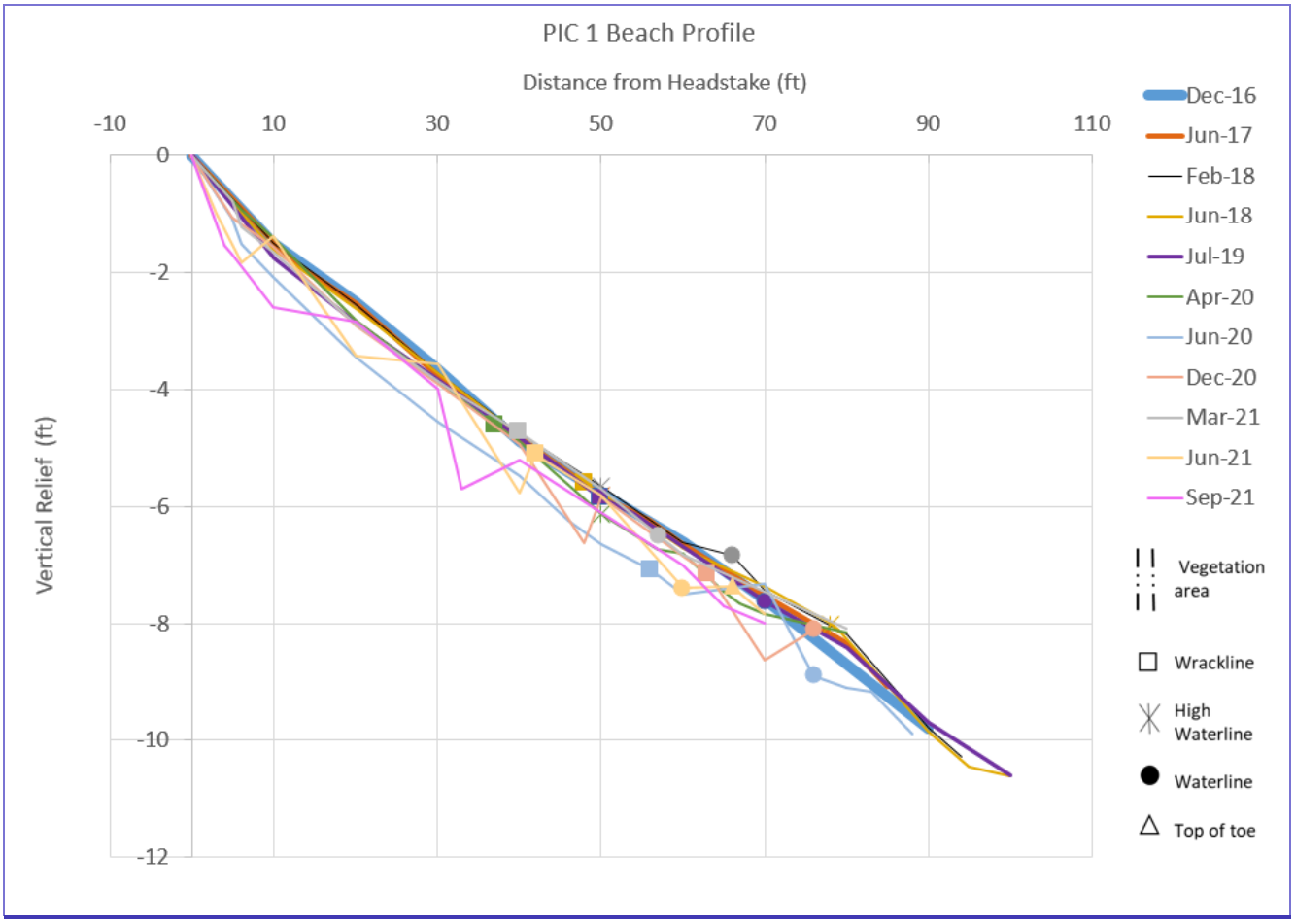
PIC 3 Highlights:

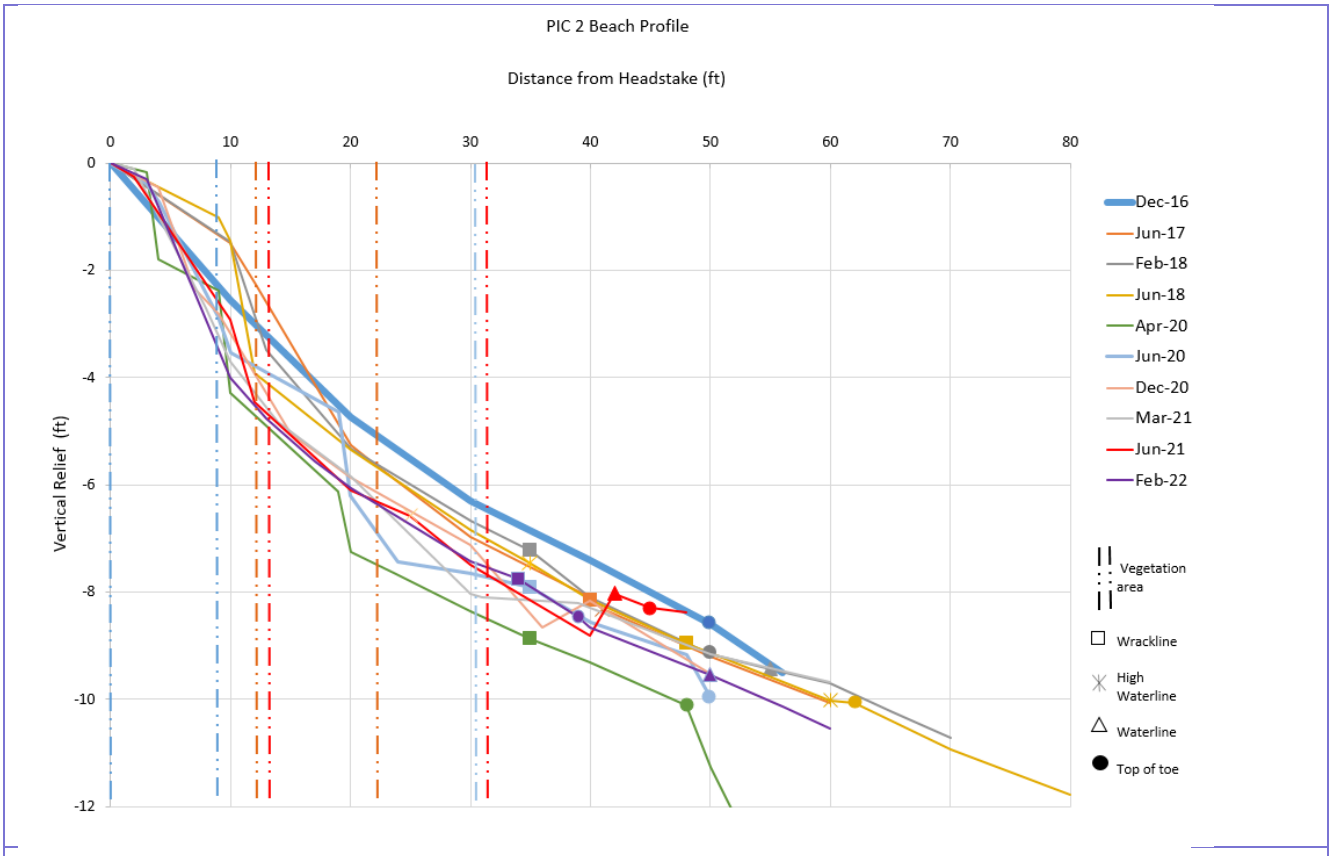
- STABLE with a Wrackline that ranges 45 – 50 ft and an elevation difference of 9 ft
- Construction happening nearby in the backshore

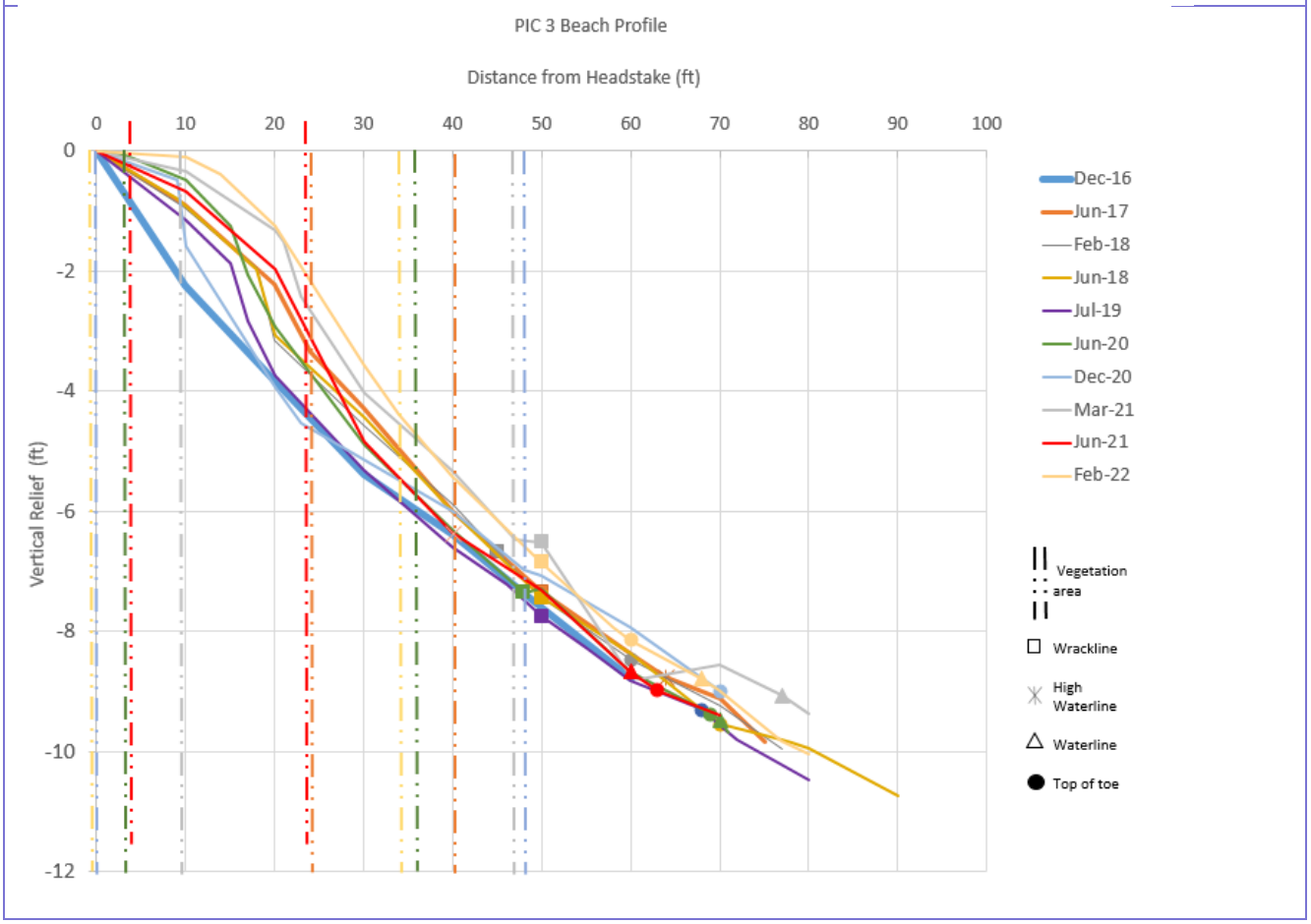



2020
2021
PIC 1
2017
2018
2021
PIC 2
2020
2021
PIC 3

PIC Beach Profiles




PIC 2 Beach Profile
Distance from Headstake (ft)
Vertical Relief (ft)
0
10
20
30
40
50
60
70
80
0
-2
-4
-6
-8
-10
-12
Dec-16
Jun-17
Feb-18
Jun-18
Apr-20
Jun-20
Dec-20
Mar-21
Jun-21
Feb-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


PIC 3 Beach Profile
Distance from Headstake (ft)
Vertical Relief (ft)
0
10
20
30
40
50
60
70
80
90
100
0
-2
-4
-6
-8
-10
-12
Dec-16
Jun-17
Feb-18
Jun-18
Jul-19
Jun-20
Dec-20
Mar-21
Jun-21
Feb-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Hopwood

Adjacent to the Chalan Kanoa reef at a distance of approximately 500 meters, the Hopwood shoreline is subjected to 100-year flood and additional velocity hazard (wave action). An account from a resident suggests that this shoreline has experienced accretion since the mid-1900s. Thus, the vegetation and sand in this area may be several decades old. Shoreline is susceptible to ***incidental erosion,*** in which the beach profile may be restored after erosion generated from an extreme storm event.

Flourishing vegetation line indicates how that ***storm surge*** has not reached the backshore during this period. The short width makes the shoreline susceptible to future sea level rise and the reach of storm surge. Wave overtopping and overwhelmed tidal flows from the channel down south may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. Under southwest conditions, longshore could potentially be going from south to north while north-northwest conditions indicate the opposite.

Hopwood 1 Highlights:

- ERODING with a Wrackline that ranges 22 – 41 ft and an elevation difference of 6 ft
- Shoreline erosion and dynamic vegetation line are direct impacts from storm surge.
- Nearby outfall has influence on ***sediment transport.***

Hopwood 2 Highlights:

- ERODING in the long-term with a Wrackline that ranges 16 – 30 ft with an elevation difference of 5.5 ft
- Dec-16 through Aug-17 was the initial headstake until it went undetected after a storm event. Dec 2020 record is an outlier from surveyor error.

Hopwood 3 Highlights:

- DYNAMIC that ranges 27 – 47 ft and an elevation difference of 7 ft
- Variation in entries are influenced by the outfall north of the headstake.

2022

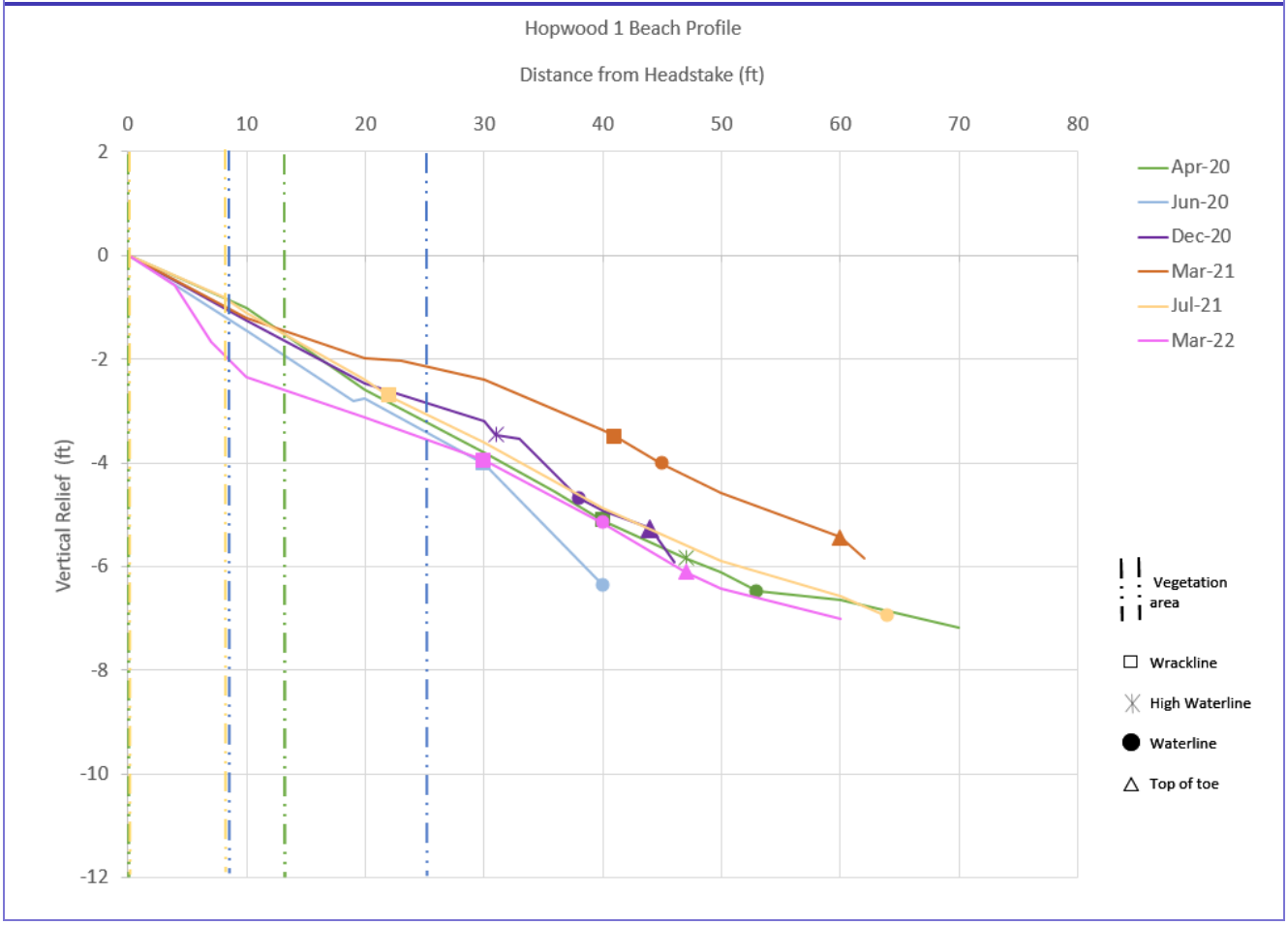
Hopwood 2

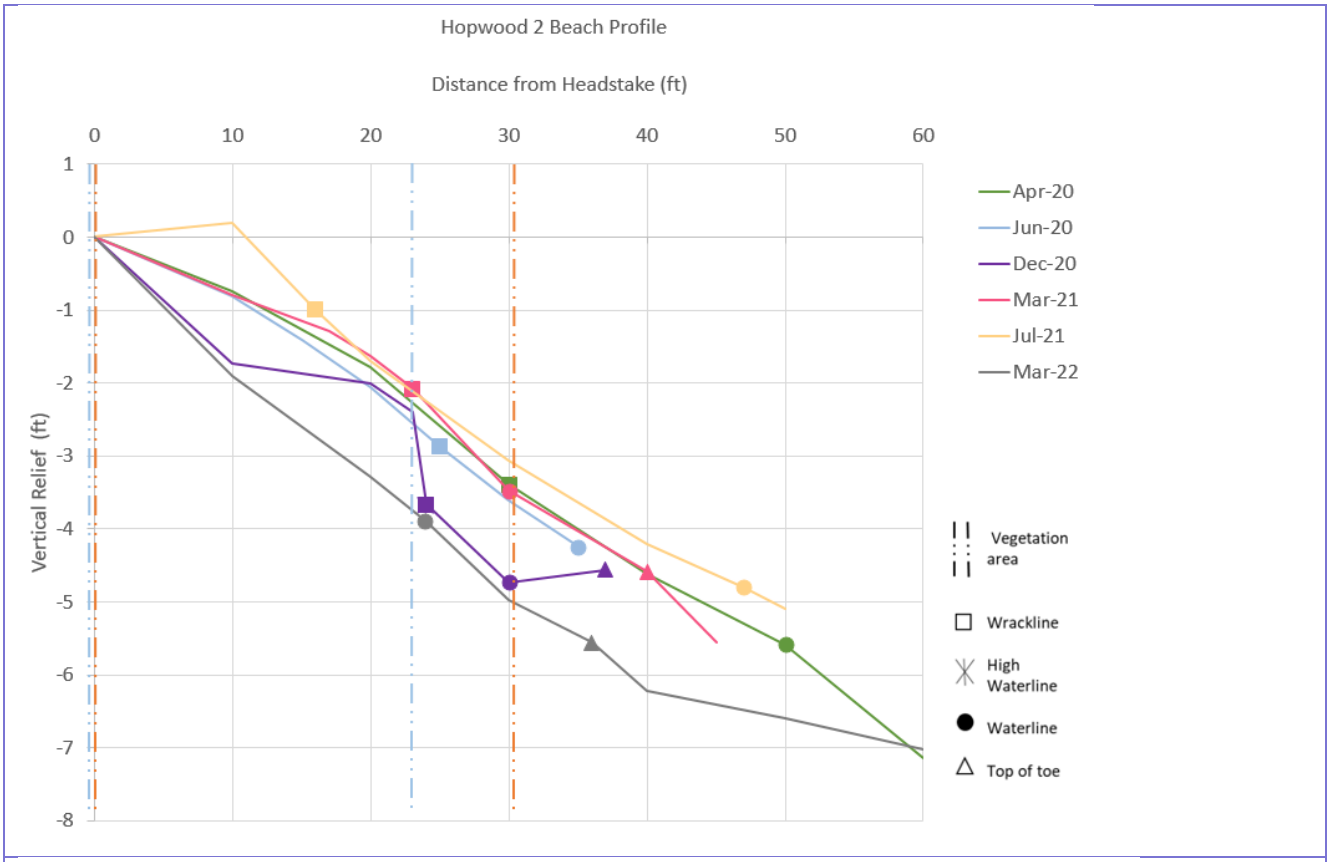
2022

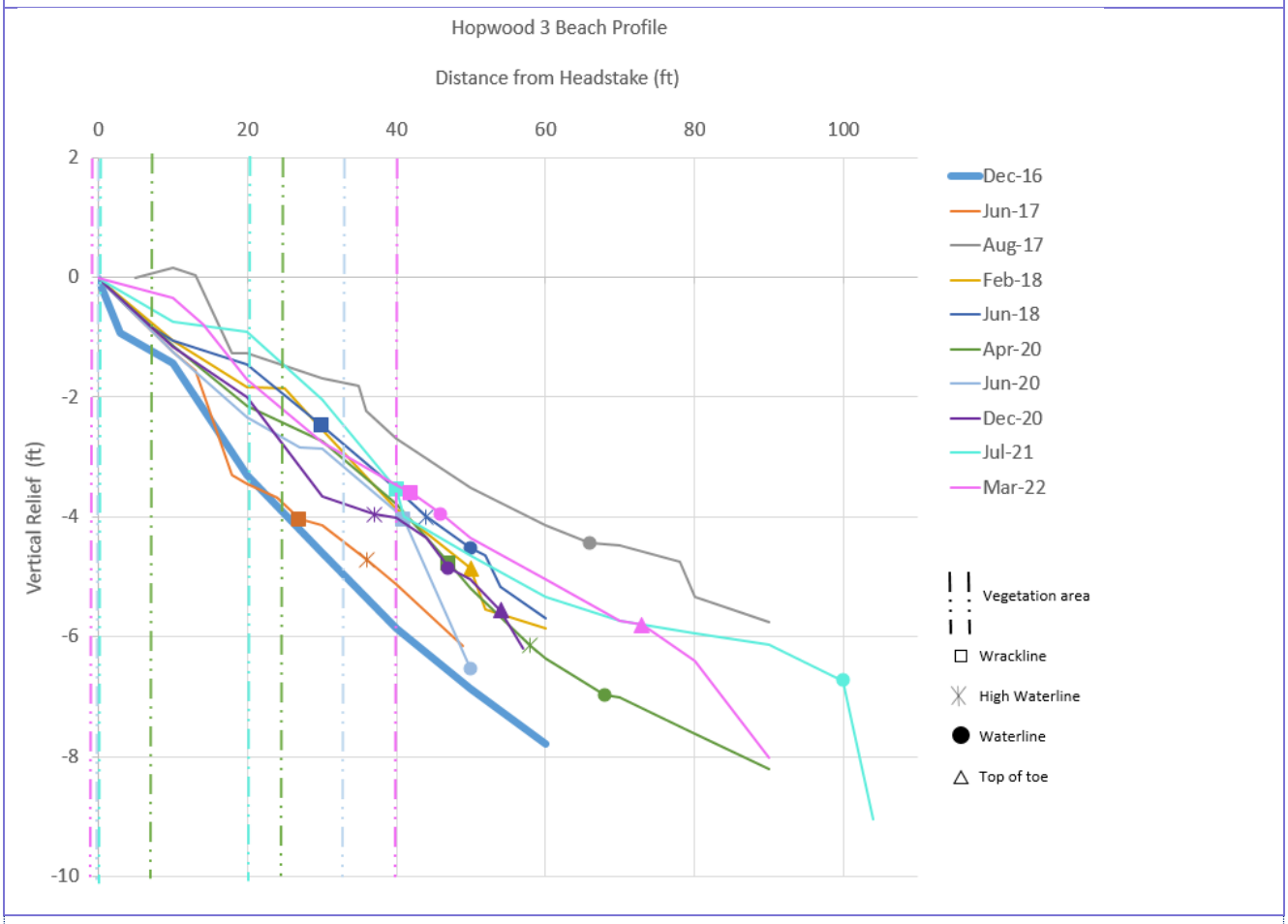
Hopwood 3

Hopwood Beach Profiles

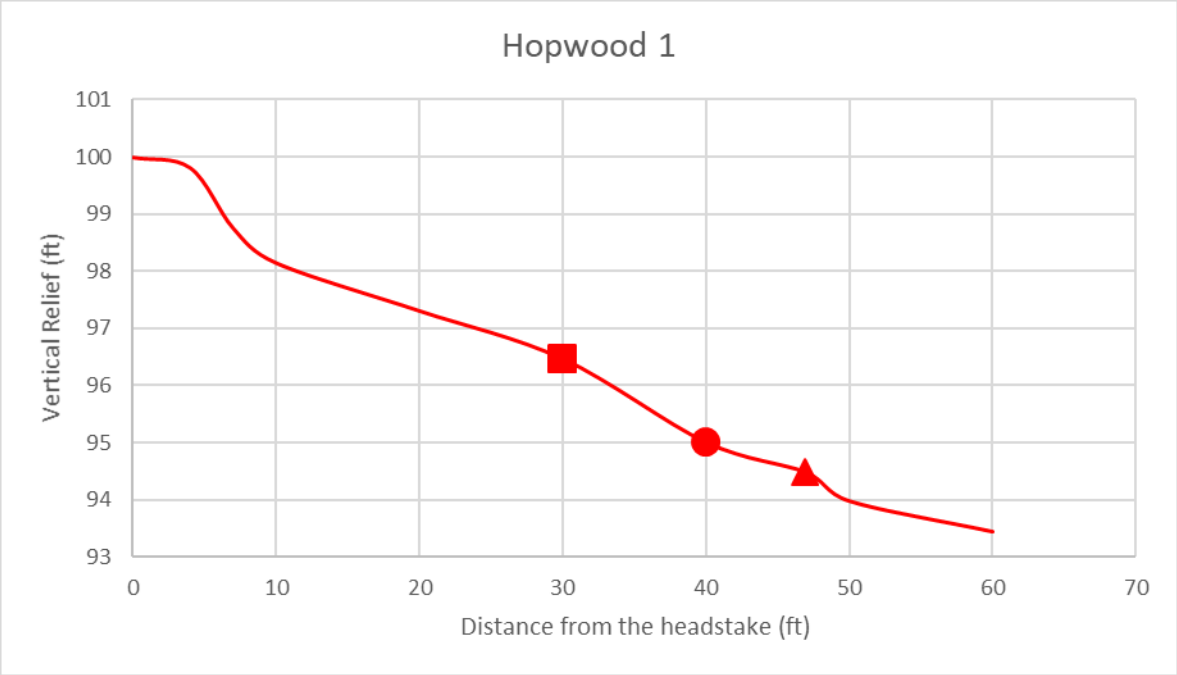
Berger Level

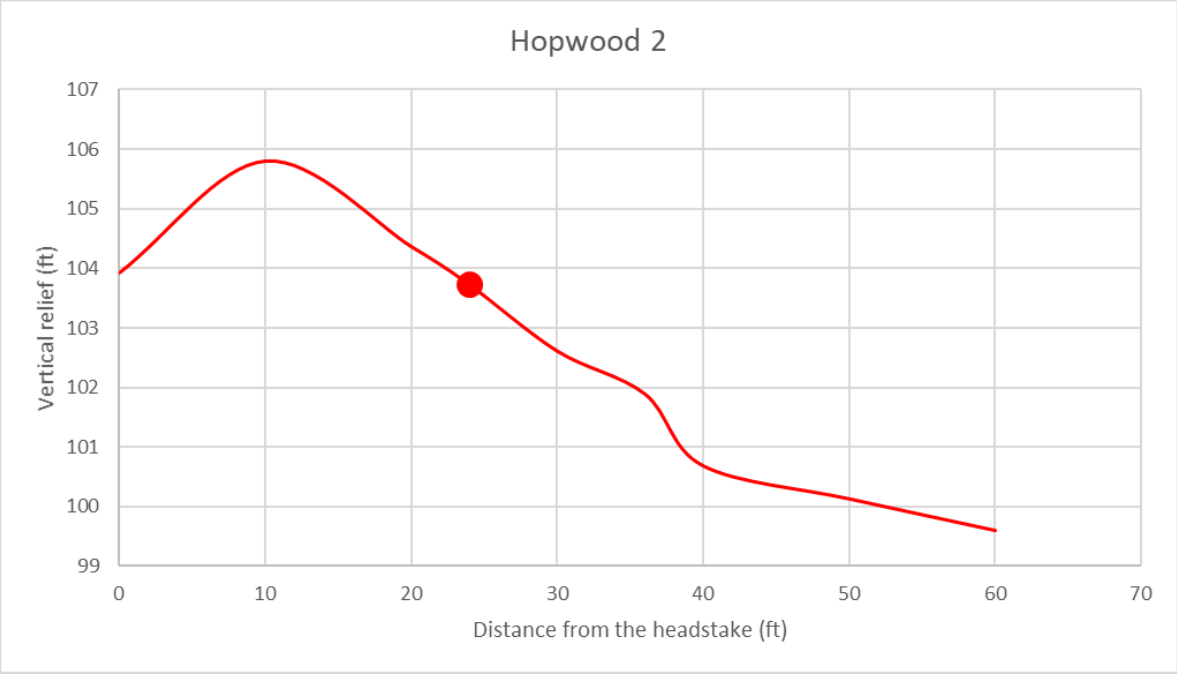


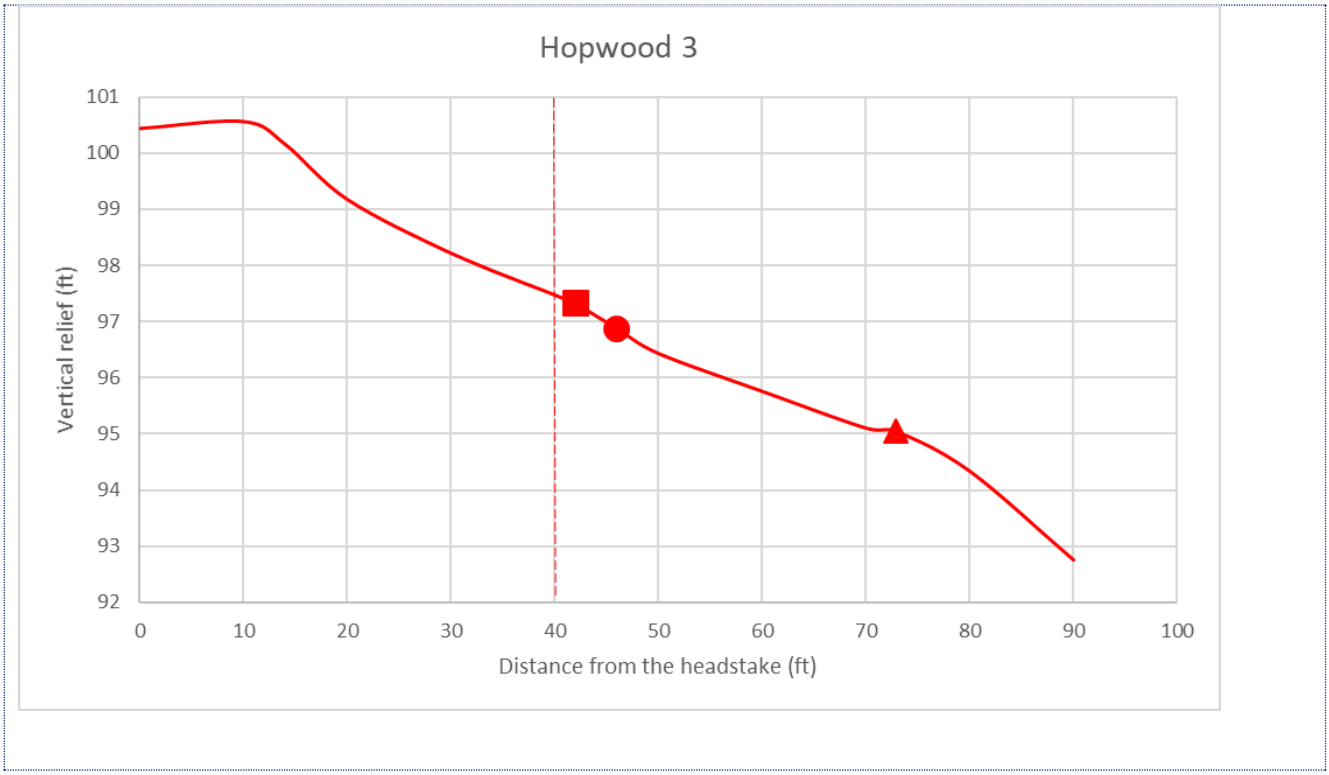

Hopwood 2 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
1
0
-1
-2
-3
-4
-5
-6
-7
-8
Vertical Relief (ft)
Apr-20
Jun-20
Dec-20
Mar-21
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Hopwood 3 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
2
0
-2
-4
-6
-8
-10
Vertical Relief (ft)
Dec-16
Jun-17
Aug-17
Feb-18
Jun-18
Apr-20
Jun-20
Dec-20
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station






Hopwood 3
Vertical relief (ft)
101
100
99
98
97
96
95
94
93
92
0
10
20
30
40
50
60
70
80
90
100
Distance from the headstake (ft)

Aquarius

Aquarius is parallel to the Chalan Kanoa channel, which greatly influences movement though the flow in and out of the southern lagoon. The nearby sand bar indicates the active sediment transport in this area during higher wave conditions. Dependent on their direction and strength, waves have the ability to pull sand into the water and push sand back up to shore. The gentle northeast winter trade winds have been observed to push sand up into the shore.

This shoreline appears to be temporarily accreting, yet vehicular access of the berm has compacted the sandy backshore. A few years ago, small scale beach nourishment increased the width of the shoreline.

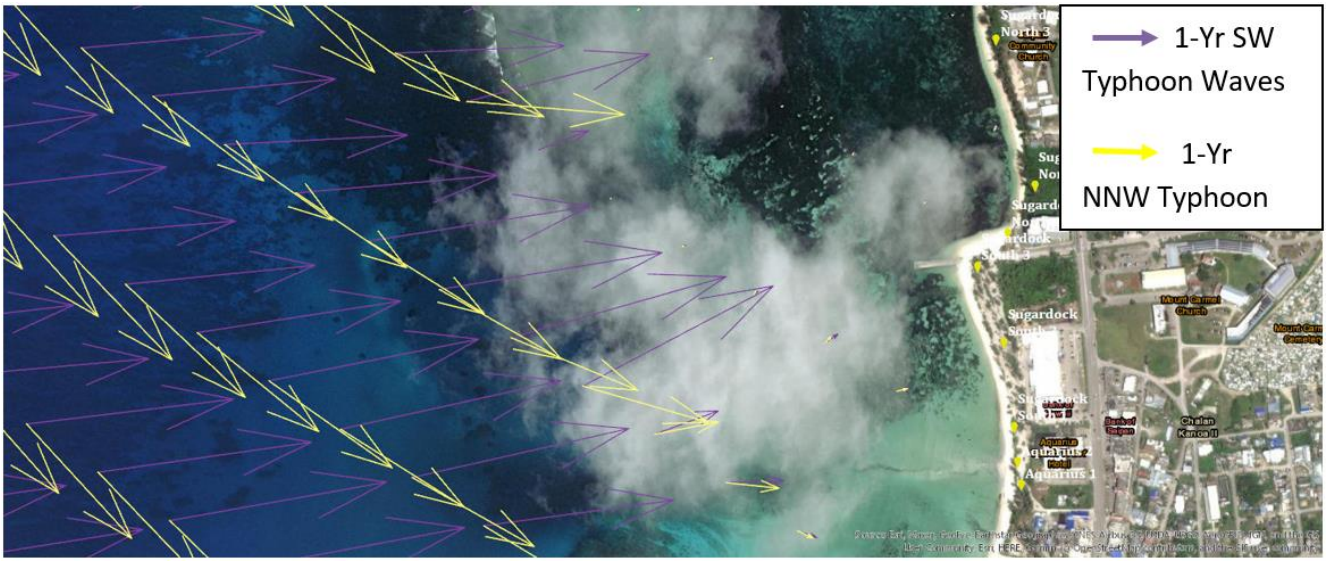
Overwhelming tidal flows from the channel down south may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. Under southwest conditions, longshore could potentially be going from south to north while north-northwest conditions indicate the opposite.

Aquarius 1 Highlights:

- STABLE with a Wrackline that ranges 35 – 48 ft and an elevation difference of 9 ft
- Nearby outfall down south has influence on sediment transport.

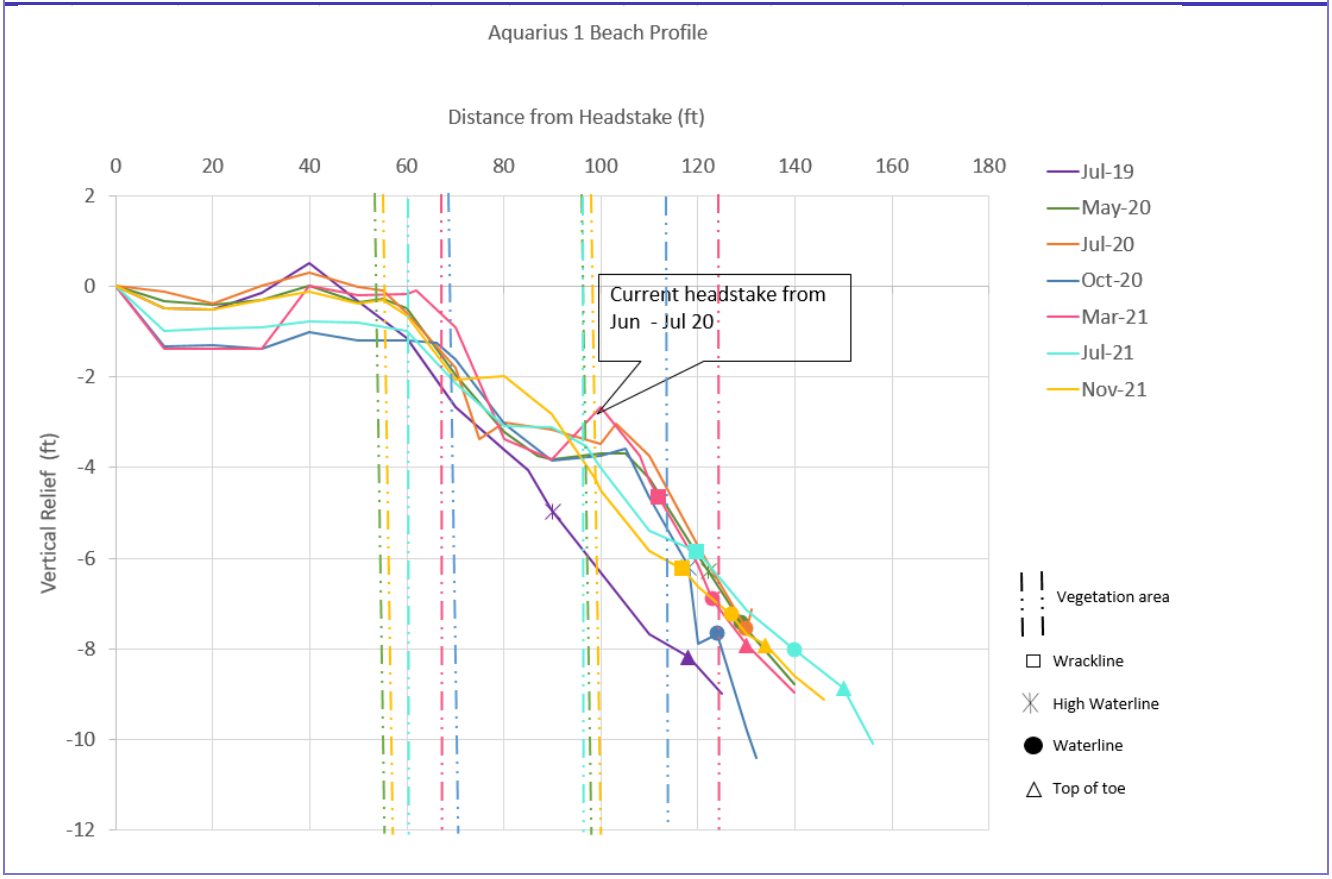
Aquarius 2 Highlights:

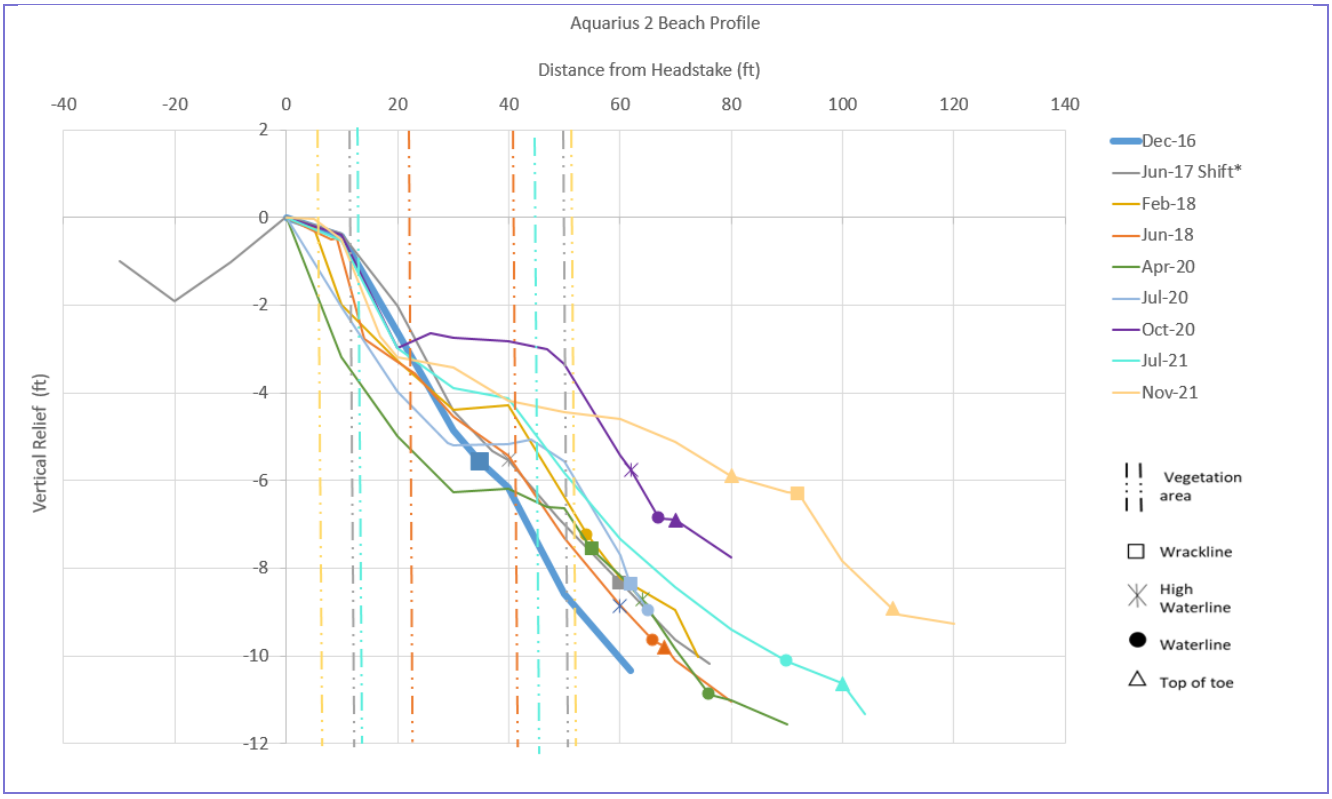
- ACCRETING in the short-term; STABLE in the long-term
- Wrackline that ranges 35 – 92 ft with an elevation difference of 10 ft
- Short-term erosion events have occurred. The sand bar could influence this dynamic behavior, suggesting that sand is pushed during typical winter conditions and pulled during typhoon conditions.



Aquarius Beach Profiles

Berger Level




Aquarius 2 Beach Profile
Distance from Headstake (ft)
-40
-20
0
20
40
60
80
100
120
140
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Dec-16
Jun-17 Shift*
Feb-18
Jun-18
Apr-20
Jul-20
Oct-20
Jul-21
Nov-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Sugar Dock

Parallel to the Chalan Kanoa Reef, Sugar Dock shoreline is generally eroding. The Chalan Kanoa Channel is adjacent to the southern portion. Obstruction of sediment transport from the dock infrastructure is the largest anthropogenic influence. The accumulation on the northern side of the dock poses a public access issue for boaters since the water depth is not suitable for unloading. Dredging remains of interest and is in planning stage.

The northern transects have less of a berm. Critical infrastructure, such as Saipan Community School and Church and the Tasi Homes, are located on the backshore. Overwhelmed tidal flows from the channel down south may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. Under southwest conditions, longshore could potentially be going from south to north while north-northwest conditions indicate the opposite.

Sugar Dock South has a variable trend while Sugar Dock North has a long-term erosion trend.

Sugar Dock South 1 Highlights:

- ACCRETING from Dec 2016 to Feb 2018 then June 2021 to Nov 2021
- ERODING from Feb 2018 to Dec 2019 then October 2020 to current
- Wrackline that ranges 30 – 70 ft with an elevation difference of 9 ft
- Short-term erosion and accretion events define this profile. The sand bar could influence this dynamic behavior, suggesting that sand is pushed during typical winter conditions and pulled during typhoon conditions.

Sugar Dock South 2 Highlights:

- ERODING with a Wrackline that ranges 17 – 60 ft with an elevation difference of 9 ft
- The berm has completely worn away, so the headstake (tree) is right when the slope begins to steadily drop into the waterline.

Sugar Dock South 3 Highlights:

- ACCRETING in the short-term since Oct 2020 with a Wrackline that ranges 30 – 59 ft and an ***elevation difference*** of 9 ft
- Vegetation line expanded indicating stability

Sugar Dock North 1 Highlights:

- ACCRETING with a Wrackline that ranges 44 – 54 ft with an elevation difference of 4.5 ft
- The dock infrastructure has enabled the accumulation of sand. Growing ironwood trees and morning glory indicate stability. Future dredging to recover proper function of the boating ramp is anticipated to greatly reduce this shoreline profile.

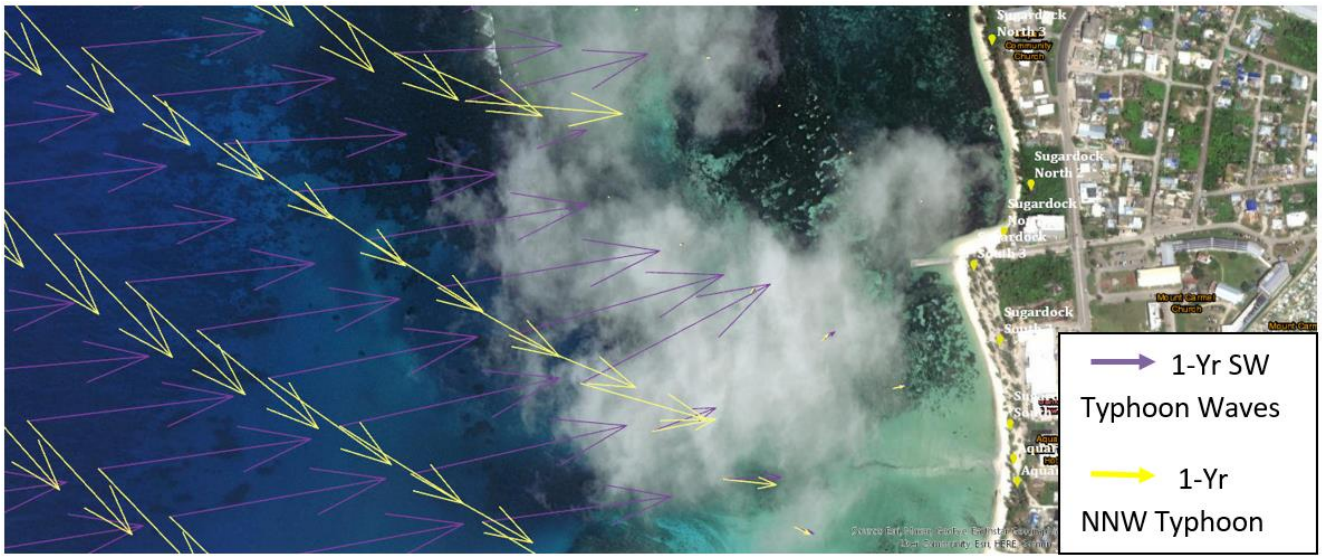
Sugar Dock North 2 Highlights:

- ERODING in the long-term with a Wrackline that ranges 50 – 66 ft with an elevation difference of 8 ft

- Abrasion from a previous storm is at 35 feet from the headstake

Sugar Dock North 3 Highlights:

- ERODING with a Wrackline that ranges 30 – 46 ft with an elevation difference of 8 ft
- Shoreline is getting steeper



Sugar Dock South 1

Sugar Dock South 2

Sugar Dock South 3

2019

2021

Sugar Dock North 1

2019

2021

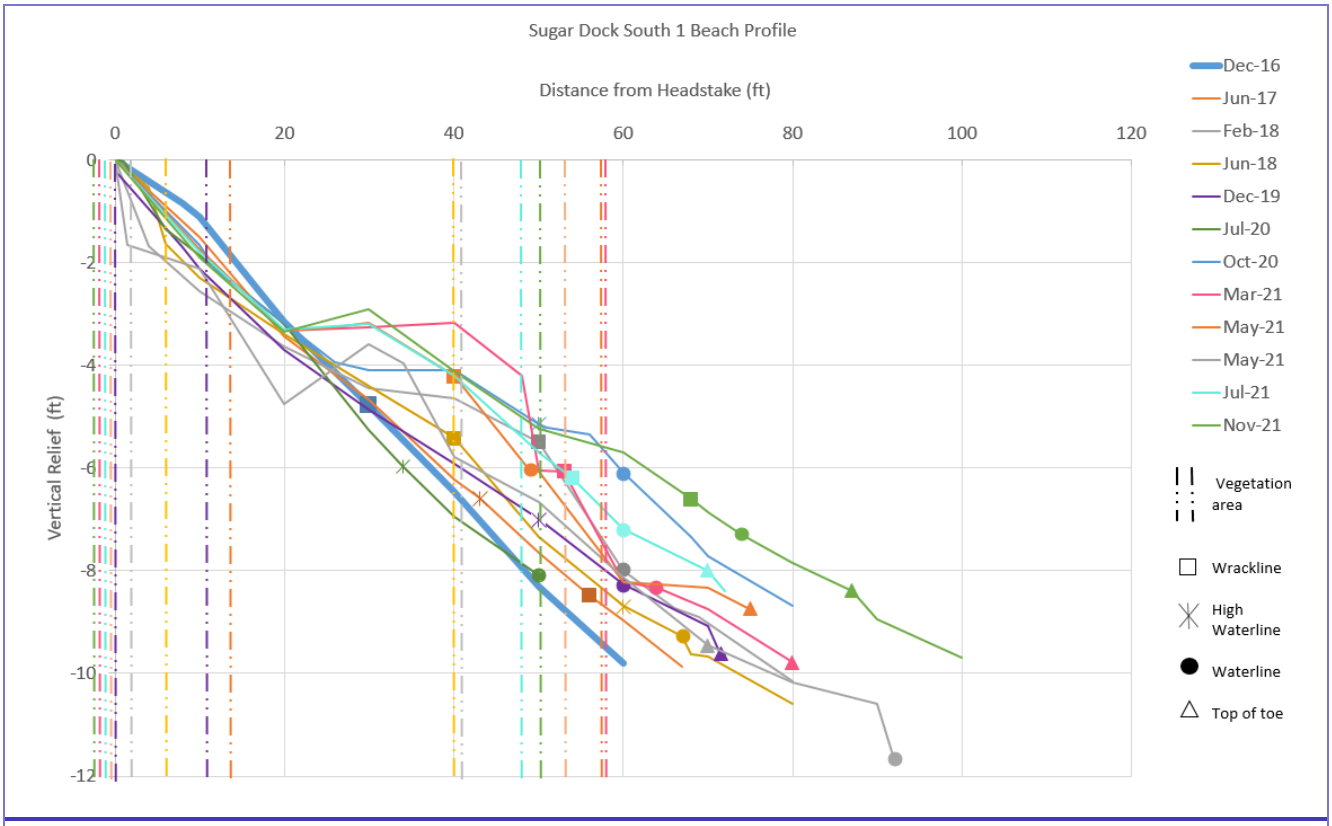
Sugar Dock North 2

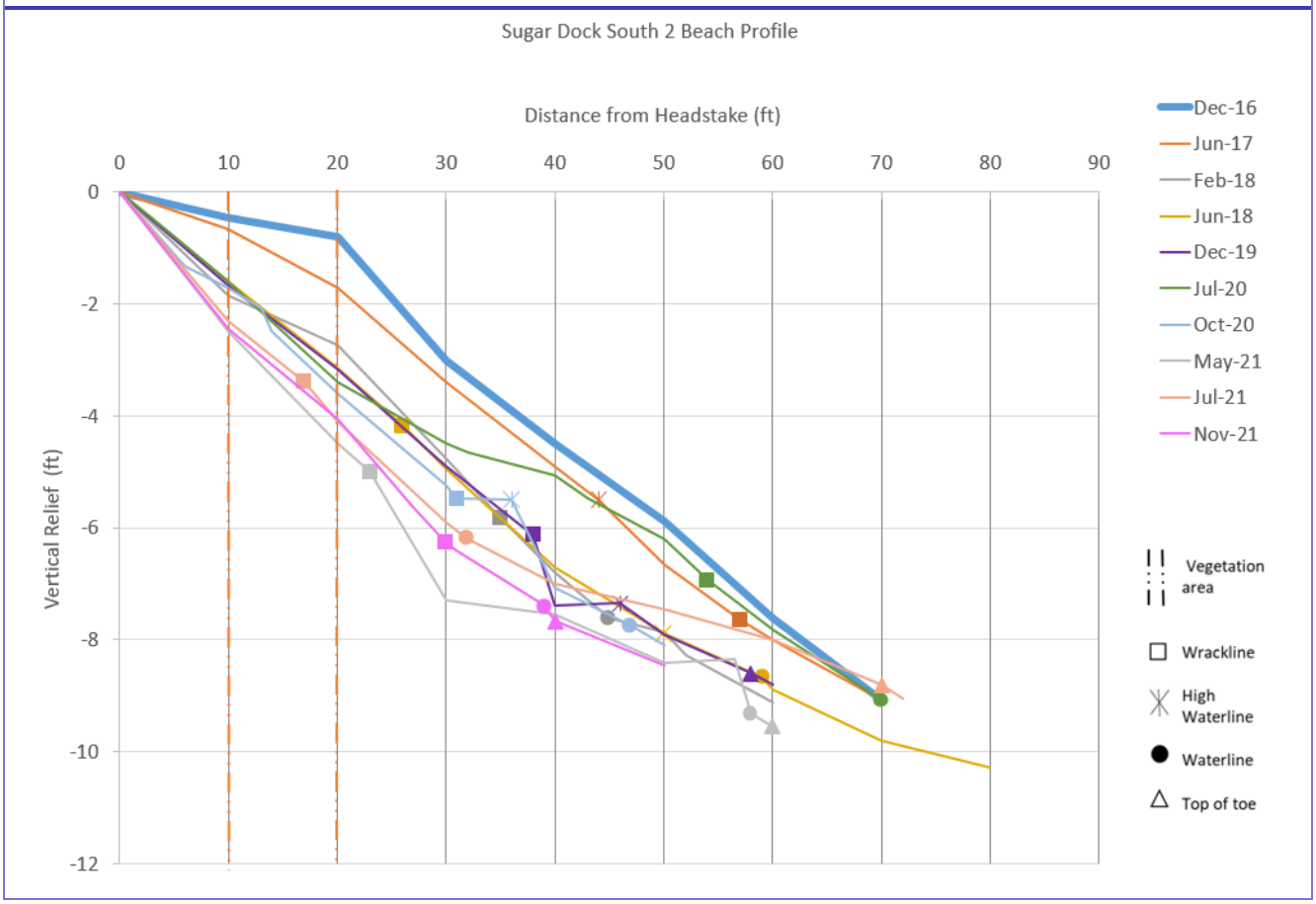
2019

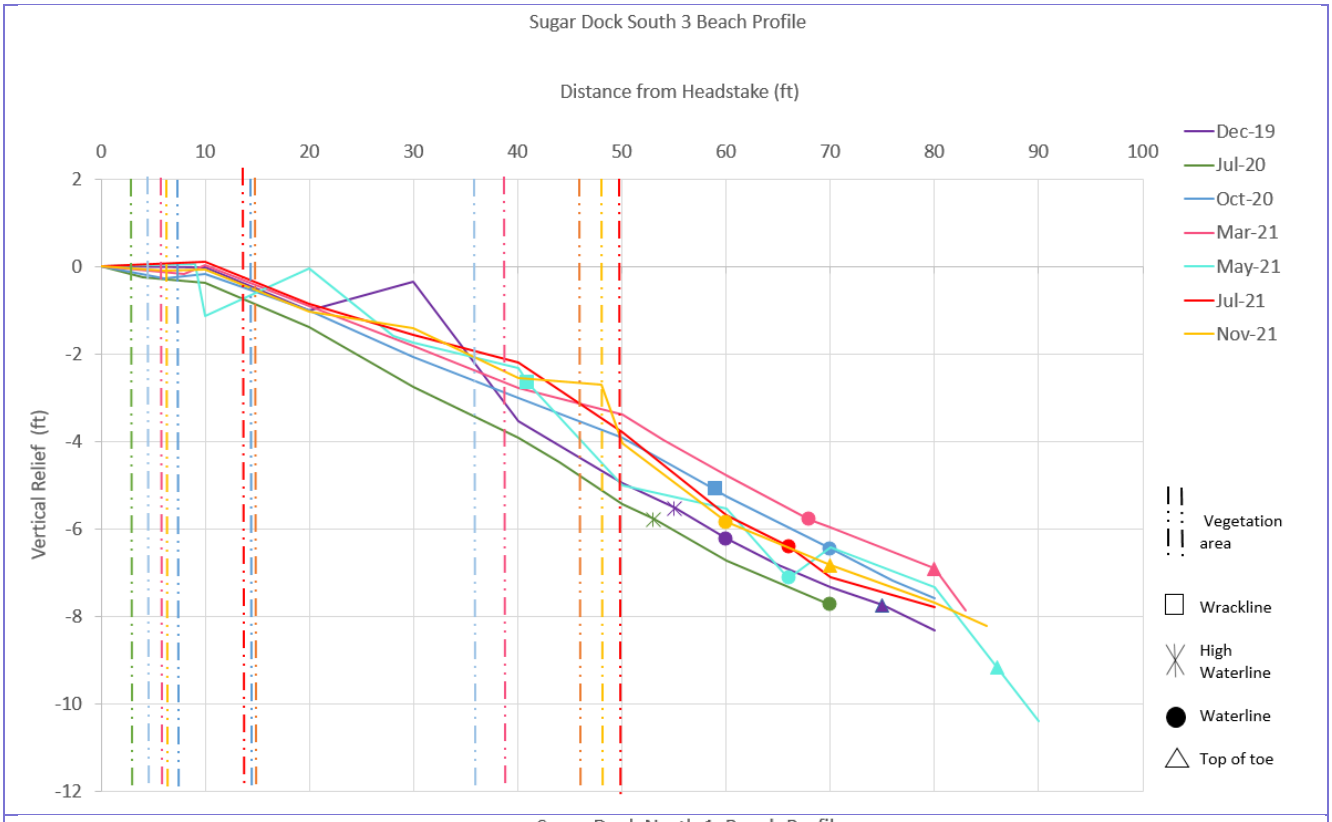
2021

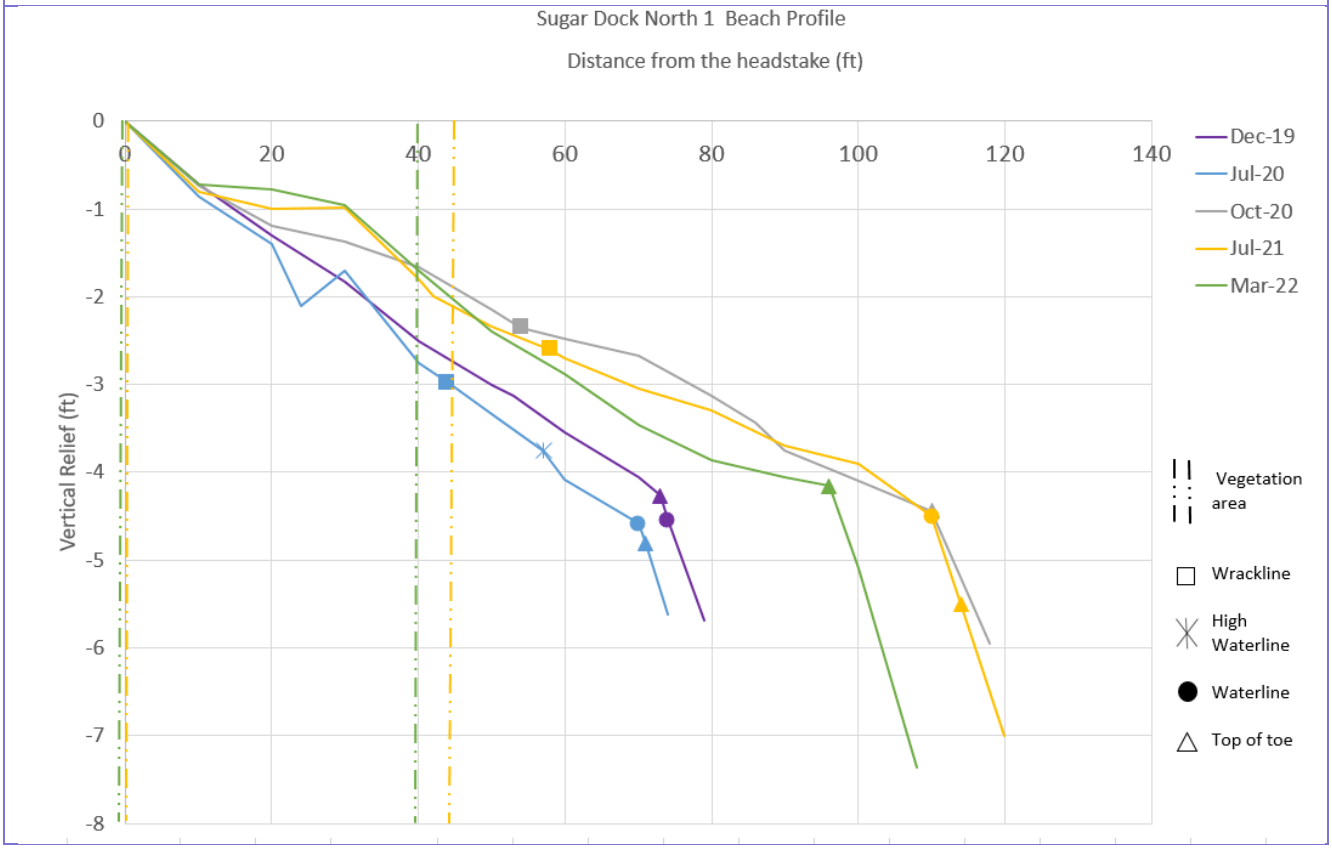
Sugar Dock North 3

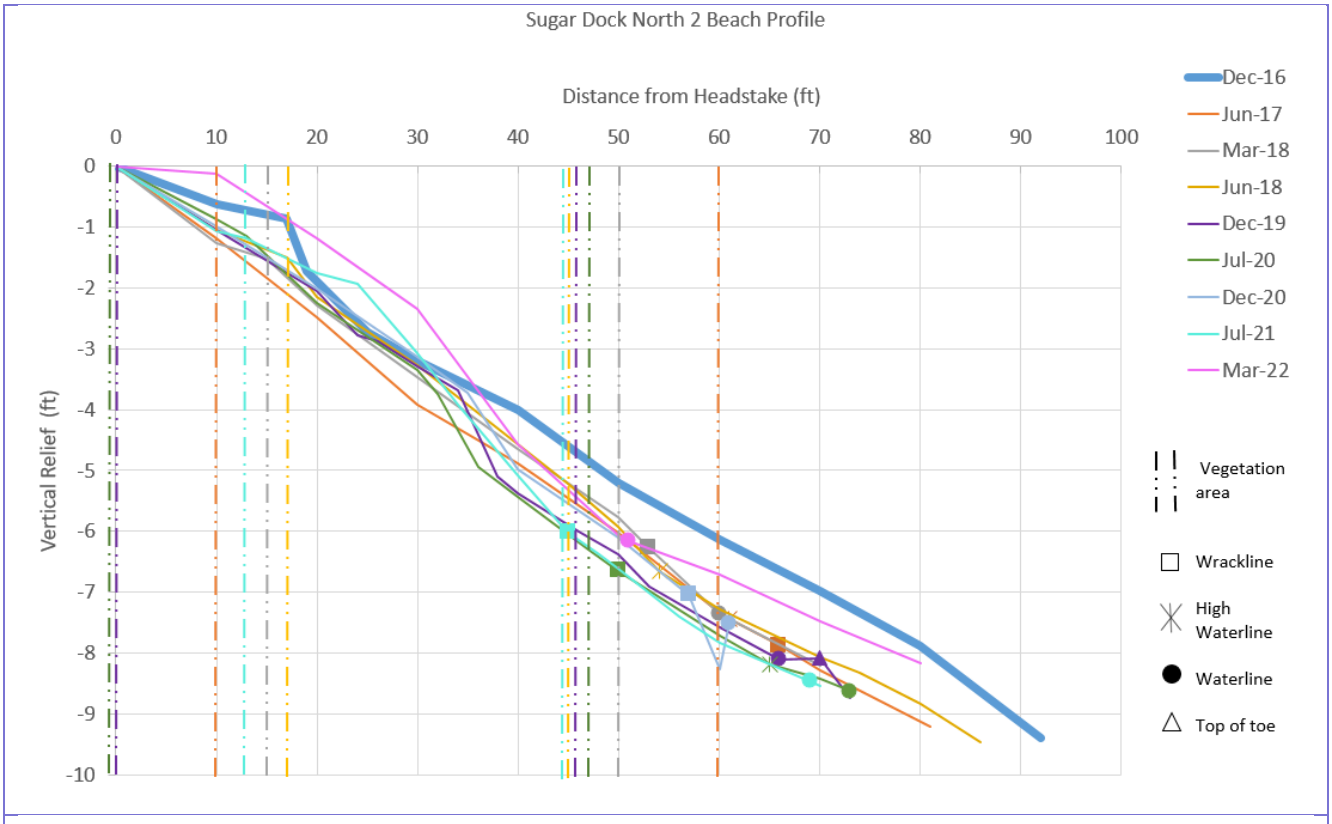
Sugar Dock Beach Profiles

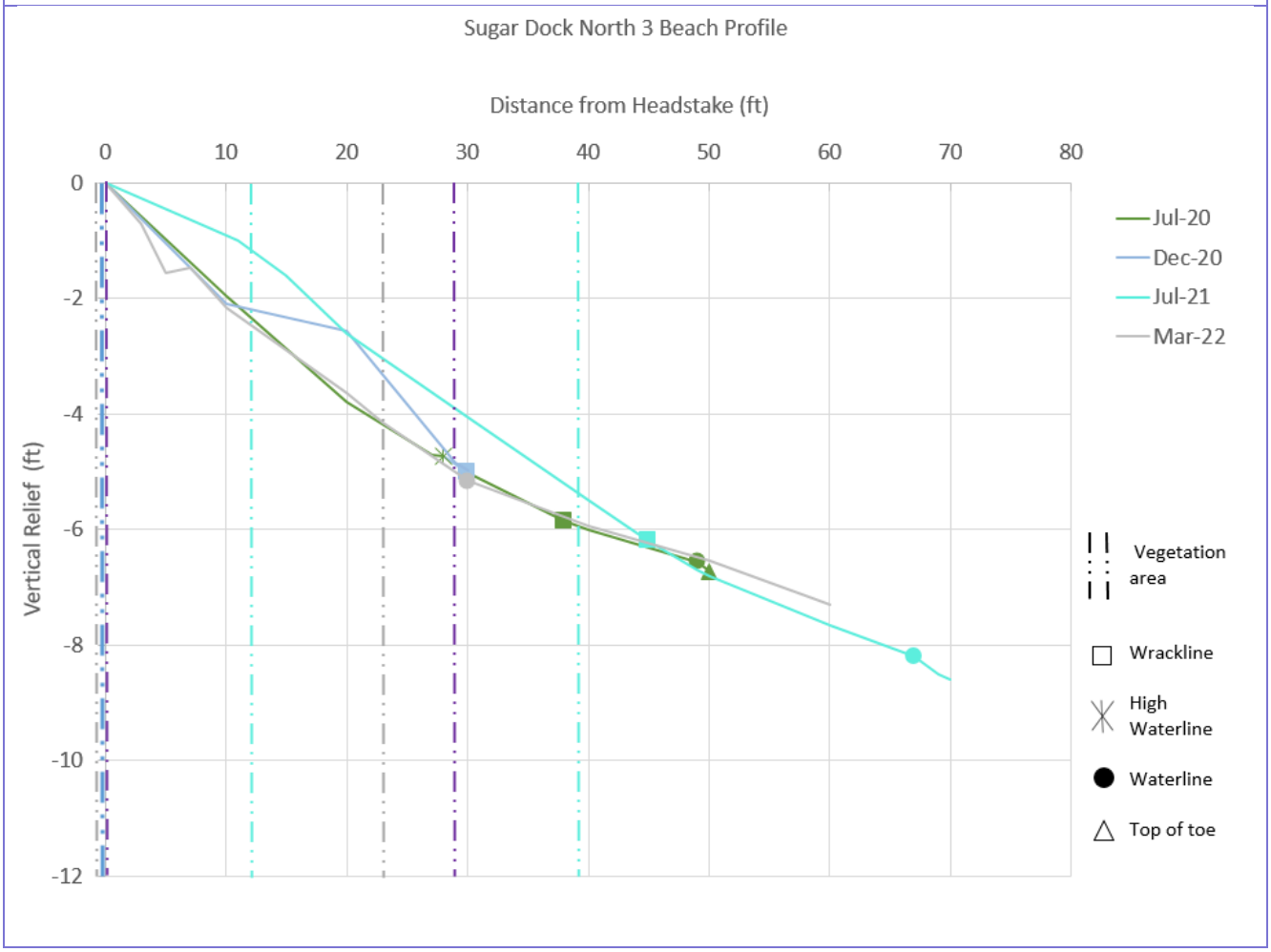




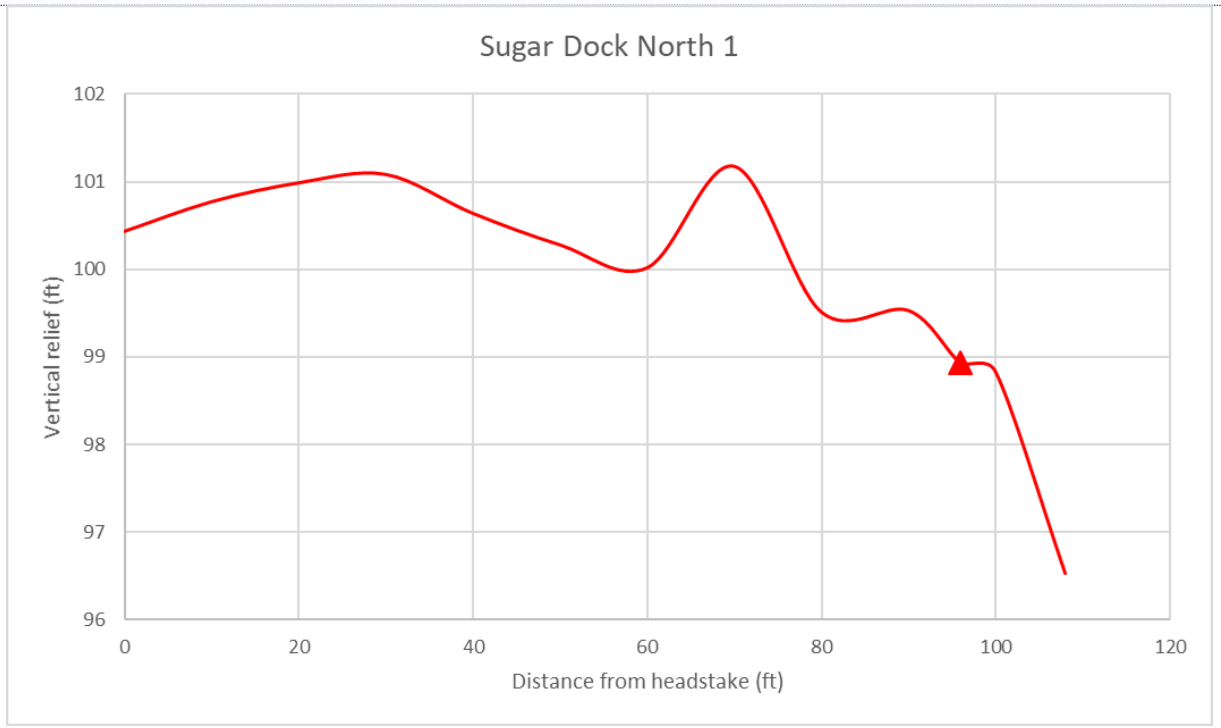

Sugar Dock South 3 Beach Profile
Distance from Headstake (ft)
Vertical Relief (ft)
0
10
20
30
40
50
60
70
80
90
100
2
0
-2
-4
-6
-8
-10
-12
Dec-19
Jul-20
Oct-20
Mar-21
May-21
Jul-21
Nov-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

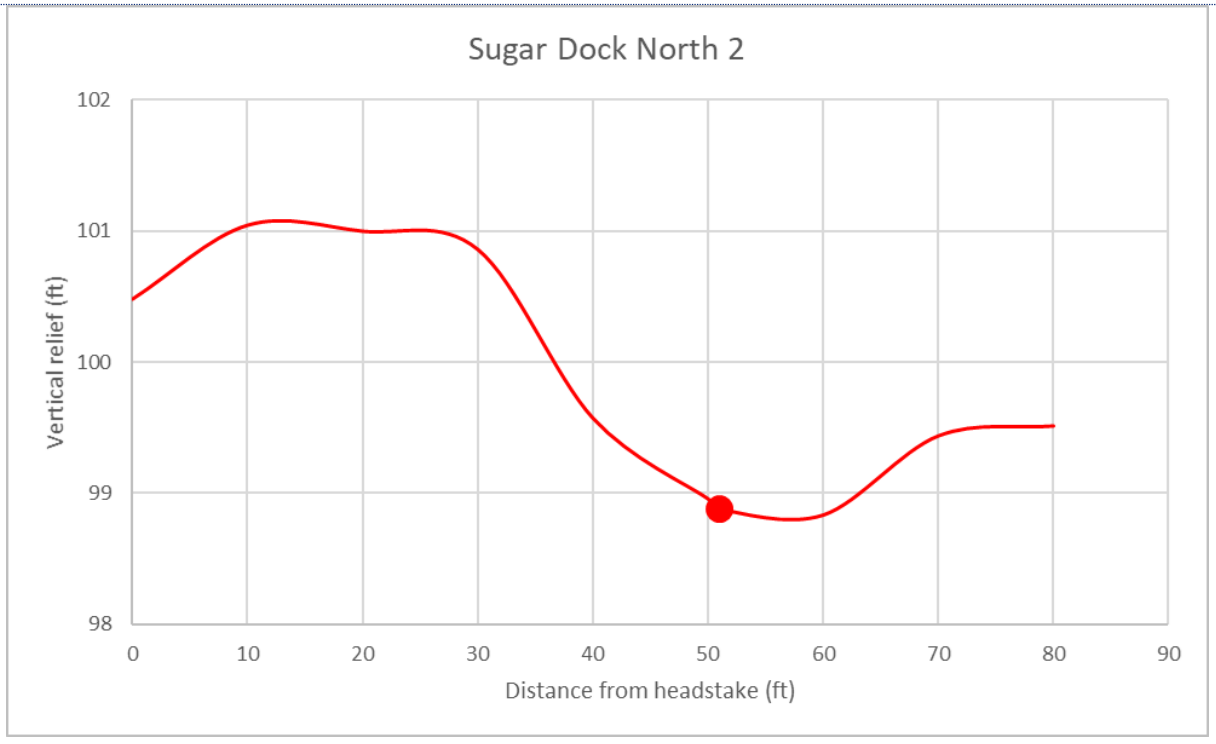

Sugar Dock North 1 Beach Profile
Distance from the headstake (ft)
Vertical Relief (ft)
0
20
40
60
80
100
120
140
0
-1
-2
-3
-4
-5
-6
-7
-8
Dec-19
Jul-20
Oct-20
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

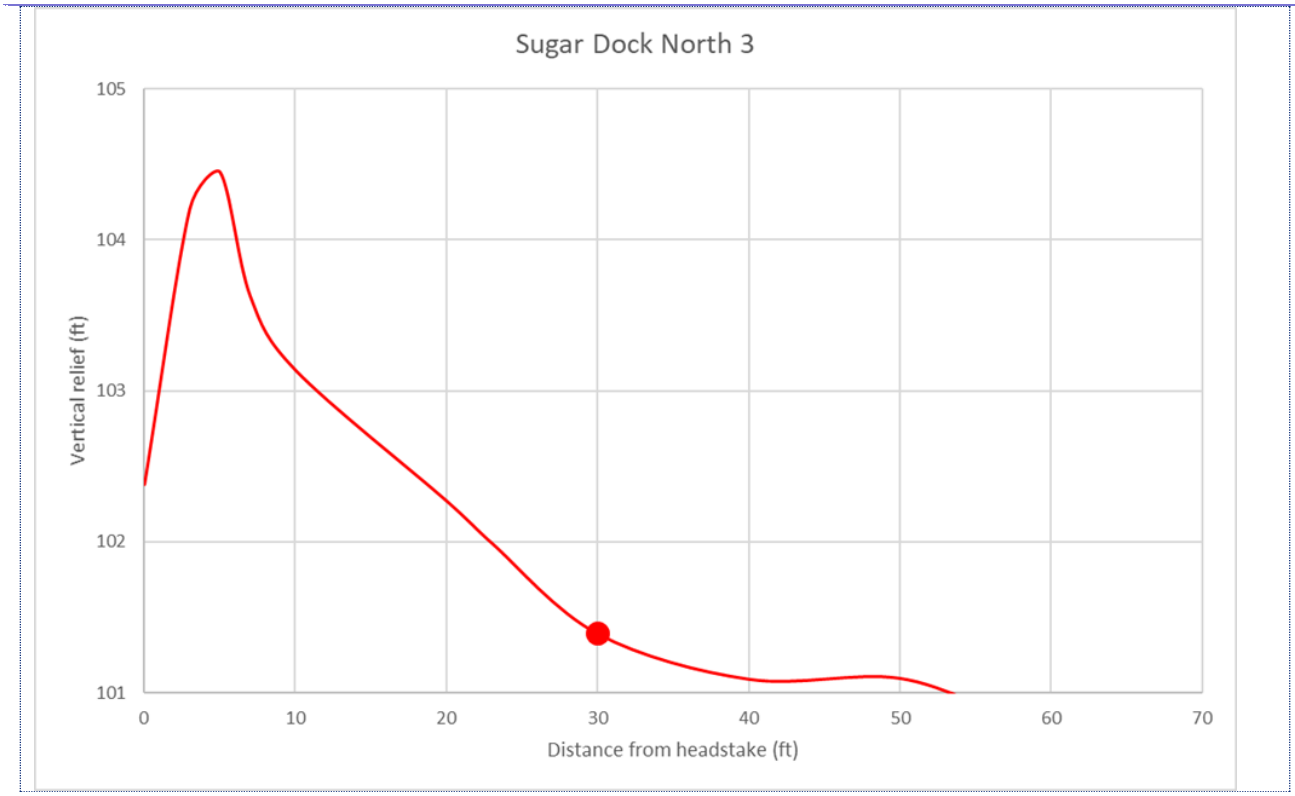

Sugar Dock North 2 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
100
Vertical Relief (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Dec-16
Jun-17
Mar-18
Jun-18
Dec-19
Jul-20
Dec-20
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Sugar Dock North 3 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
Vertical Relief (ft)
0
-2
-4
-6
-8
-10
-12
Jul-20
Dec-20
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station






Sugar Dock North 3
105
104
103
102
101
Vertical relief (ft)
0
10
20
30
40
50
60
70
Distance from headstake (ft)

Susupe Beach Park

Nearly 800 meters away from the sheltering Chalan Kanoa Reef, Susupe Beach Park is relatively stable but may be prone to storm surge. Backshore vegetation remains relatively stable and the ironwood trees appears to be thriving. Most of the foreshore environment is vegetated.

Previous restrictions to the beach park have been relaxed and uplifted in this reporting period. Wave overtopping and overwhelmed tidal flows may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. However, improved resolution on nearshore dynamics may explain longshore processes for this area.

Susupe Beach Park 1 Highlights:

- STABLE with a Wrackline that ranges 40 – 52 ft and an elevation difference of more than 8 ft

Susupe Beach Park 2 Highlights:

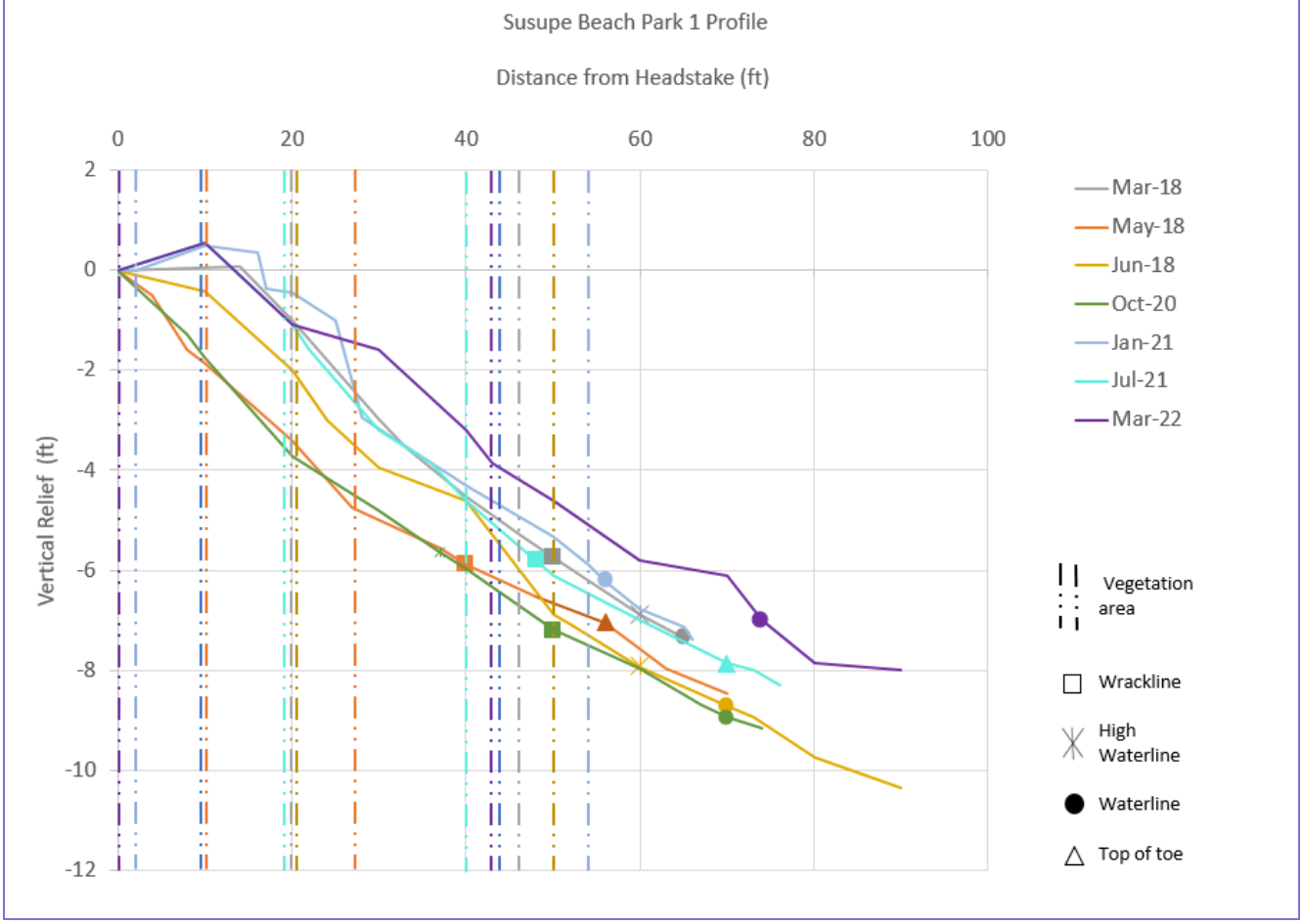
- STABLE with a Wrackline that ranges 47 – 70 ft and an elevation difference of more than 8 ft

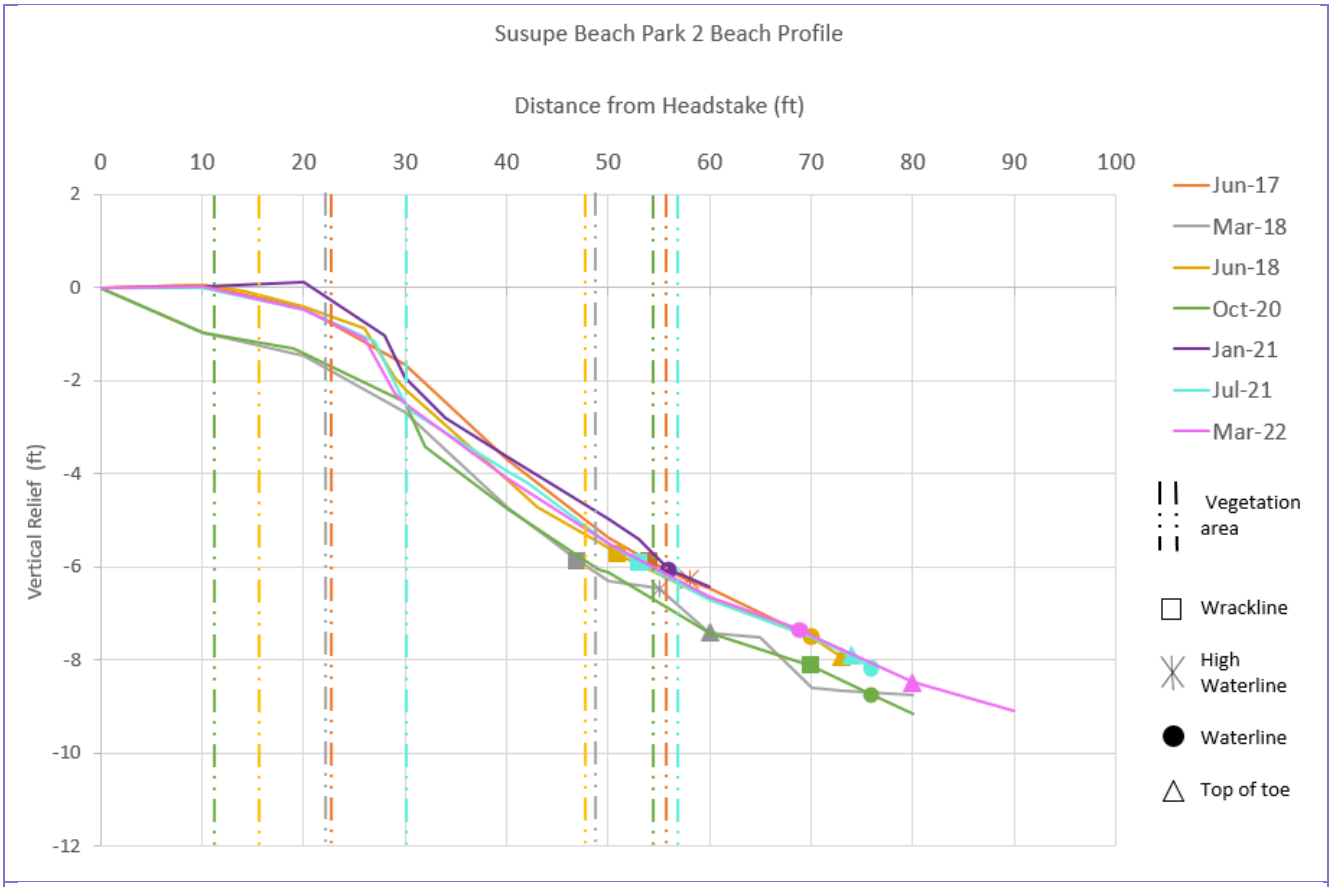
Susupe Beach Park 3 Highlights:

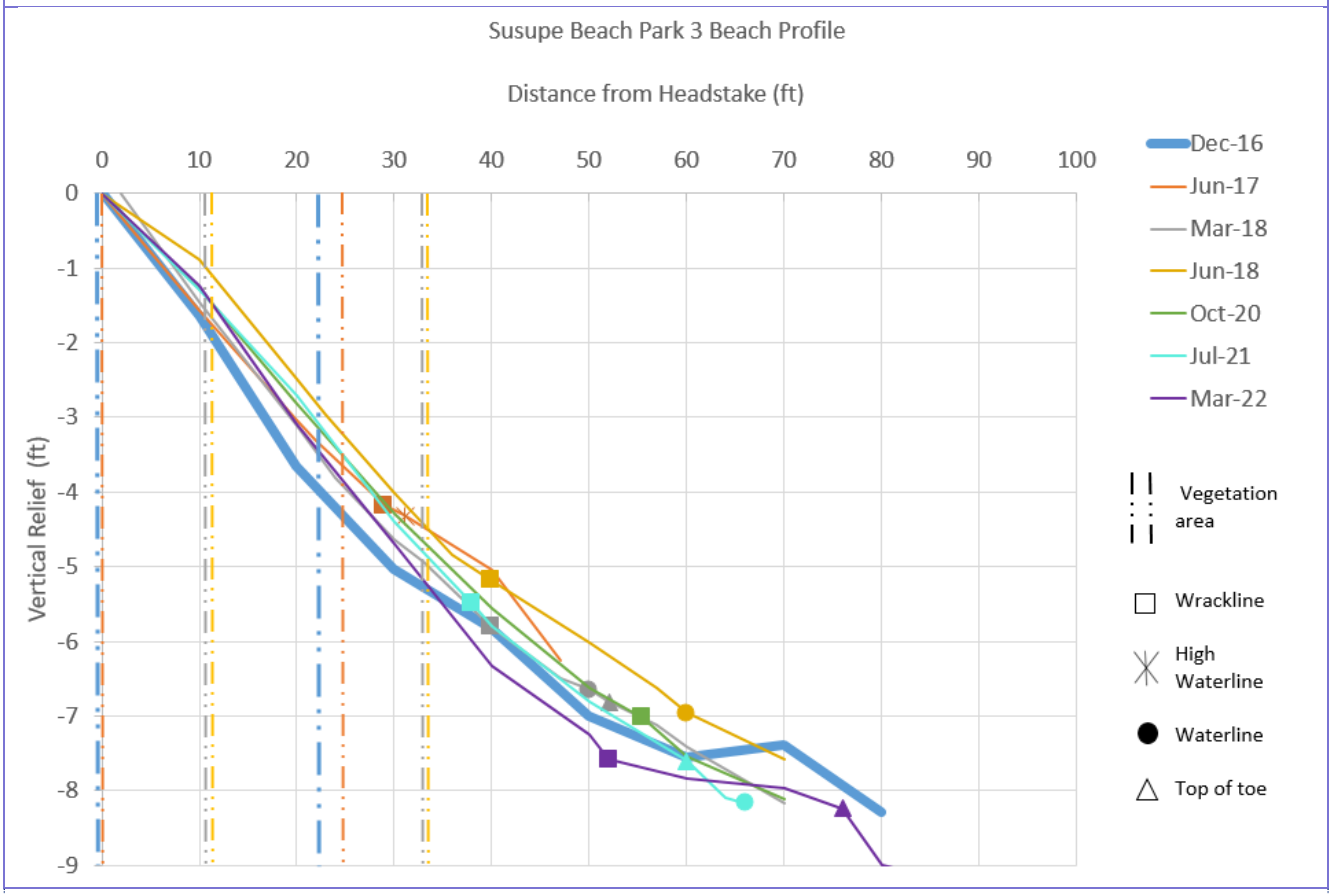
- STABLE with a Wrackline that ranges 29 – 50 ft and an elevation difference of 7 ft

Susupe Beach Park Beach Profiles

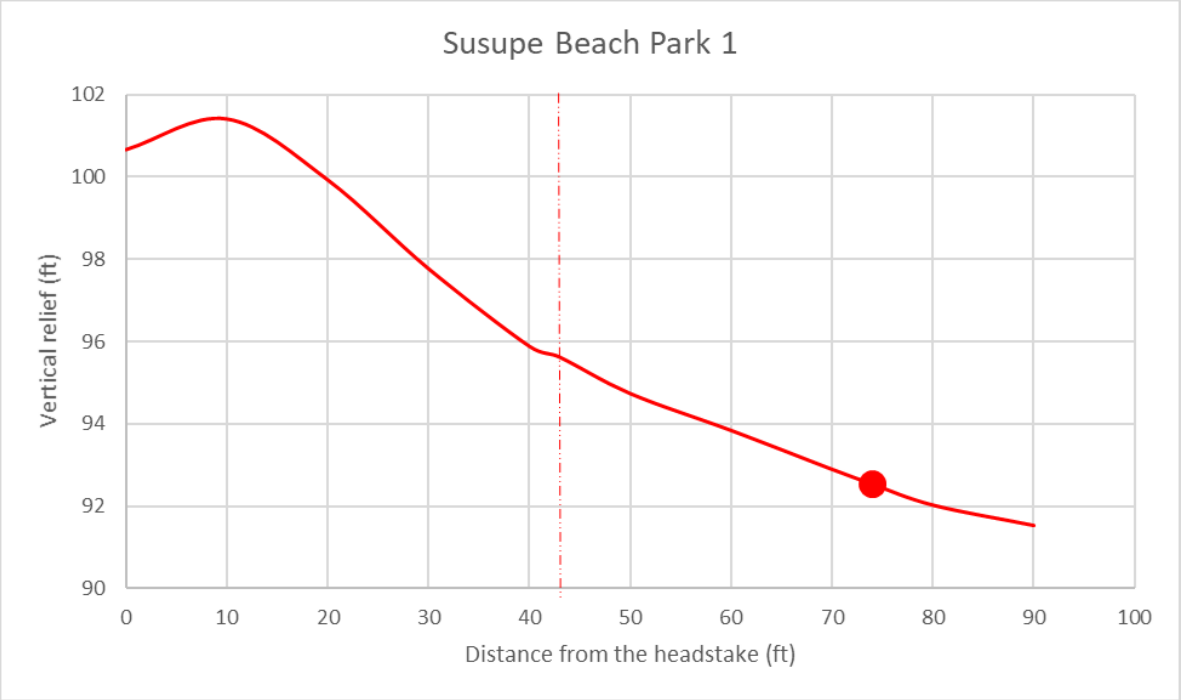
Berger Level

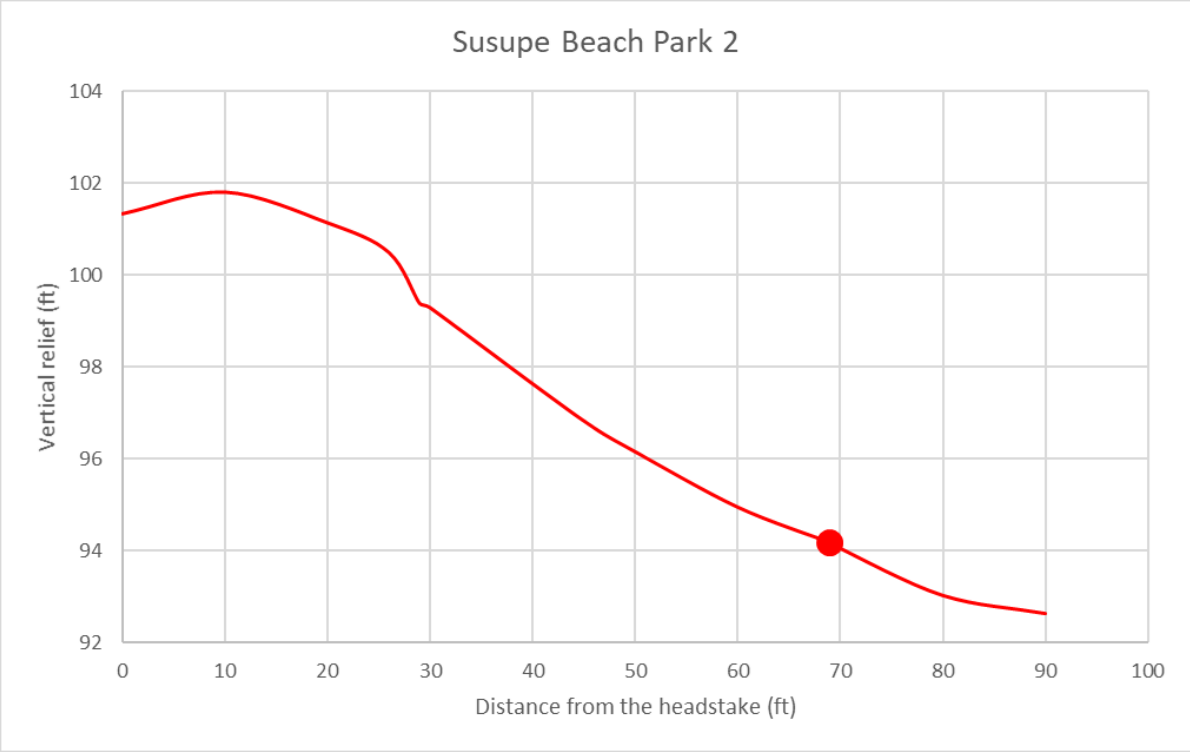


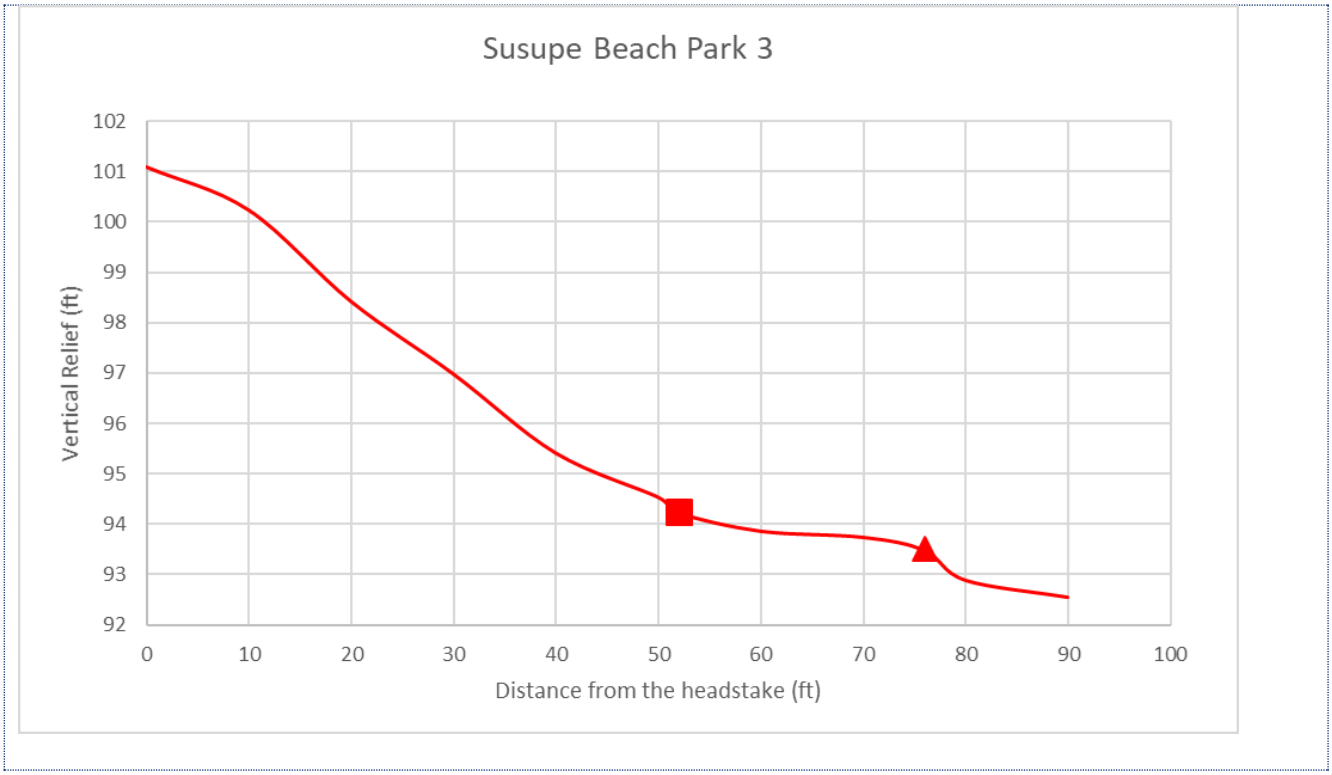

Susupe Beach Park 2 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
100
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Jun-17
Mar-18
Jun-18
Oct-20
Jan-21
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Susupe Beach Park 3 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
100
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Vertical Relief (ft)
Dec-16
Jun-17
Mar-18
Jun-18
Oct-20
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station






Susupe Beach Park 3
Vertical Relief (ft)
102
101
100
99
98
97
96
95
94
93
92
0
10
20
30
40
50
60
70
80
90
100
Distance from the headstake (ft)

Kilili

Kilili Beach is sheltered by the fringing reef, which is around 4,500 ft away. North side is accreting while the south side is relatively stable with the exception of Kilili South 1. In the beginning, it experienced erosion until it started stabilizing then accreting in 2019. This period saw erosion, but natural sediment input may rebuild lost beach.

An account from a cultural practitioner using this shoreline implies that this stretch of beach is at risk of storm surge during powerful storm events. It appears that southwest conditions could greatly impact this site. Kilili has noticeable variation from seasonal wave conditions. However, improved resolution on nearshore dynamics may explain longshore processes for this area.

Kilili South 1 Highlights:

- ERODING in the short-term with a Wrackline that ranges 26 – 35 feet with an elevation difference of 6 ft
- Short-term erosion events have occurred on June 2020 and then September 2021. This transect has shown beach recovery in between.

Kilili South 2 Highlights:

- ERODING in the short-term with a Wrackline that ranges 47 – 70 ft with an elevation difference of 8 ft
- The storm of September 2021 has eroded the shoreline. Slight variation on the berm could be from surveyor error.

Kilili South 3 Highlights:

- ERODING in the short-term with a Wrackline that ranges 42 – 55 ft and an ***elevation difference*** of 8 ft
- This shifting shoreline feature may suggest sediment entering and exiting the area.

Kilili North 1 Highlights:

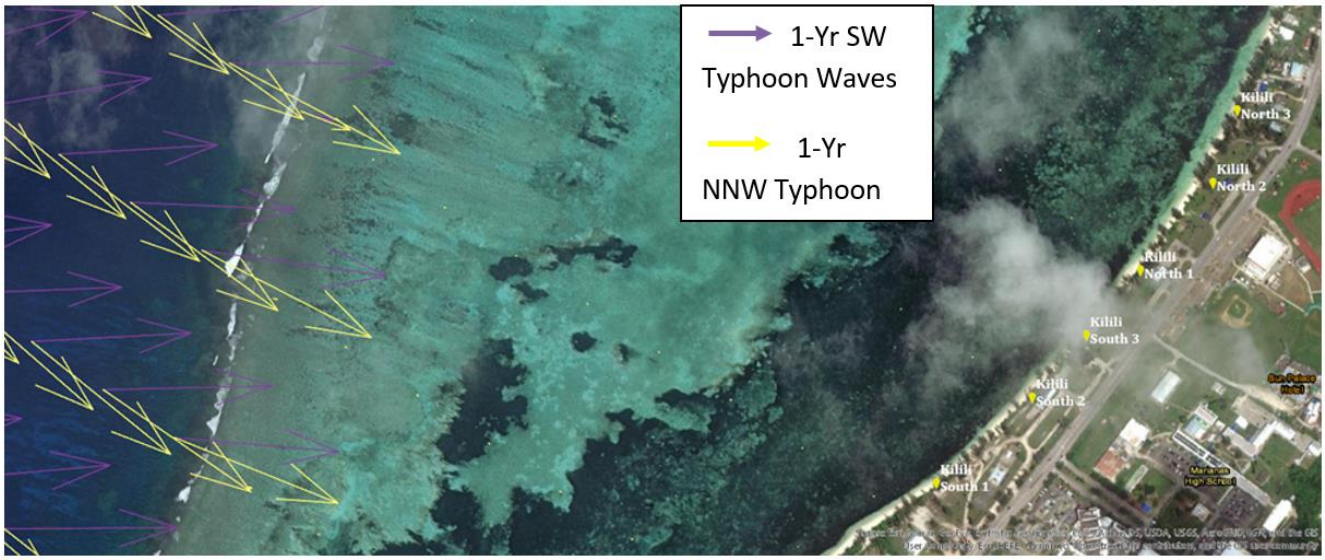
- ERODING with a Wrackline that ranges 44 – 128 ft with an elevation difference of 9 ft

Kilili North 2 Highlights:

- STABLE with a Wrackline that ranges 50 – 88 ft with an elevation difference of 8 ft
- There are discrepancies in the data caused by surveyor error. Given that the headstake is further inland, this profile is expected to be longer and indicates an estimation of the proximity to the high tide line, or wrackline, is from the pavilions.

Kilili North 3 Highlights:

- ERODING with a Wrackline that ranges 26 – 54 ft with an elevation difference of 8 ft



Kilili South 1

Kilili South 2

Kilili South 3

Kilili North 1

2021

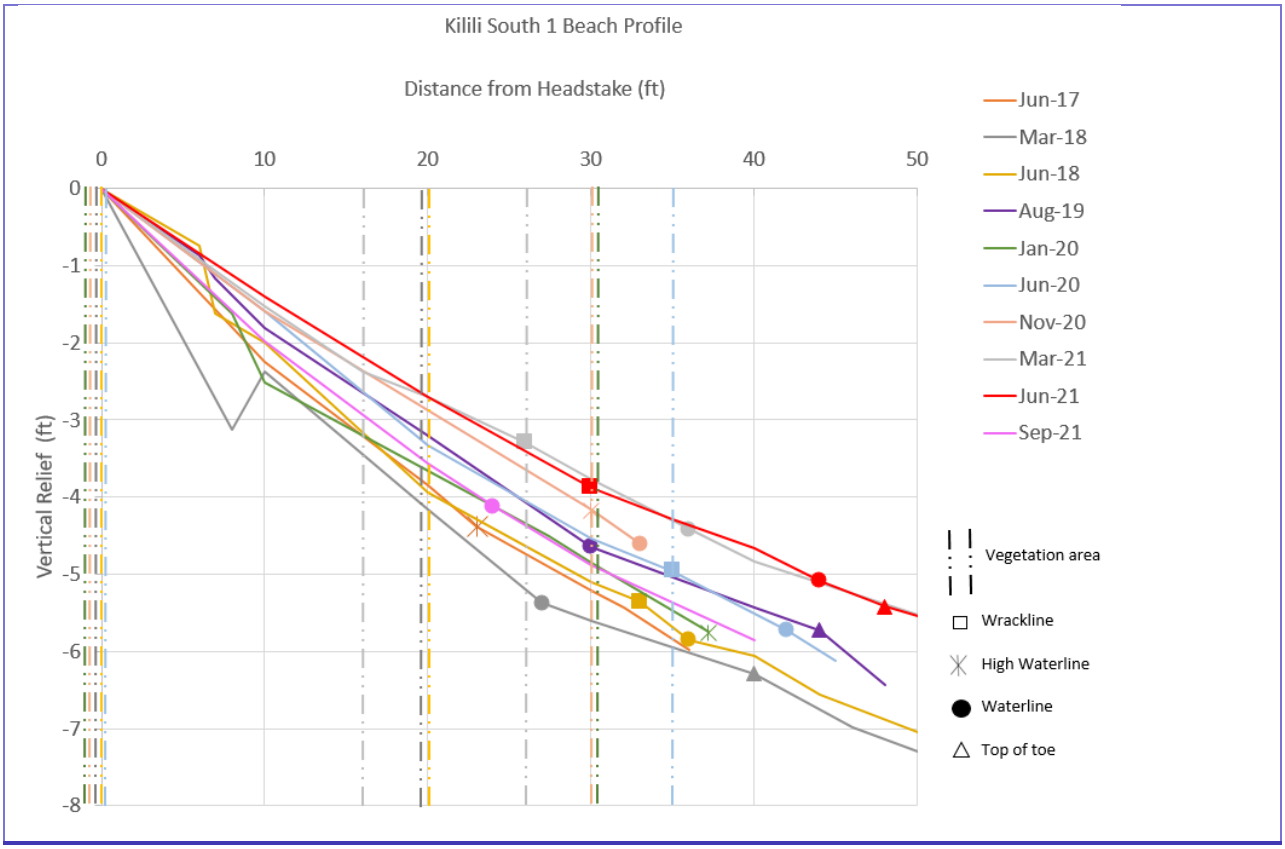
Kilili North 2

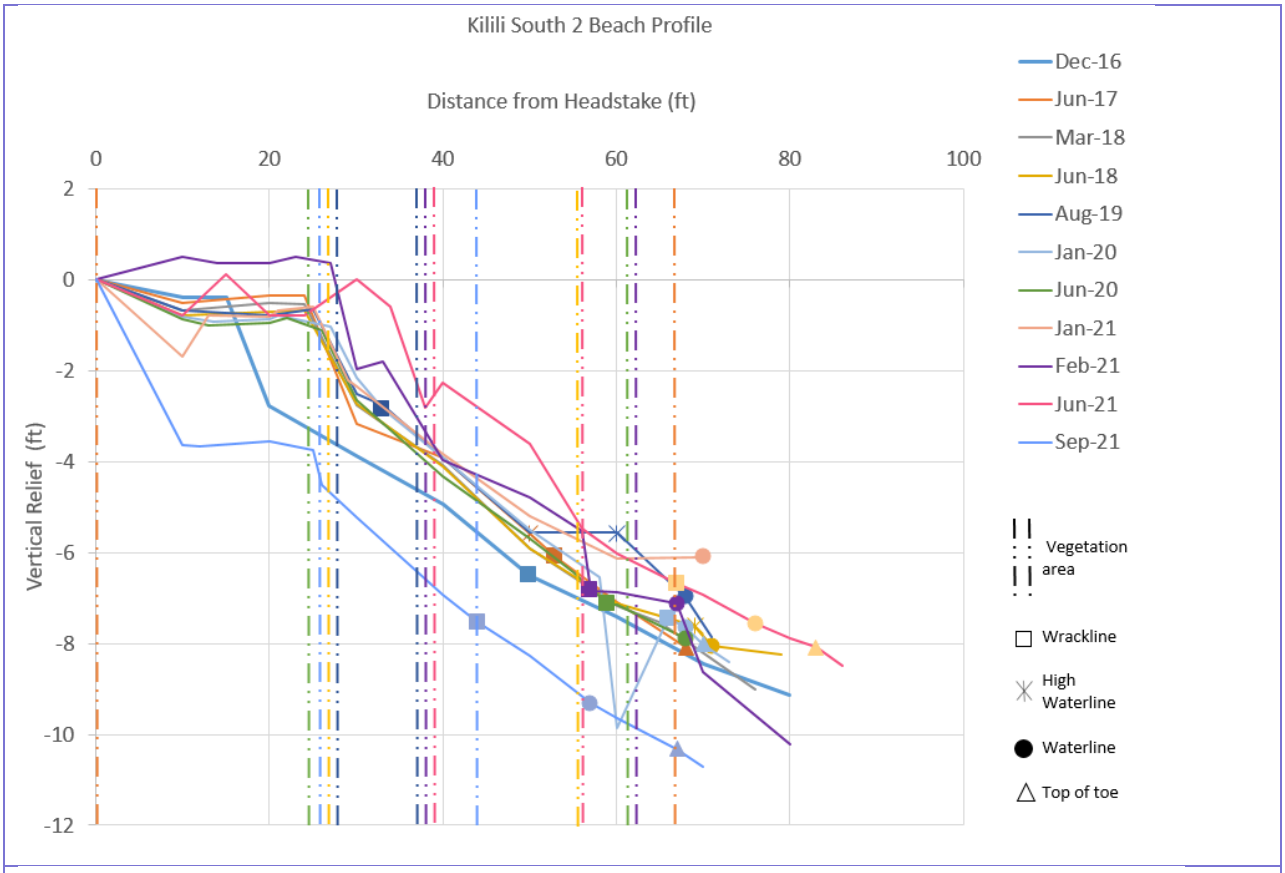
2020

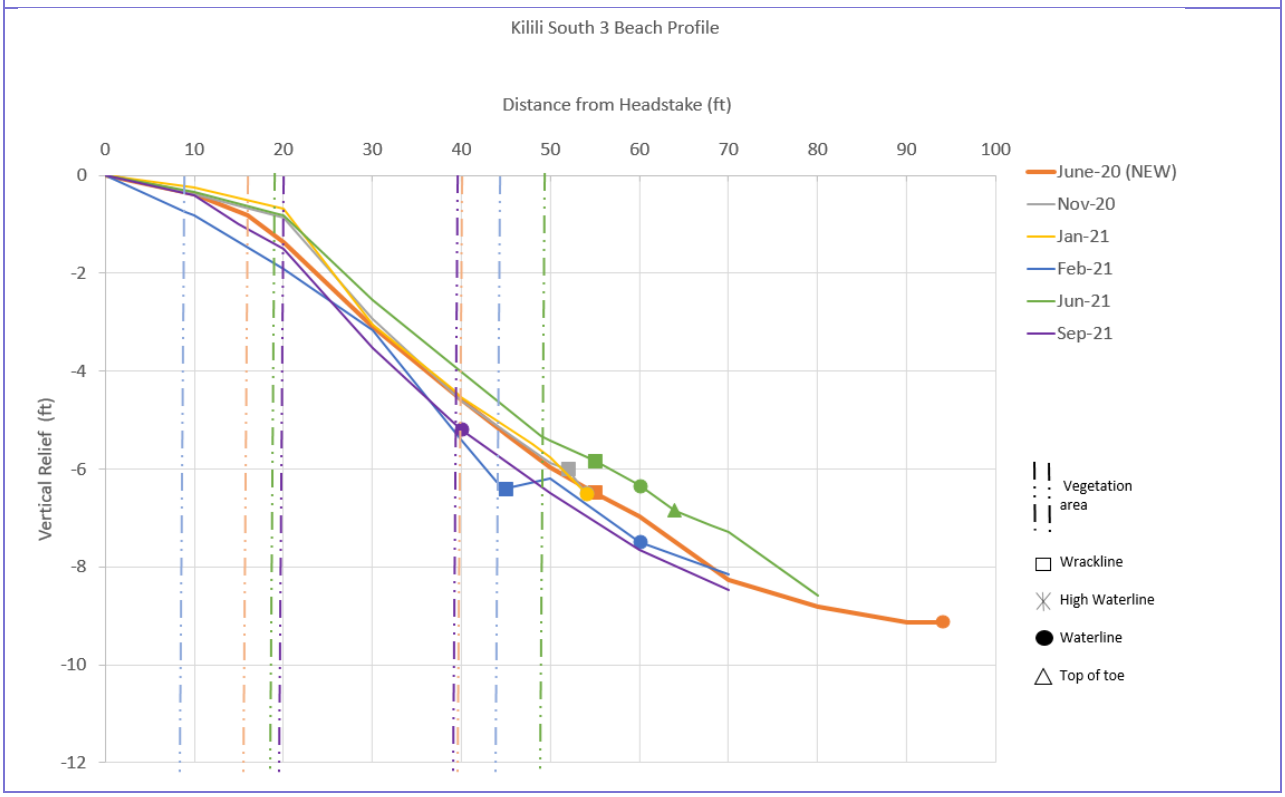
2021

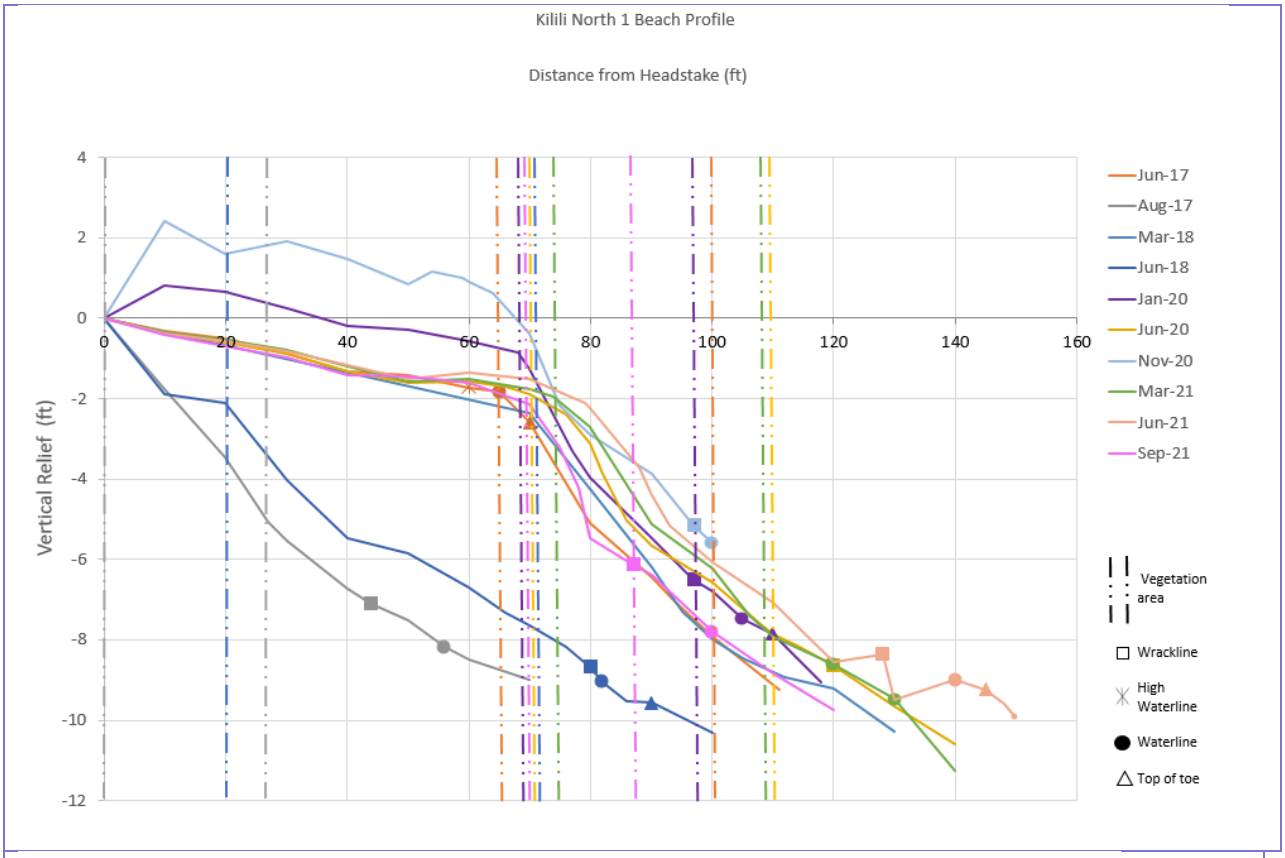
Kilili North 3

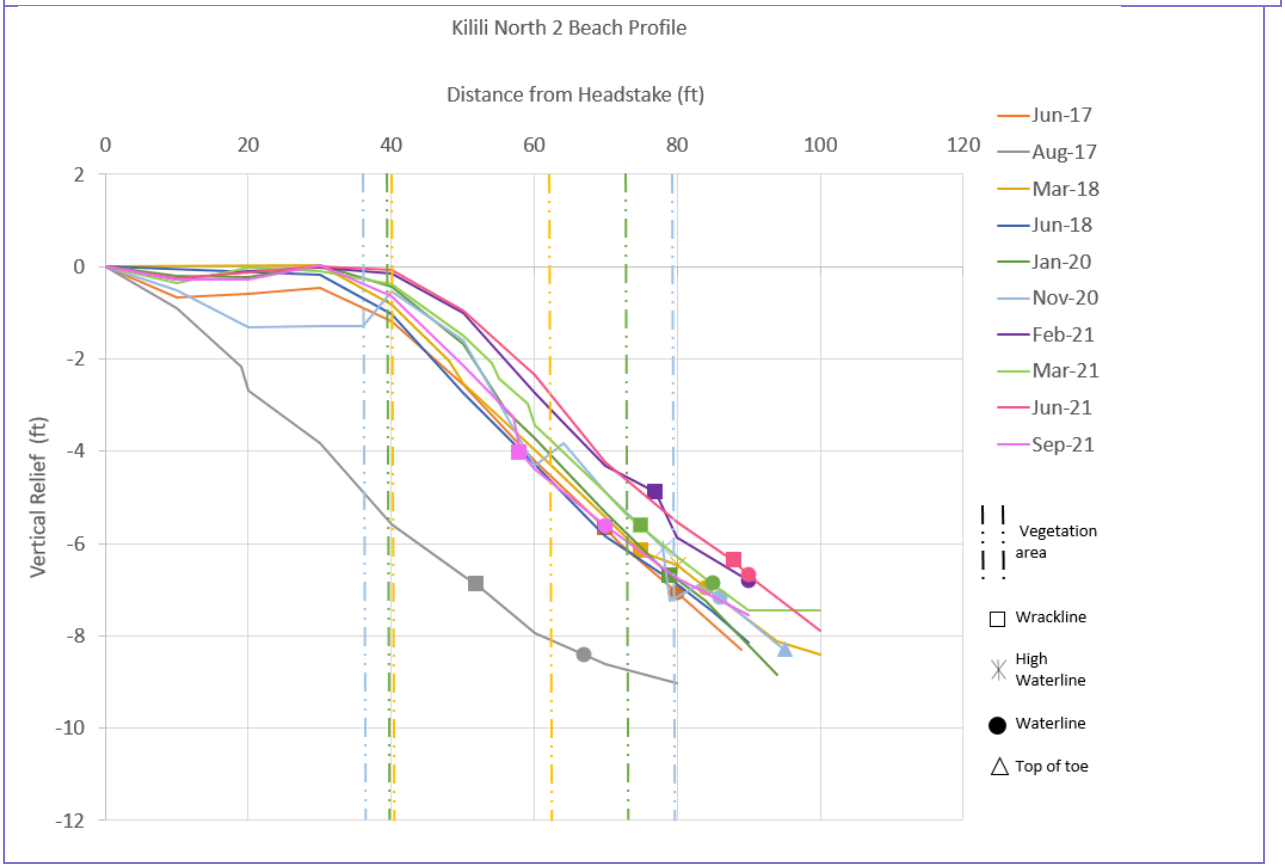
Kilili Beach Profiles

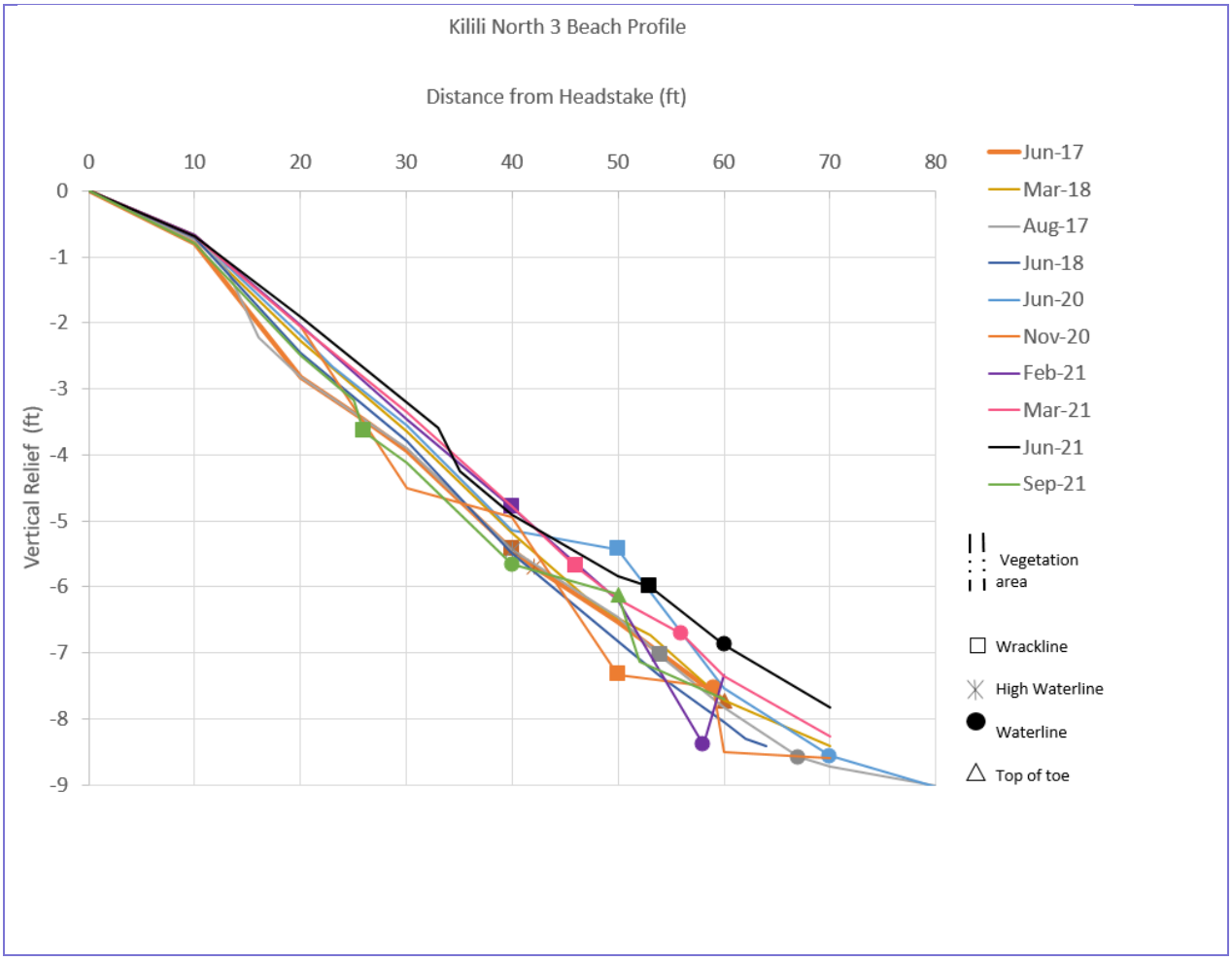



Kilili South 2 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Dec-16
Jun-17
Mar-18
Jun-18
Aug-19
Jan-20
Jun-20
Jan-21
Feb-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Kilili South 3 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
100
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
June-20 (NEW)
Nov-20
Jan-21
Feb-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Kilili North 1 Beach Profile
Distance from Headstake (ft)
Vertical Relief (ft)
4
2
0
-2
-4
-6
-8
-10
-12
0
20
40
60
80
100
120
140
160
Jun-17
Aug-17
Mar-18
Jun-18
Jan-20
Jun-20
Nov-20
Mar-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Kilili North 2 Beach Profile
Distance from Headstake (ft)
Vertical Relief (ft)
2
0
-2
-4
-6
-8
-10
-12
0
20
40
60
80
100
120
Jun-17
Aug-17
Mar-18
Jun-18
Jan-20
Nov-20
Feb-21
Mar-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Kilili North 3 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
Vertical Relief (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Jun-17
Mar-18
Aug-17
Jun-18
Jun-20
Nov-20
Feb-21
Mar-21
Jun-21
Sep-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Oleai

Parallel to the Garapan reef, Oleai shoreline is short and adjacent to the parking lot of Oleai Beach Bar. The restaurant facility in Oleai 1 transect is less than 50 ft away from the waterline indicating that the restaurant is vulnerable to storm surge and sea level rise.

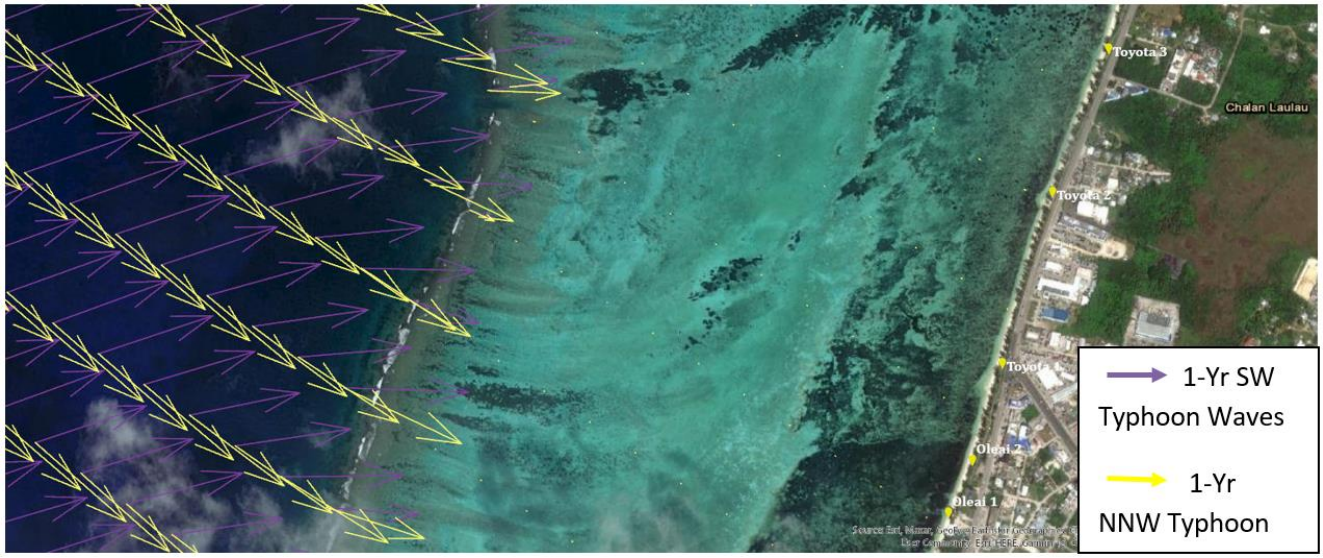
Stabilization measures are necessary to protecting the infrastructure from an encroaching waterline, so recording the shoreline positon may assist proper decision-making in addressing this issue. Wave overtopping and overwhelmed tidal flows may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site.

Oleai 1 Highlights:

- ERODING with a Wrackline that ranges 8 – 33 ft and an elevation difference of more than 6 ft
- Tides and seasonal wave conditions influence the beach width. The shoreline receives grooming through the restaurant's management to move washed up debris more inland to expose a sandy shoreline.

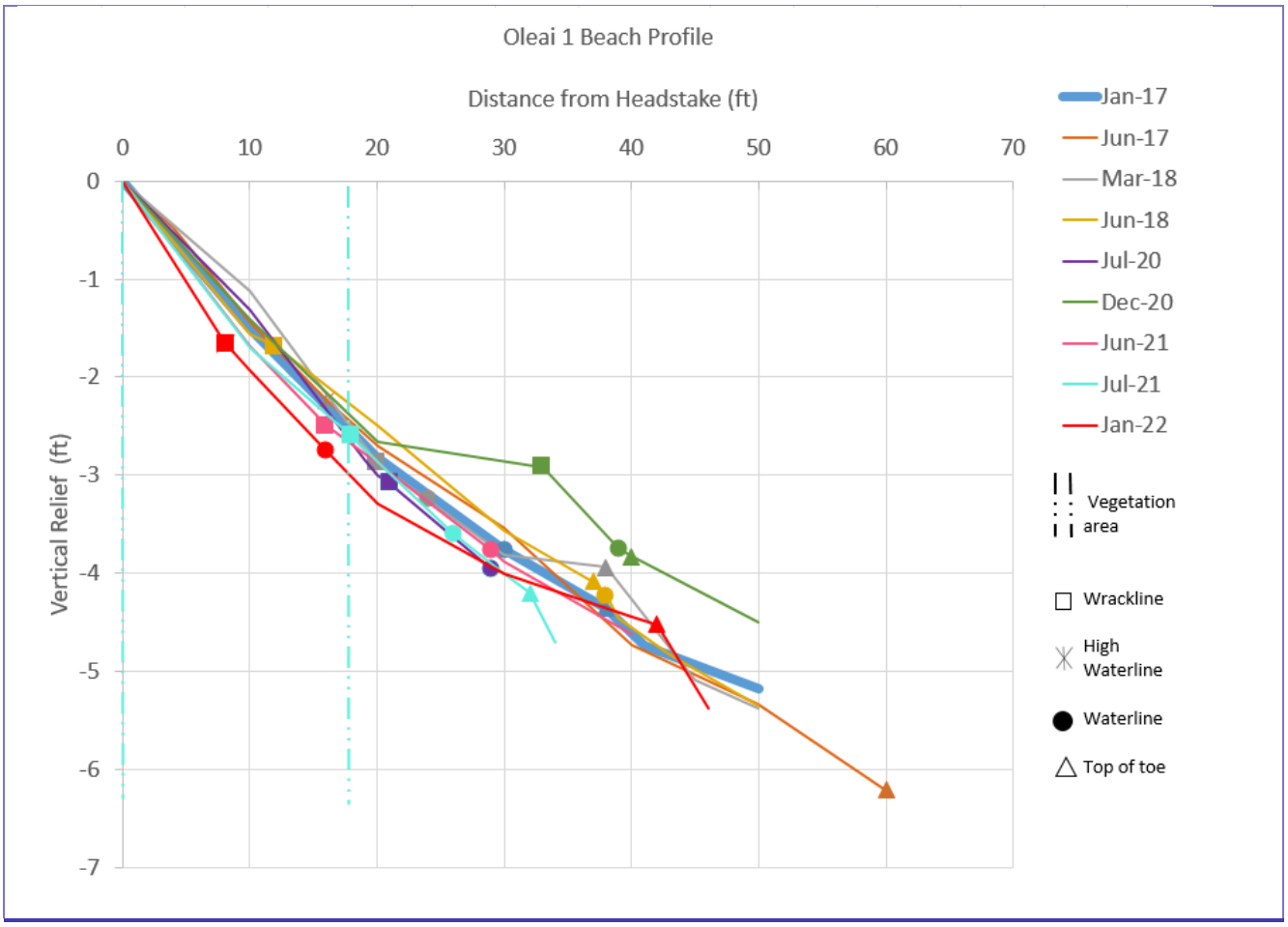
Oleai 2 Highlights:

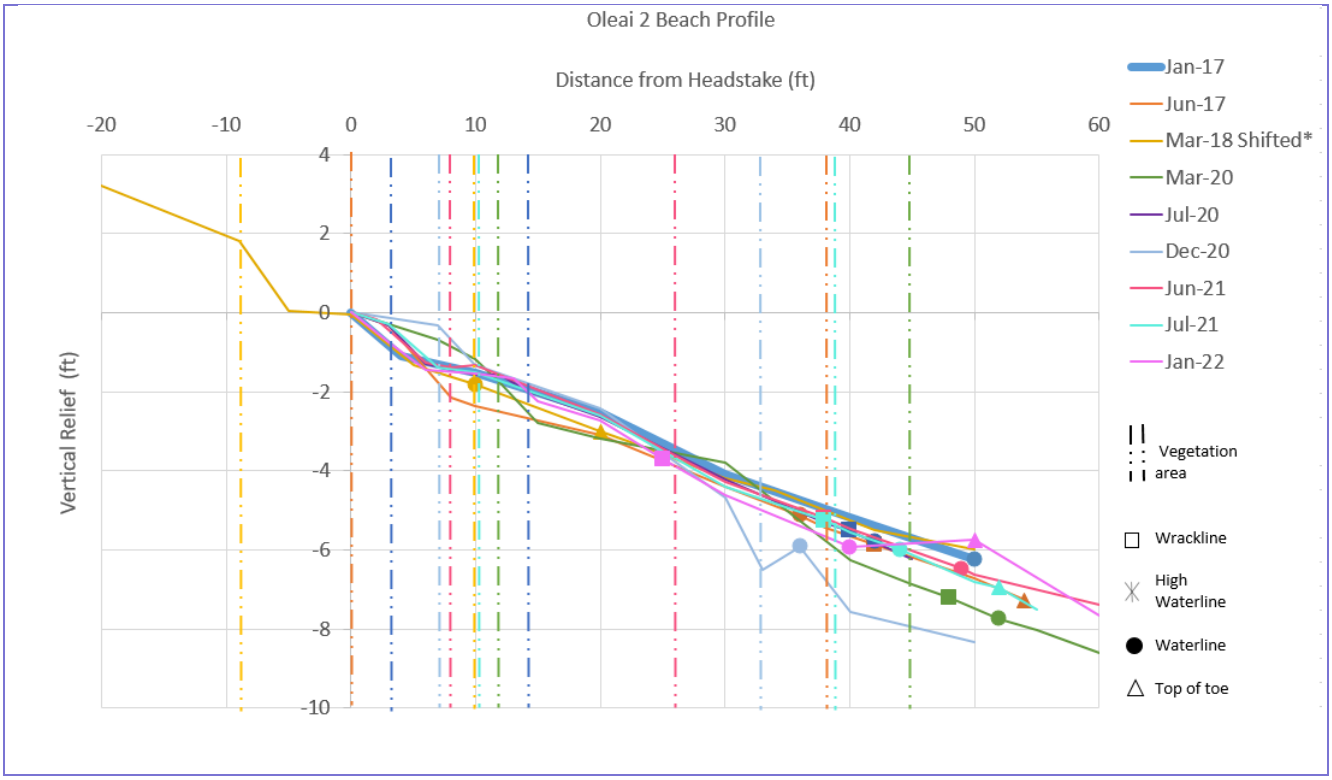
- ERODING with a Wrackline that ranges 23 – 48 ft and an elevation difference of 7 ft



Oleai 2

Oleai Beach Profiles





Toyota

Toyota shoreline encompasses a portion of the Beach Road pathway with the railing and ADA pathway down to the shore. This area is prone to abrasion after storm surge events, which has historically damaged the pathway infrastructure. The toe is exposed during low tide.

Along with erosion by storm surge, sea level rise threatens this shoreline and its highly developed backshore, the Toyota intersection and the surrounding businesses. Both typhoon conditions bring strong wave energies that greatly erode the short shoreline away. Wave overtopping and overwhelmed tidal flows may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. However, improved resolution on nearshore dynamics may explain longshore processes for this area.

Toyota 1 Highlights:

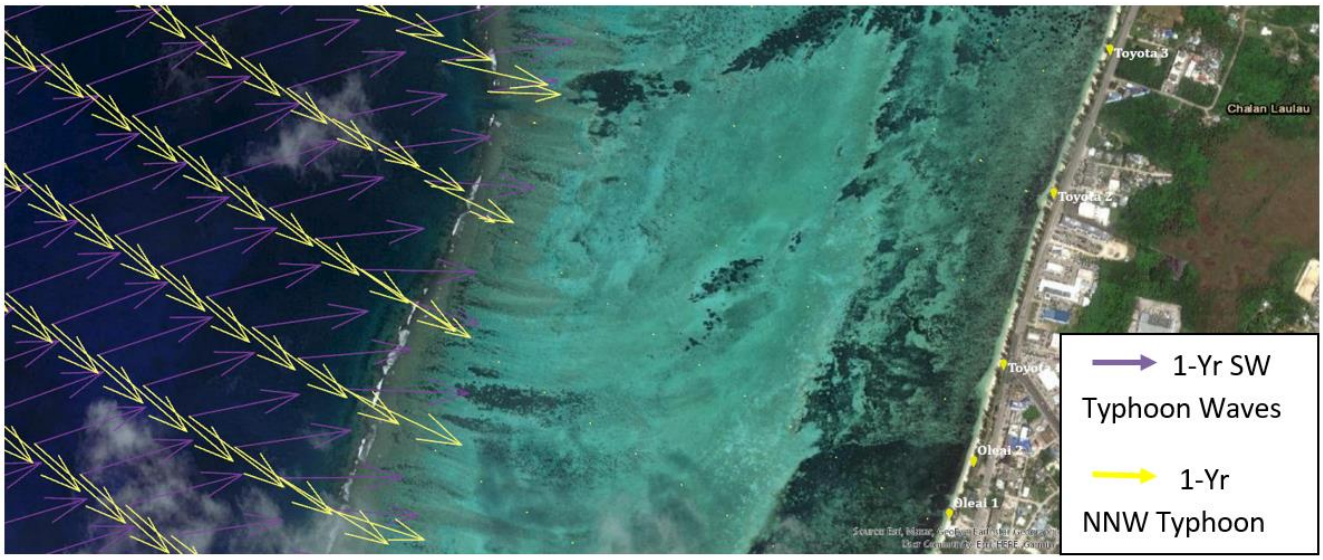
- ERODING in the short-term and STABLE in the long-term
- Wrackline that ranges 30 – 68 ft and an elevation difference of 10 ft

Toyota 2 Highlights:

- ERODING with a Wrackline that ranges 20 – 30 ft with an elevation difference of 9 ft
- Erosion was obvious on June 2018

Toyota 3 Highlights:

- STABLE that ranges 30 – 58 ft and an elevation difference of 8 ft
- Period of erosion and accretion

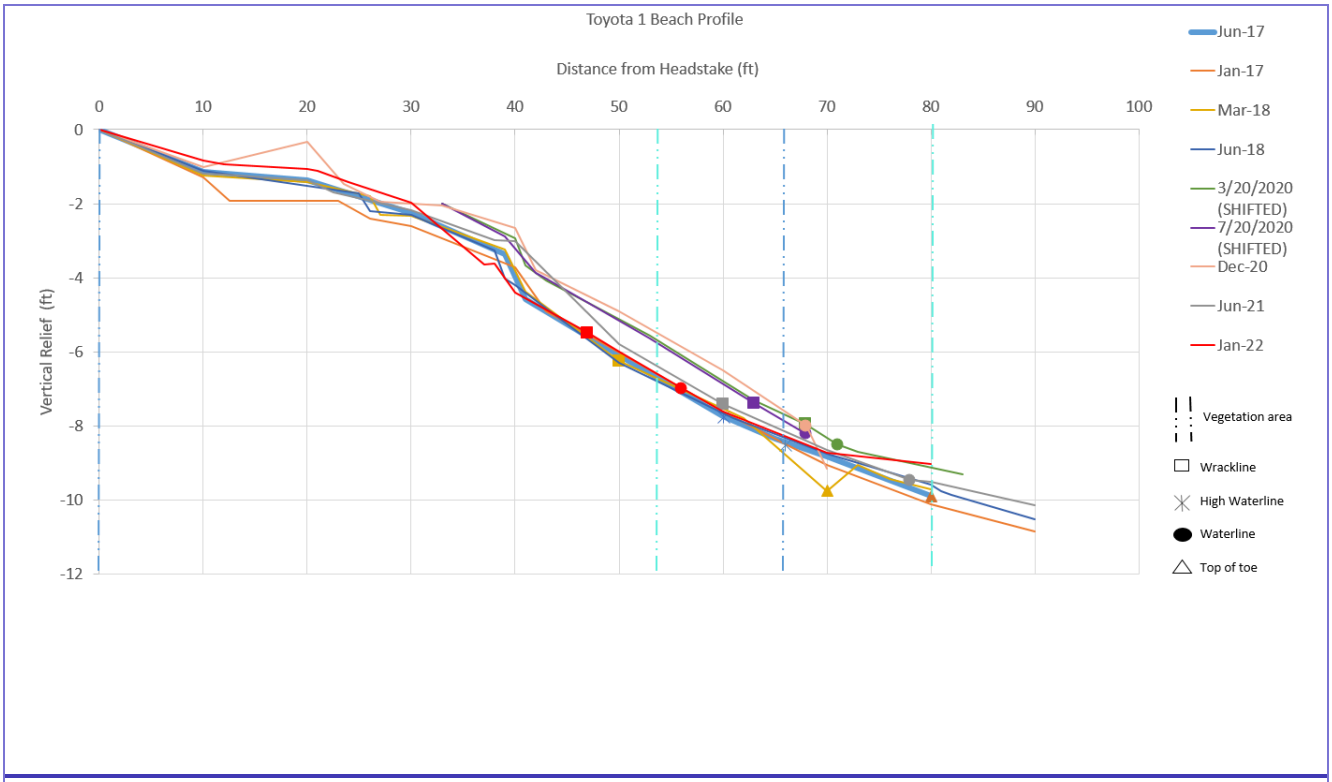


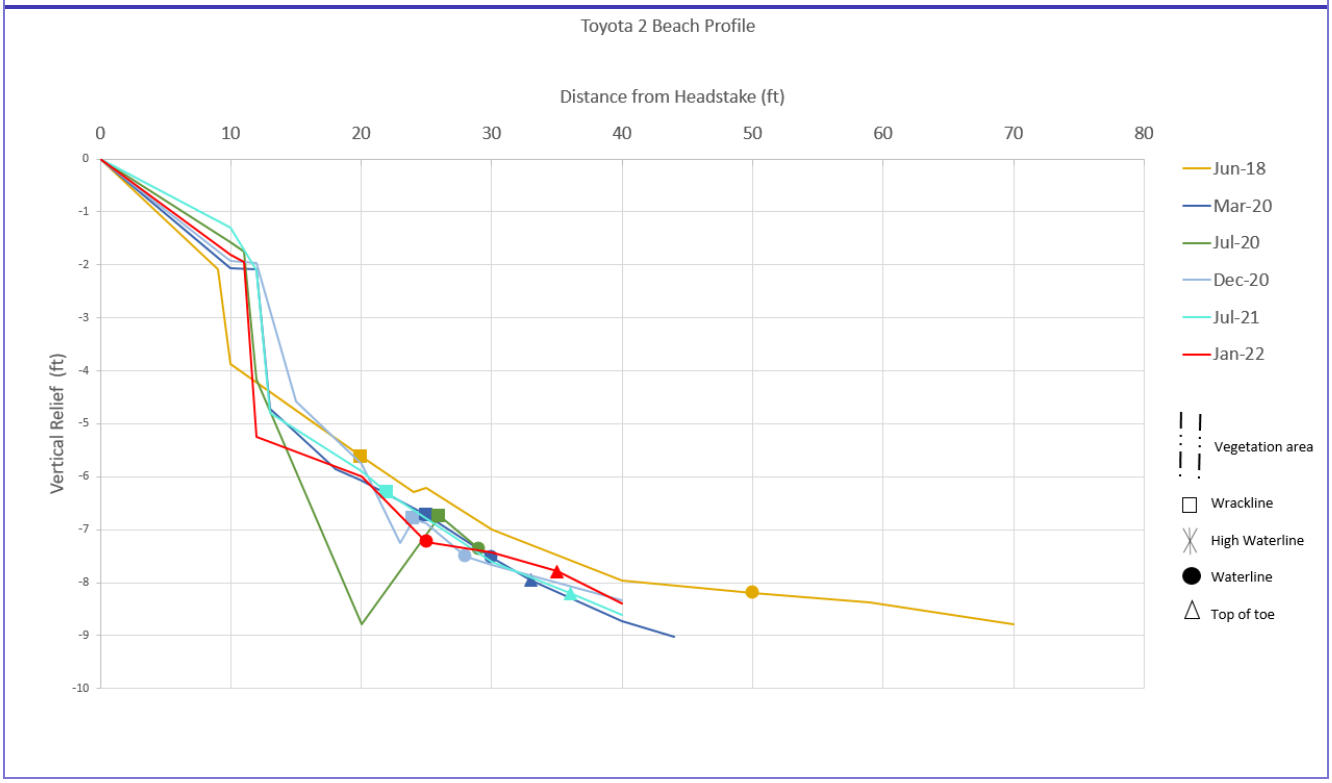
Toyota 1

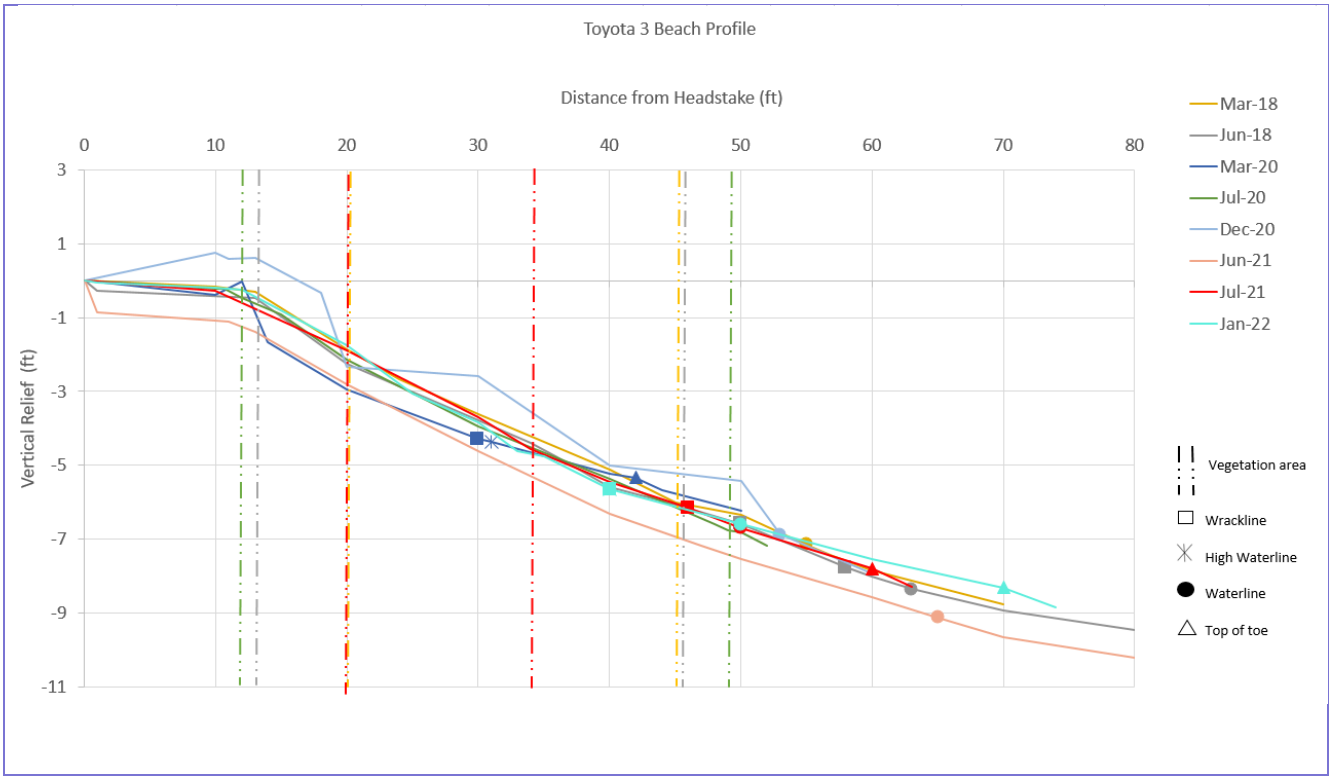
Toyota 2

Toyota 3

Toyota Beach Profiles






Toyota 3 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
3
1
-1
-3
-5
-7
-9
-11
Vertical Relief (ft)
Mar-18
Jun-18
Mar-20
Jul-20
Dec-20
Jun-21
Jul-21
Jan-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Quartermaster

The Quartermaster shoreline has few sandy spots. The beach profiles suggest the area is relatively stable or dynamic since the start of this program, likely due to sediment transport influenced by flows of the Light House Channel. However, the alarming short length of this shoreline indicates high vulnerability to storm surge and sea level rise. The backshore has pre-existing critical infrastructure, including Beach Road. The headstakes are a few feet away from this infrastructure and then a several feet away from the main road.

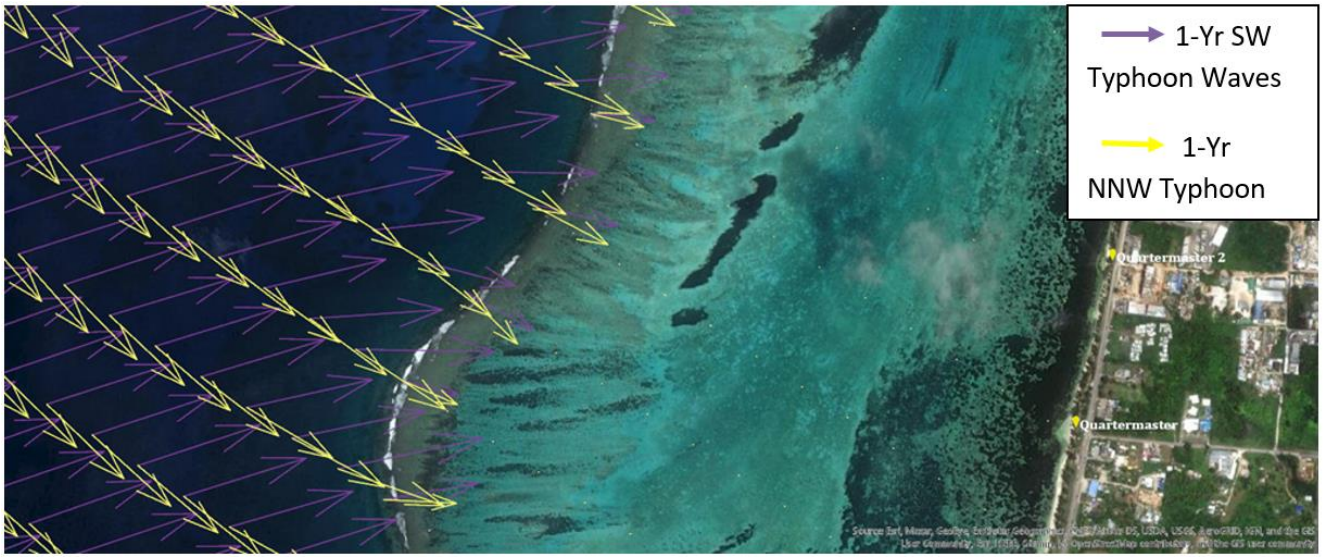
Present vegetation and seagrasses attenuate wave energy. However, other stabilization measures have been sought to address the loss of shoreline. This shoreline is moderately steep with high tidal influence. Wave overtopping and overwhelmed tidal flows may impact this site during both typhoon wave conditions. It appears that southwest conditions could greatly impact this site. However, improved resolution on nearshore dynamics may explain longshore processes for this area.

Quartermaster 1 Highlights:

- ERODING with a Wrackline that ranges 35 – 40 ft and an elevation difference of 9 ft
- Relatively stable yet seasonally dynamic
- Low tide difference is high
- Nearby drainage has some influence

Quartermaster 2 Highlights:

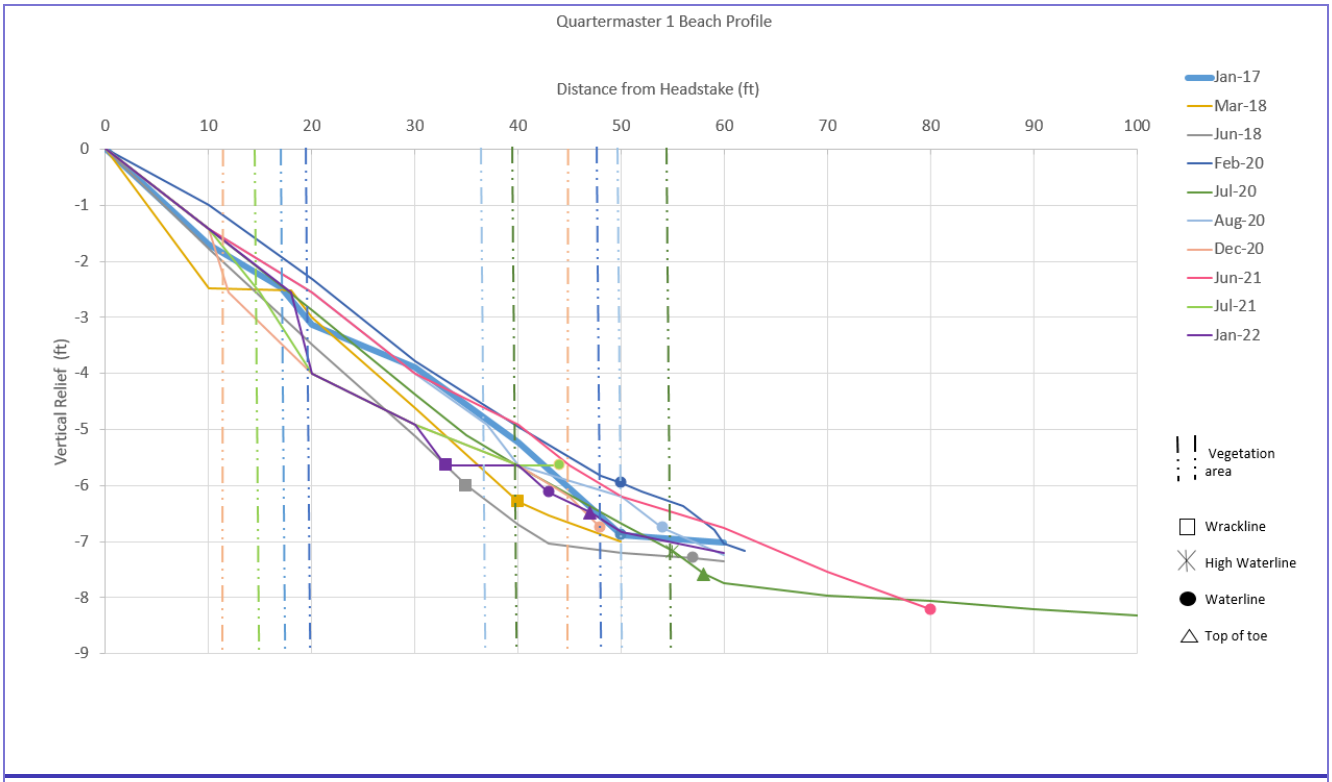
- STABLE with a Wrackline that ranges 30 – 52 ft with an elevation difference of 7 ft
- Low tide difference is high

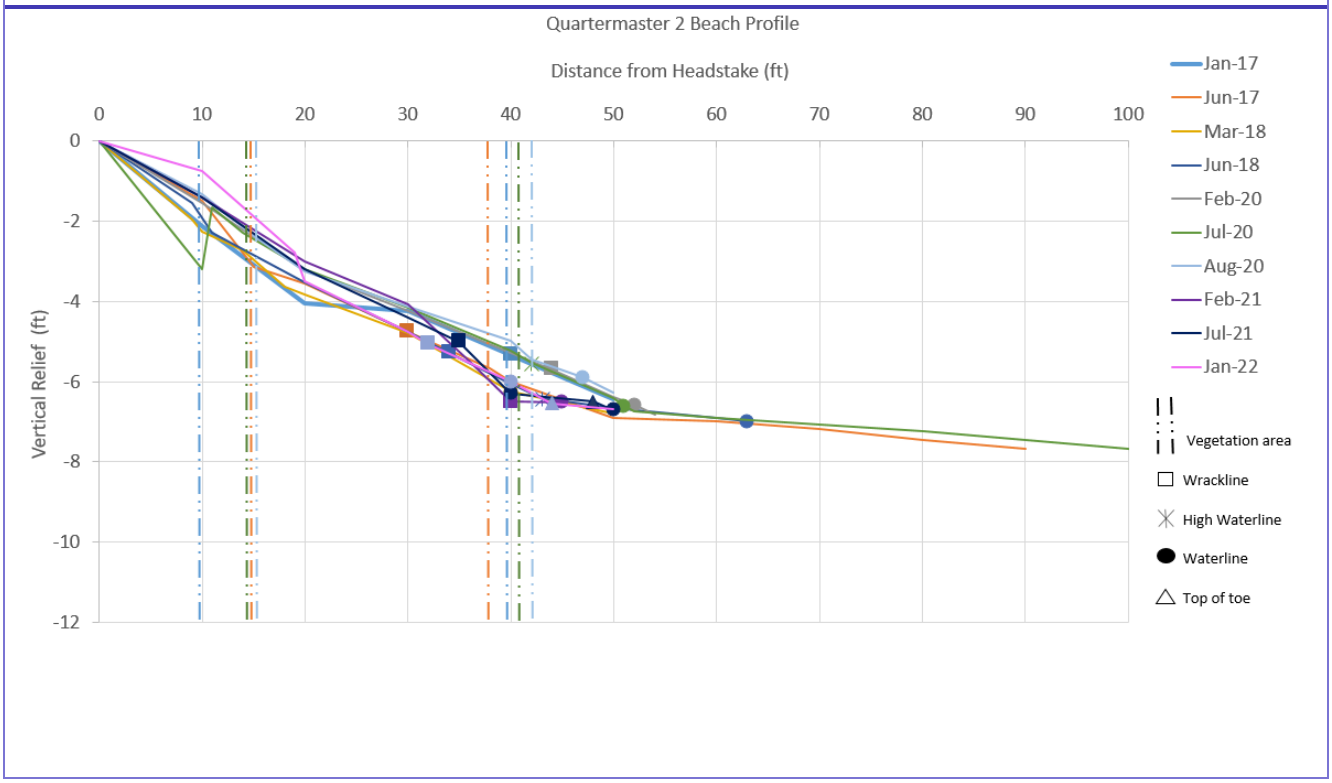


Quartermaster 1

Quartermaster 2

Quartermaster Beach Profiles





Hafa Adai

Located within the Garapan Lagoon and adjacent to patch reef, Grandvrio Hotel's sandy beach, we call "Hafa Adai", has been growing in width. This accretion starkly contrasts to Fiesta and Hyatt shoreline (to the north) and Garapan district shoreline (to the south). The thriving young ironwood trees in the nearshore signify that this area has not experienced damage from the storms of 2021. Rather, sand may have been deposited during storm events. The outfall south of the hotel is speculated to have an hydraulic effect on the shoreline but monitoring efforts have not observed its real-time impact on the accumulation. Sediment from the north could be shifting to the south. For both typhoon wave conditions, this area is better sheltered than the northern sites.

The closure of Grandvrio hotel due to the pandemic has allowed shoreline vegetation to overgrow on grounds that were previously groomed. This indicates stabilization of both the backshore and nearshore area, but plant removal may be anticipated once the shoreline receives foot traffic from tourists.

Hafa Adai 1 Highlights:

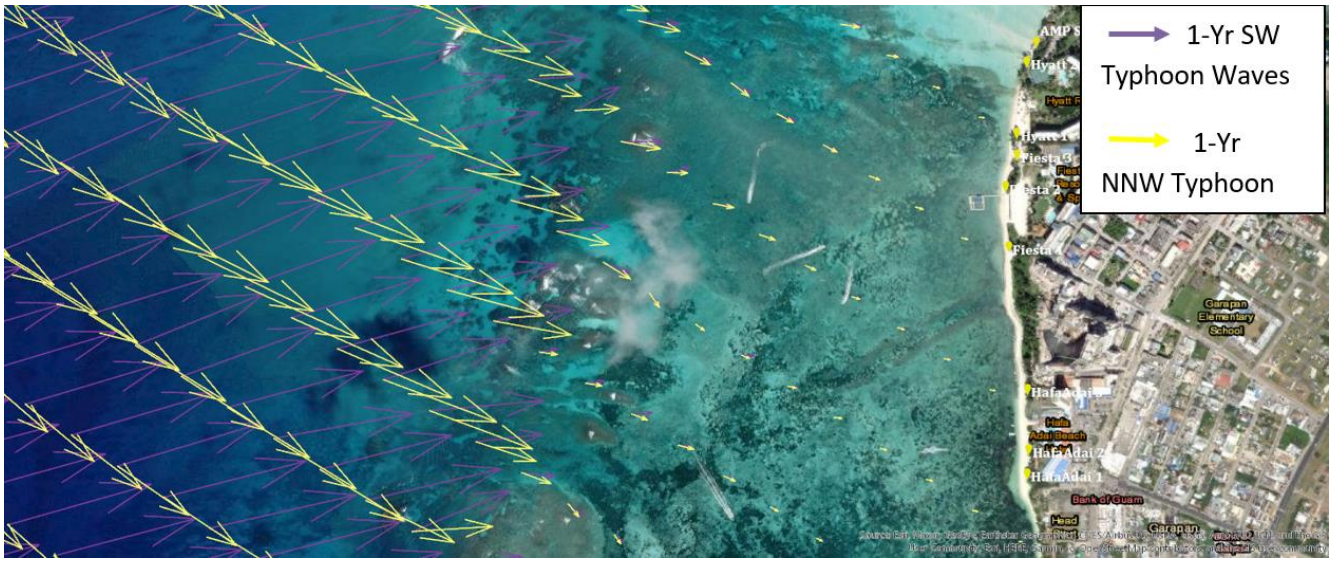
- ACCRETING in the short-term with a Wrackline that ranges 20 – 52 ft and an elevation difference of 9 ft
- Outfall influenced

Hafa Adai 2 Highlights:

- ACCRETING with a Wrackline that ranges 56 – 79 ft with an elevation difference of 7 ft

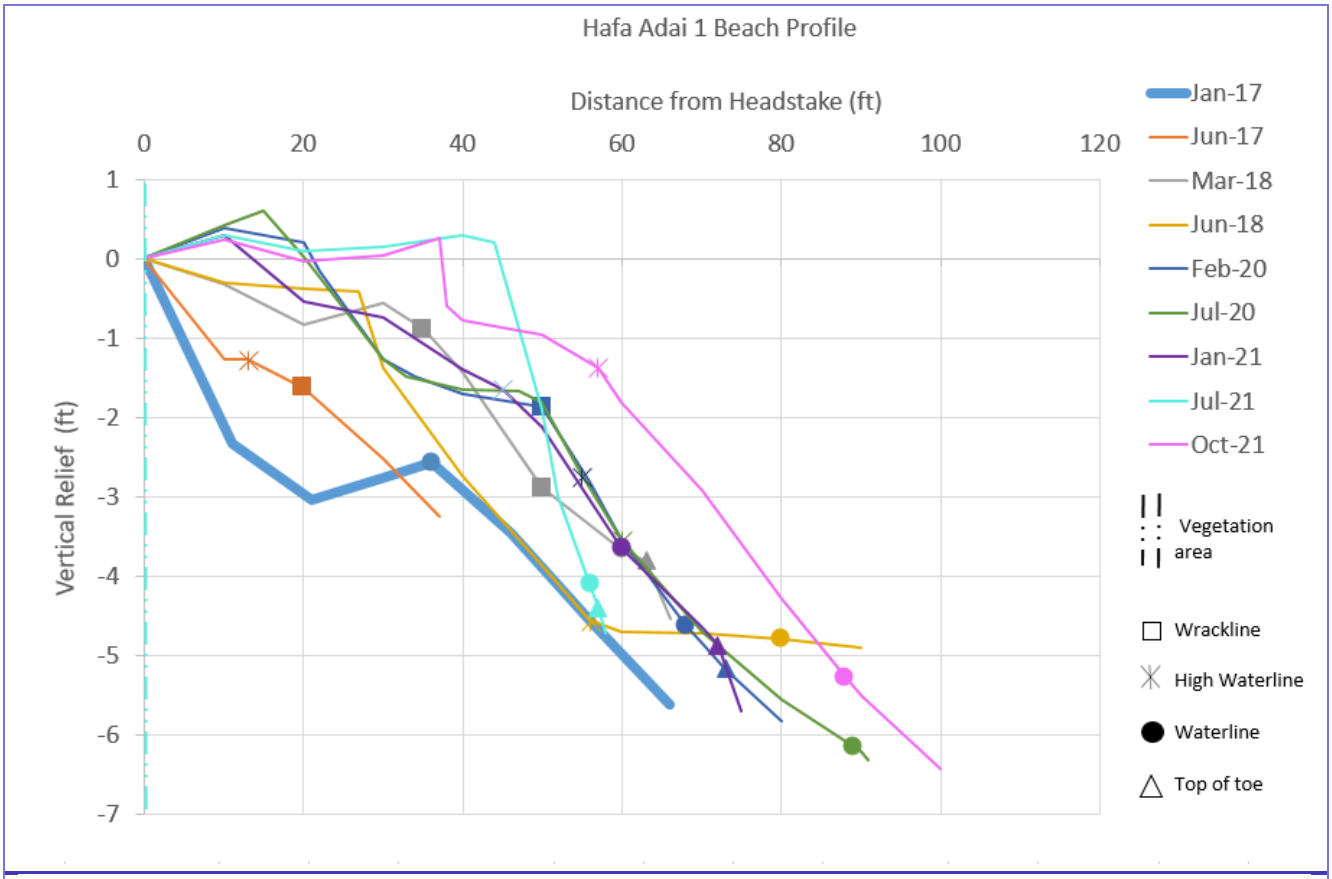
Hafa Adai 3 Highlights:

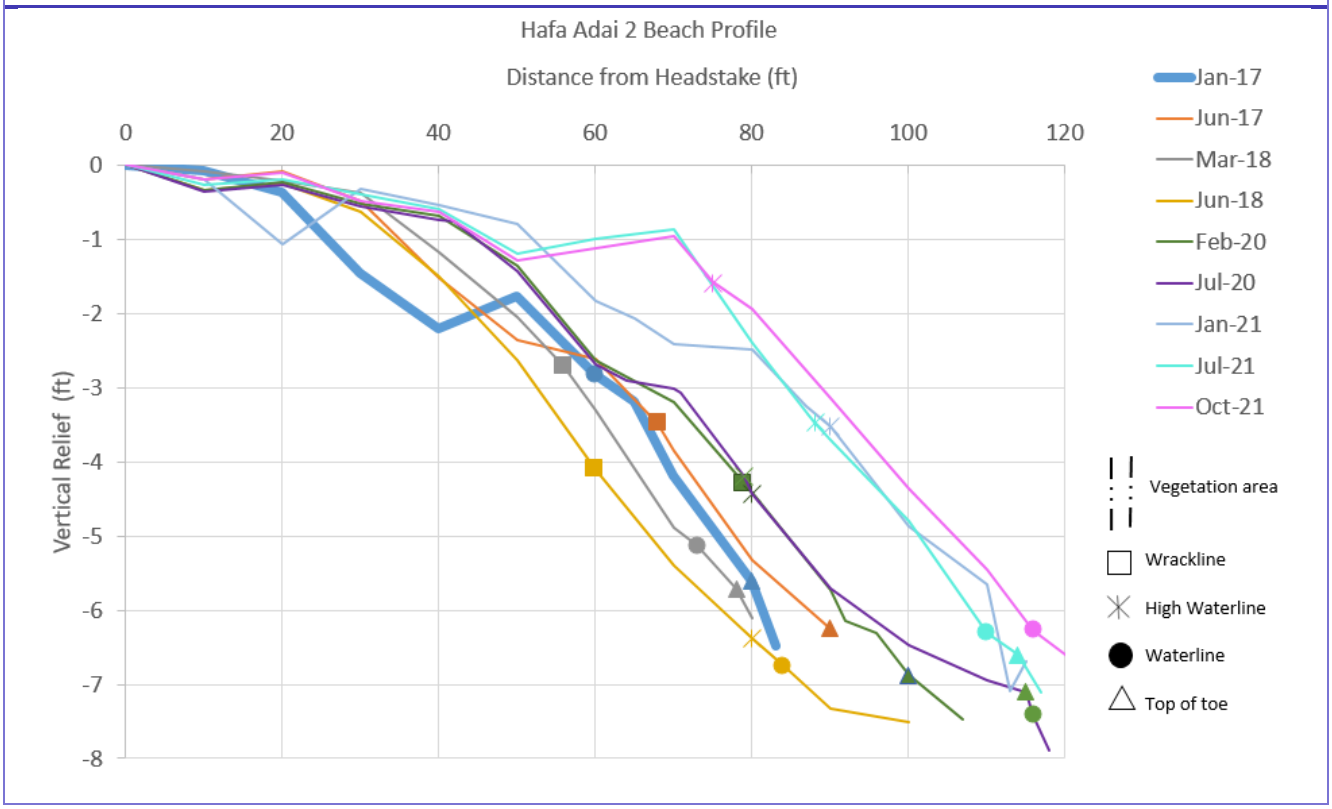
- ACCRETING with a Wrackline that that ranges 40 – 88 ft and an elevation difference of 6.5 ft
- As the shoreline has been gaining volume and length in three years, this stretch of shore naturally developed infrastructure. From July 2020 through Feb 2021, a row of ironwood trees grew and blocked the transect, making surveying difficult from Feb 2021 and onward.

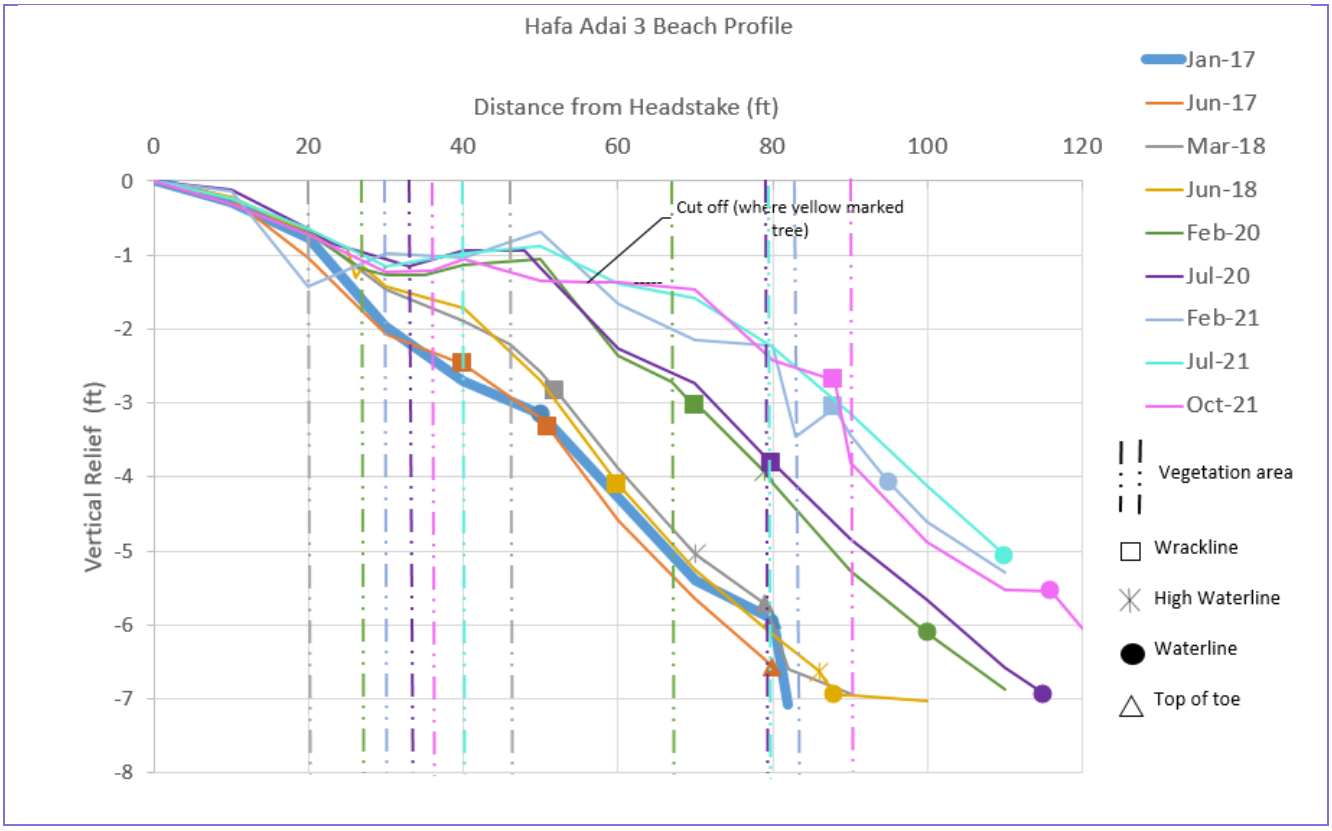



2020
2021
Hafa Adai 1
2020
2021
Hafa Adai 2
2020
2021
Hafa Adai 3

Hafa Adai Beach Profiles






Hafa Adai 3 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
Vertical Relief (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
Cut off (where yellow marked tree)
Jan-17
Jun-17
Mar-18
Jun-18
Feb-20
Jul-20
Feb-21
Jul-21
Oct-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Fiesta

Unlike down south, Fiesta has less reef and seagrass to attenuate wave energy. High energy waves were observed to rush through during storm events and dramatically chip away the shoreline. Fiesta beach has steep abraded berms that have retreated inland and will impact recreational activity facilities conducted nearby. Powerful north-northwest typhoon flows have overtopped the reef and sent strong wave energies through the channel, moving sand within a shorter time period. Watersports operators and hotel operators are impacted by the reduced shoreline area. The south transect, bordering the IPI Casino building, is speculated to have influence from the nearby outfall north of the area. We spatially mapped the top of the storm berm with the Trimble and Total Station after the tropical storm in September to monitor the wave damage and overtopping in the area. Two headstakes are discontinued due to damage from storms in late 2021.

Fiesta 1 Highlights:

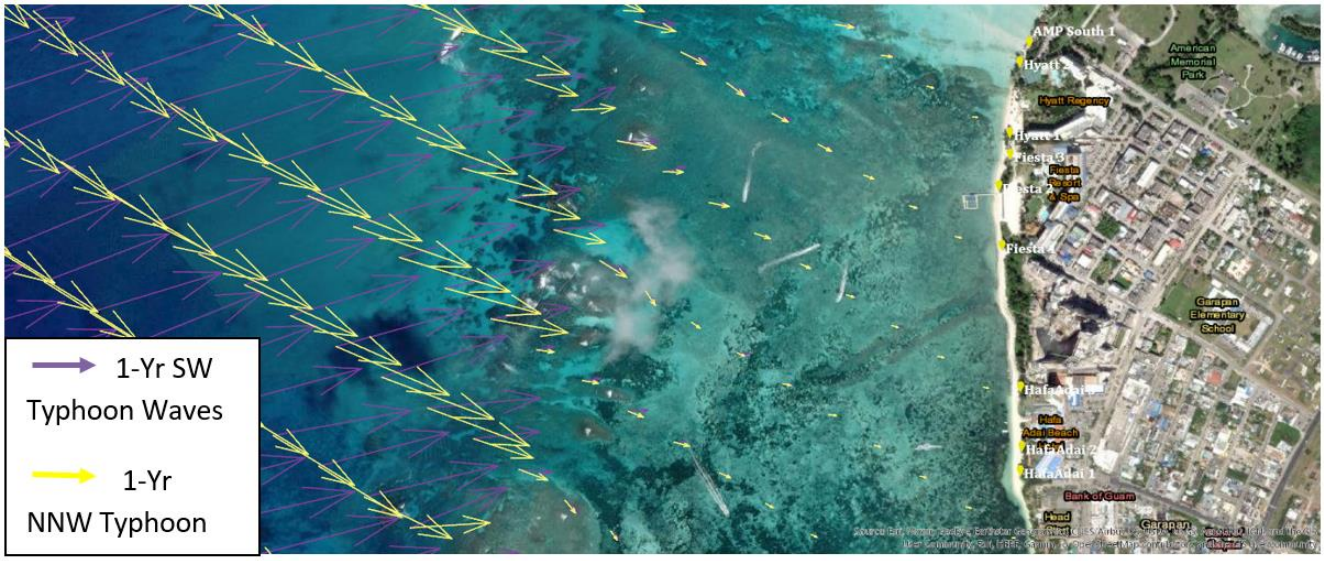
- ACCRETING with a Wrackline that ranges 30 – 55 ft and an elevation difference of 7 ft
- Outfall influenced

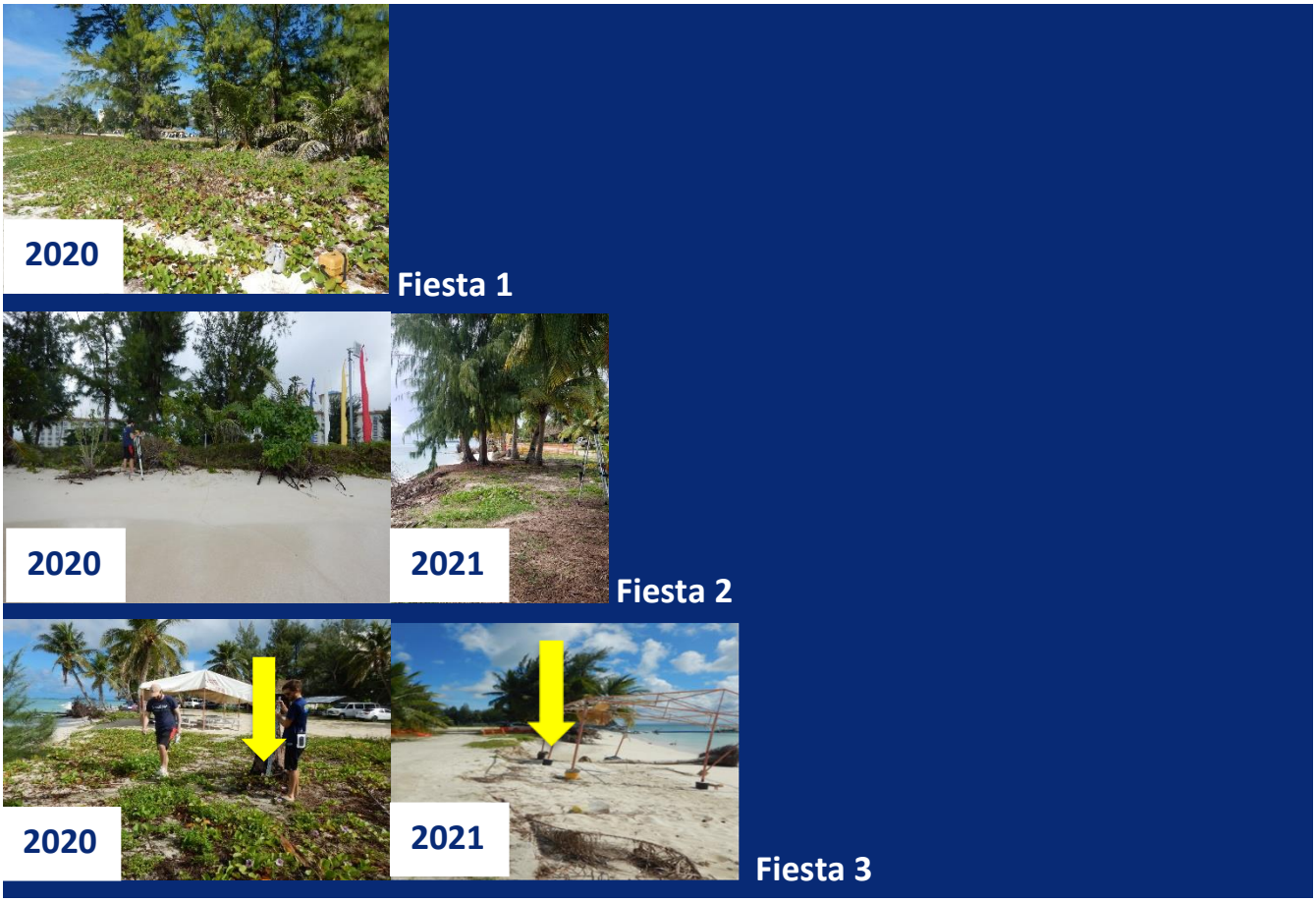
Fiesta 2 Highlights:

- ERODING and REPLACED
- LOSS of shoreline by ~20 ft since 2018
- Beach profile of Feb 2021 to Jul 2021 showed the ***High Waterline*** ranges 30 – 40 ft with an elevation difference of 6 ft
- **History:** The January 2018 to July 2020 headstake indicated a berm loss of around 10 ft from Jan 2018 through July 2020. The shoreline grew steeper, which enabled further erosion of the shoreline. The one displayed here preceded and was abraded by a September 2021 storm.

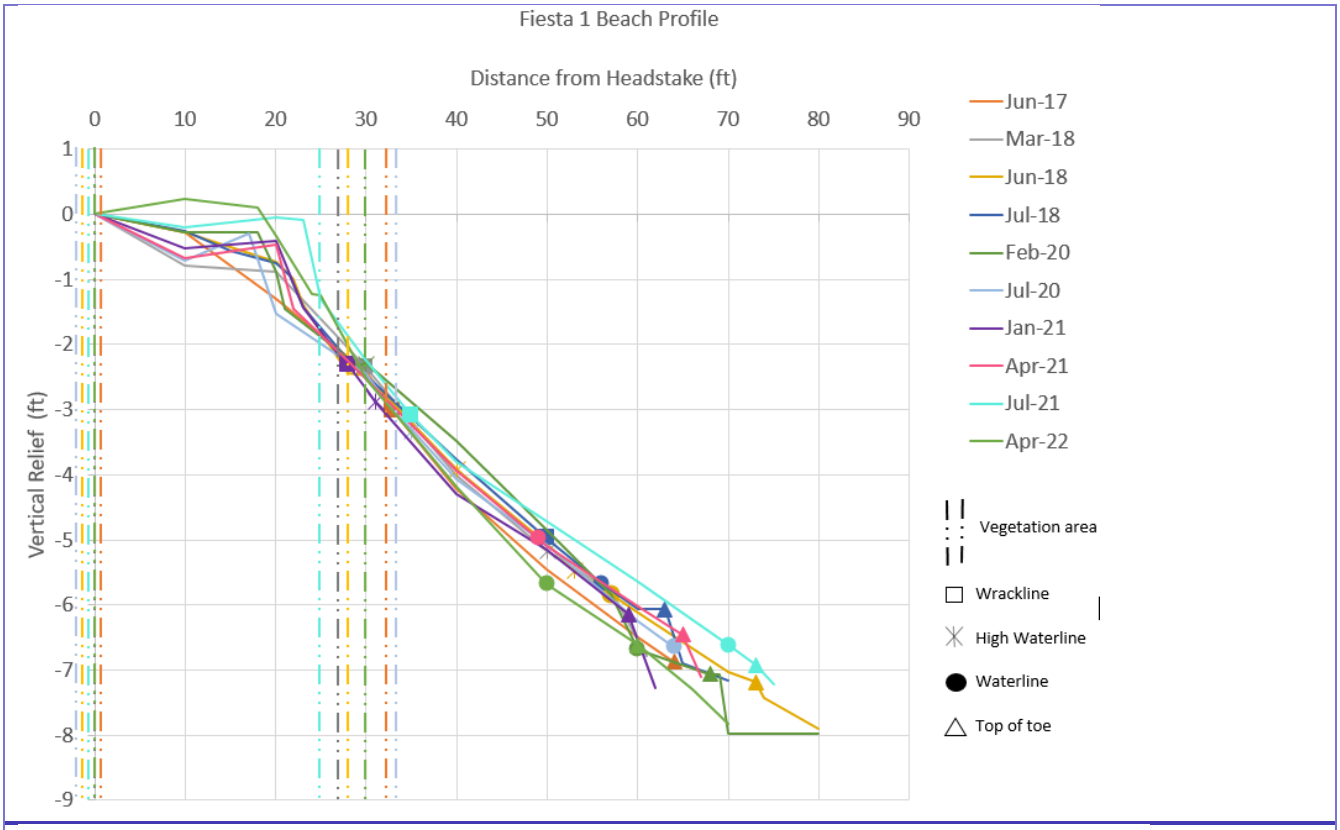
Fiesta 3 Highlights:

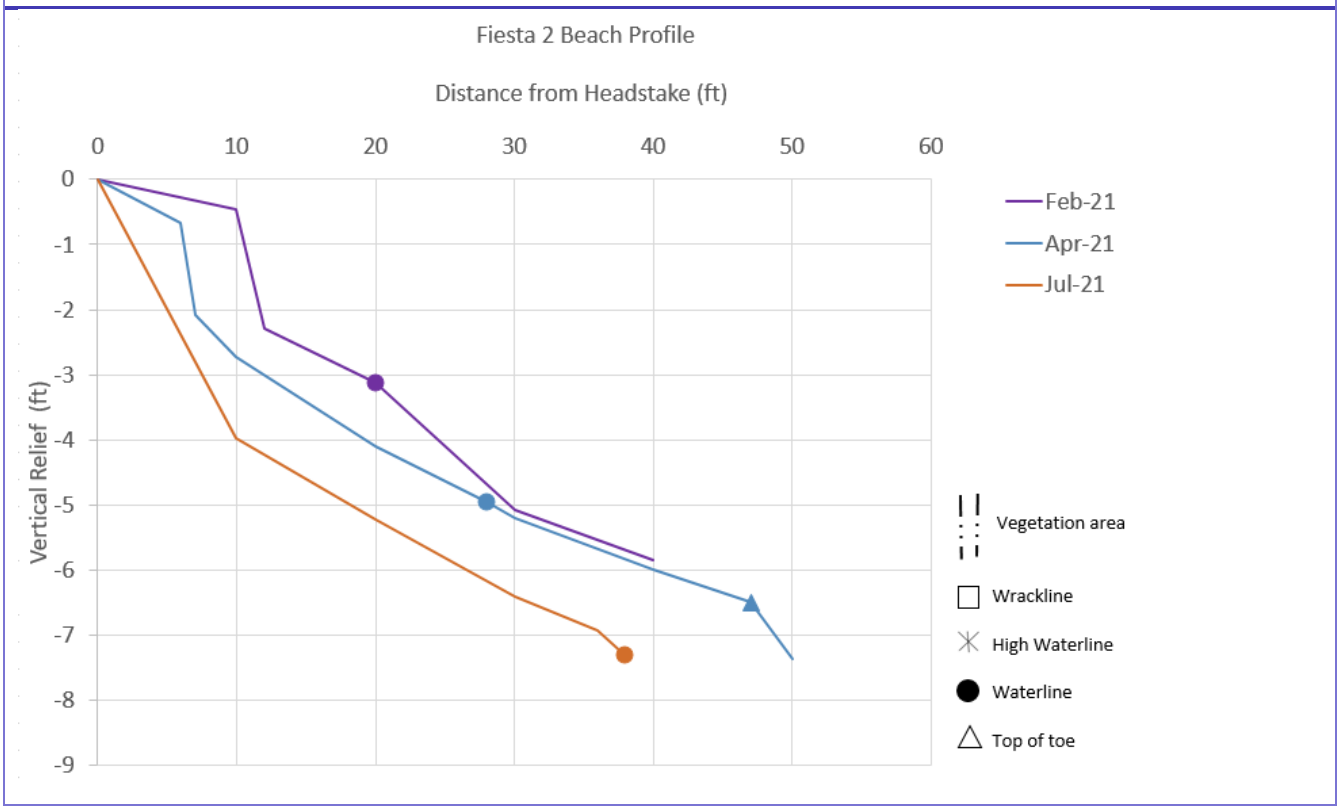
- ERODING and REPLACED
- LOSS of shoreline by ~60 ft since 2017
- Beach profile of Jun 2017 to Jun 2021 showed the ***High Waterline*** ranges 30 – 55 ft with an elevation difference of less than 6 ft
- **History:** From 2017 – 2020, the berm has retreated ~36 ft. Then from Feb 2020 – Jun 2021, erosion has reached the headstake, indicating additional of loss 16 ft. Storm-induced wave action is abrading the beach and weakening the sand. The late storms of 2021 have eaten up to the headstake and reached the road. Vehicles accessing this road are subjected to getting stuck in the softened sand or falling into the water. They are also compacting the sand. The wrackline is nonexistent due to a lack of seagrass or other potential debris in the adjacent waters.

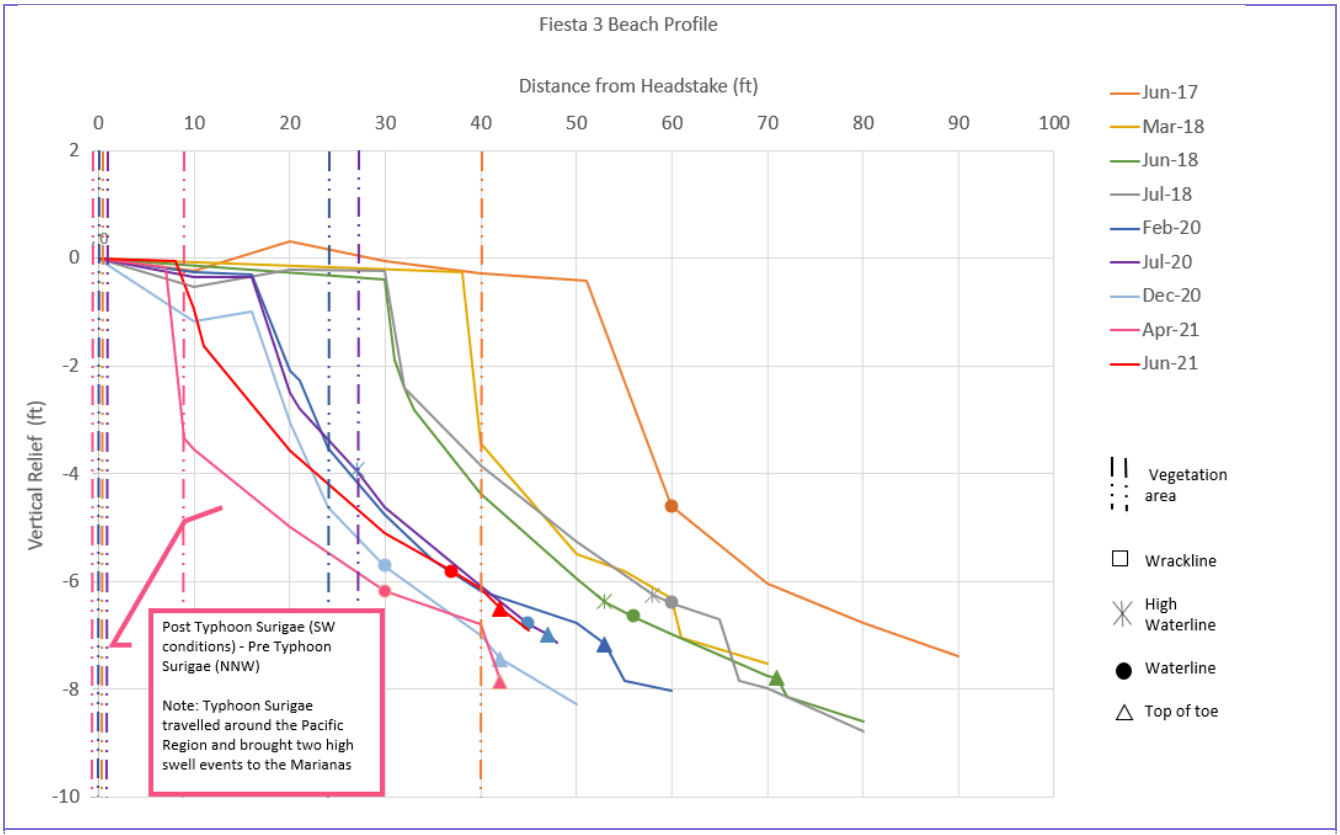




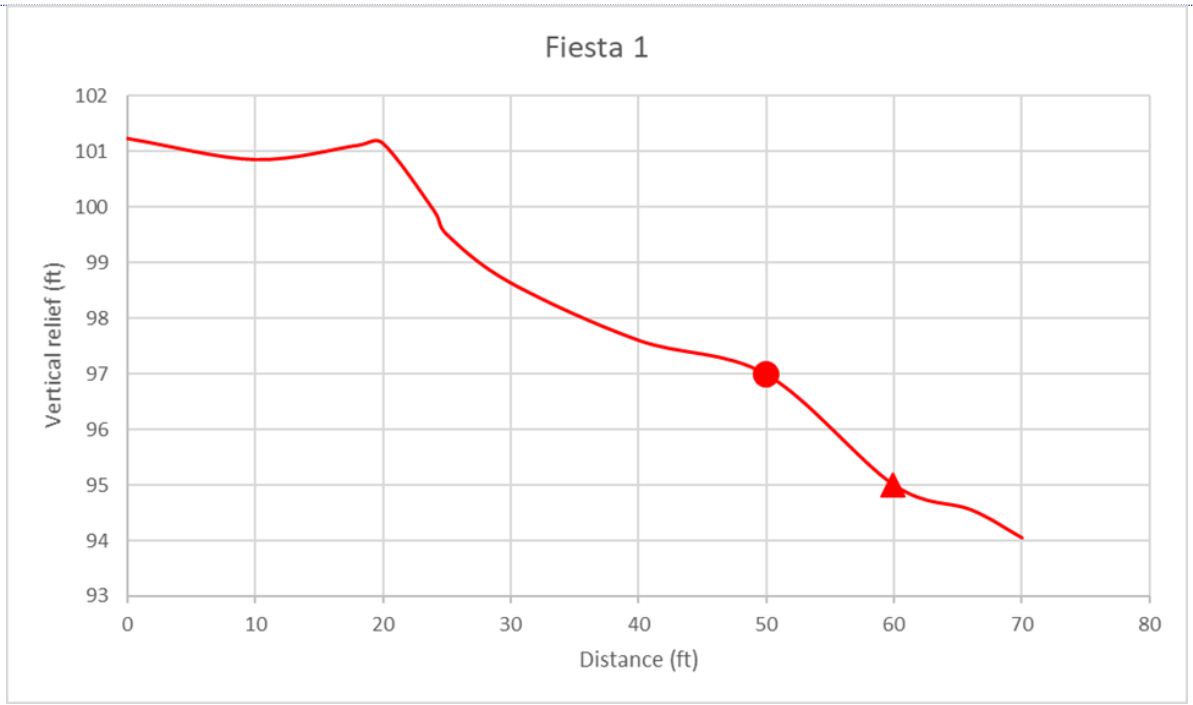
Fiesta Beach Profiles

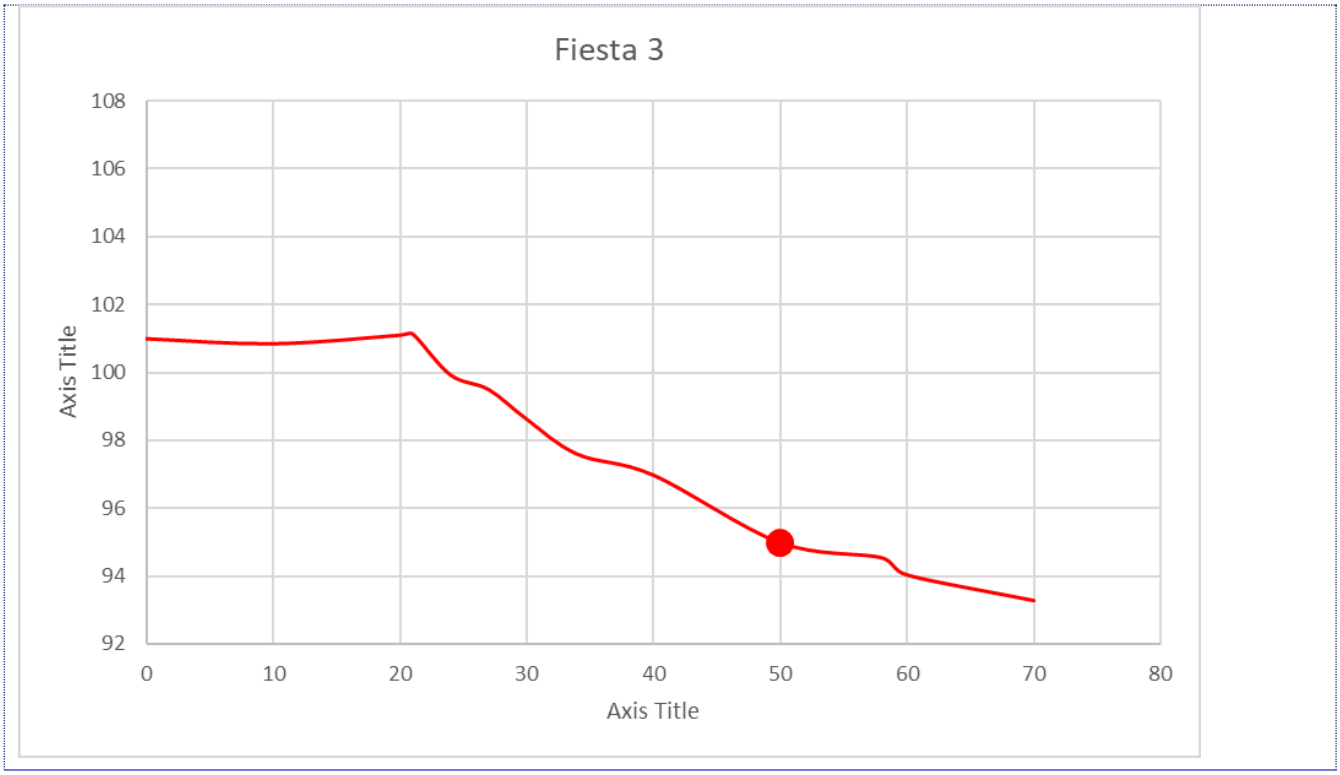

Fiesta 1 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Vertical Relief (ft)
Jun-17
Mar-18
Jun-18
Jul-18
Feb-20
Jul-20
Jan-21
Apr-21
Jul-21
Apr-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Fiesta 2 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
Vertical Relief (ft)
Feb-21
Apr-21
Jul-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe



Total Station




Fiesta 3
108
106
104
102
100
98
96
94
92
Axis Title
0
10
20
30
40
50
60
70
80
Axis Title

Hyatt

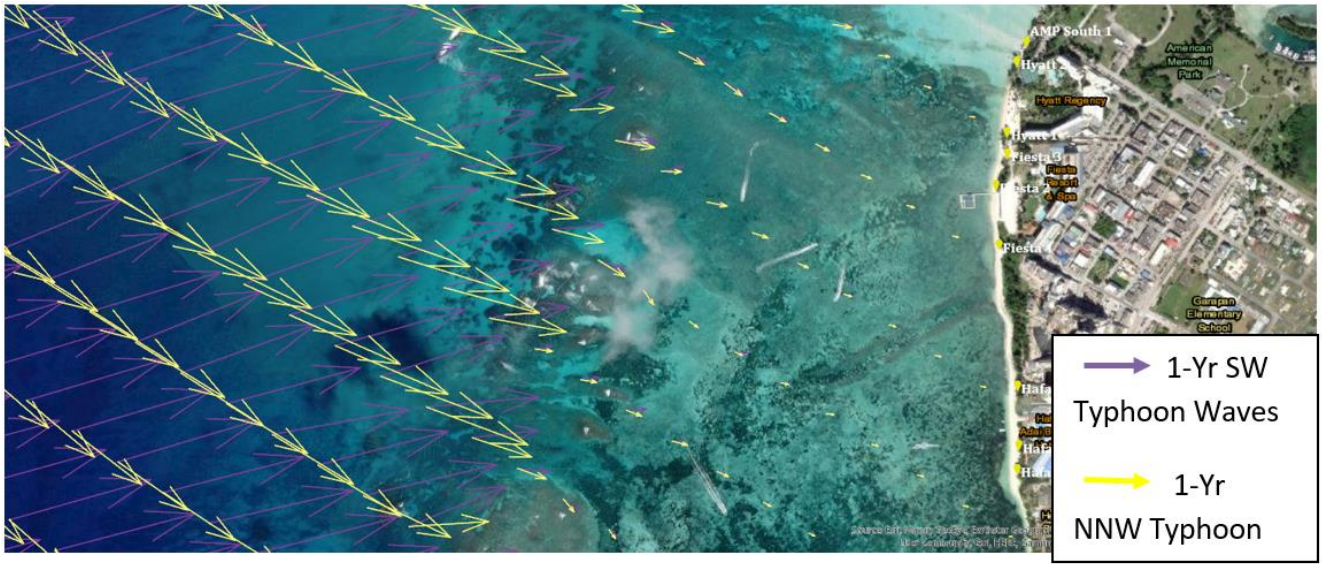
Similar to Fiesta, this section of shoreline has been chronically eroding due to strong storm-induced waves. Two head stakes were pulled into the water and rendered discontinued. Storm conditions increased wave energies bashing into the shore as it entered in through the channel. North-northwest flows have greater damage in a shorter period of time as shown with the tropical disturbance in September 2021. Southwest typhoon wave conditions still erode the shoreline.

Hyatt 1 Highlights:

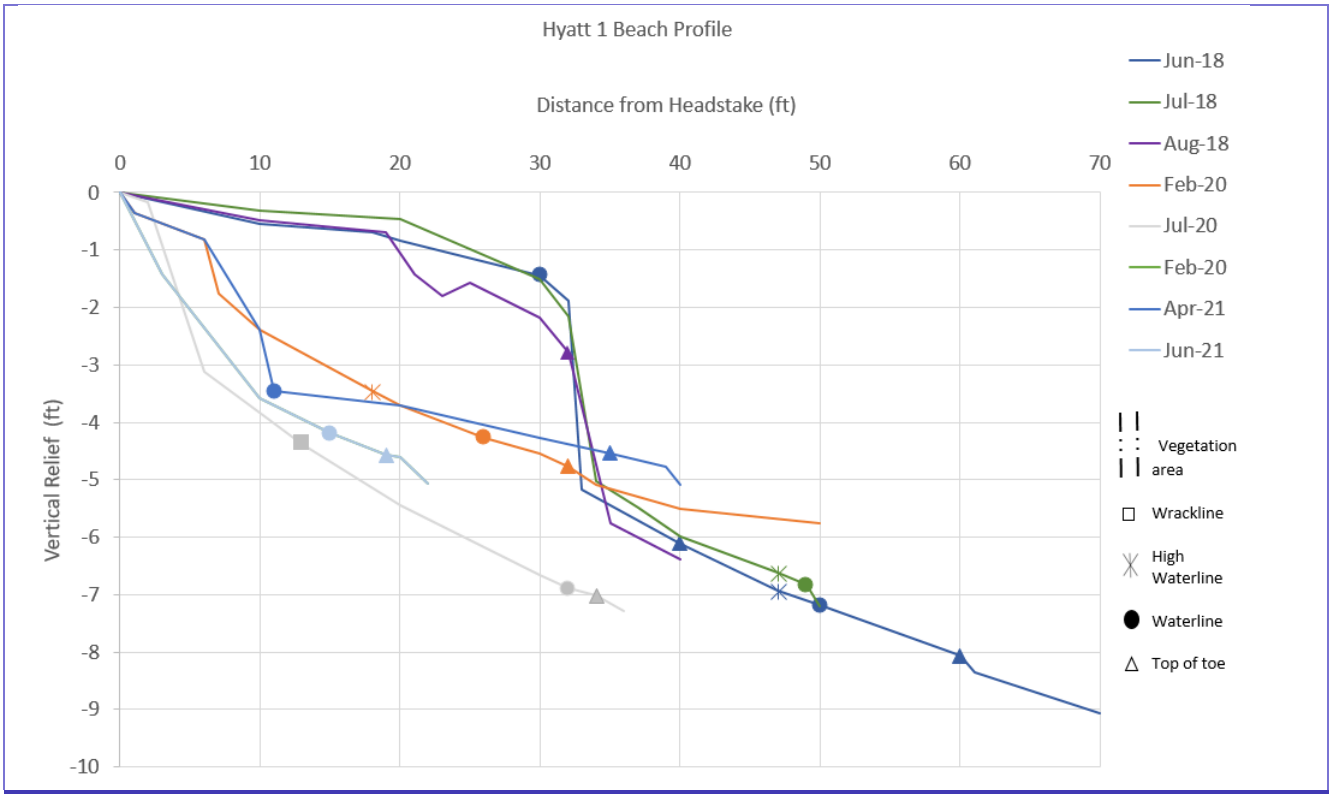
- ERODING and REPLACED with a Wrackline that ranges 30 – 55 ft and an elevation difference of less than 6 ft
- LOSS of shoreline by ~60 ft since 2017
- Outfall influenced

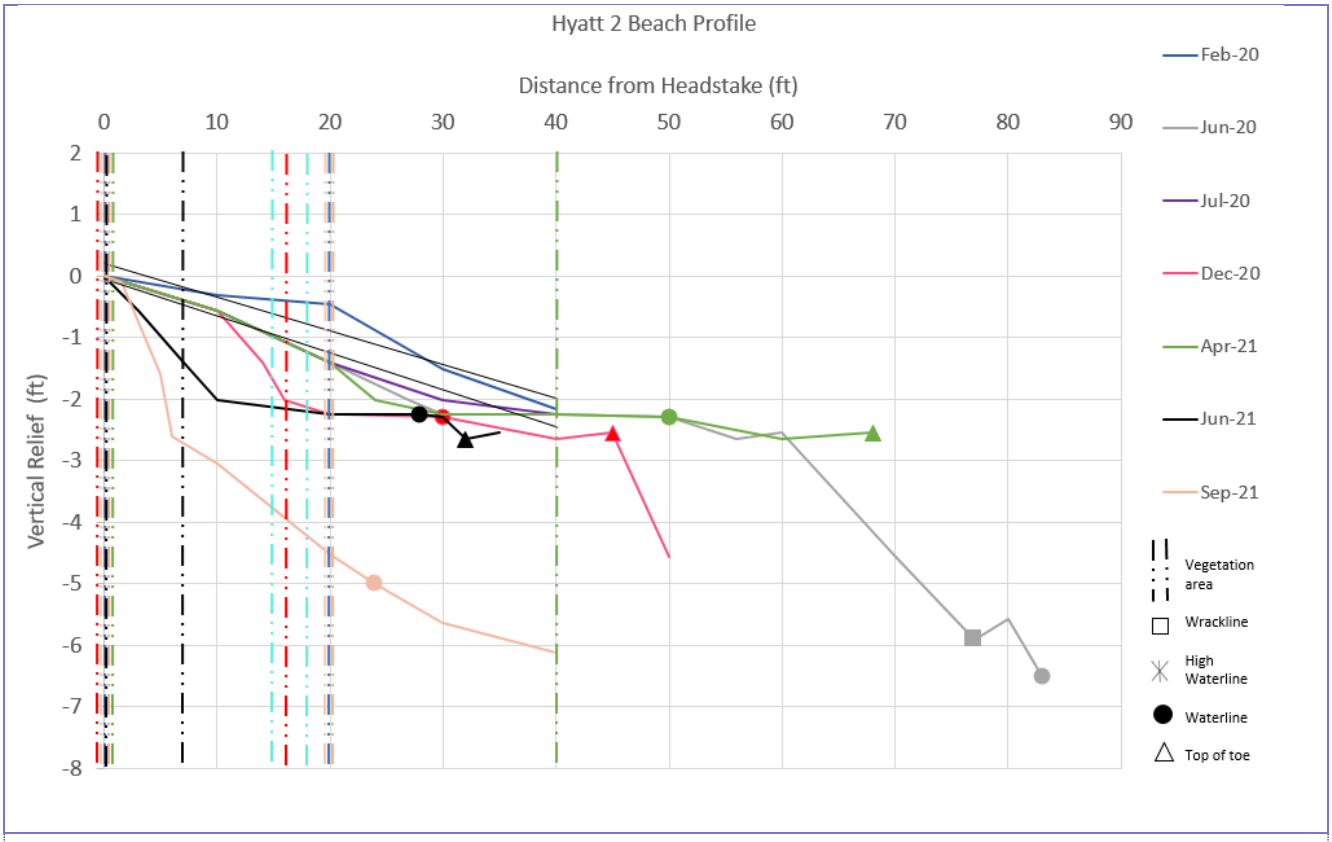
Hyatt 2 Highlights:

- ERODING and REPLACED
- LOSS of shoreline by ~30 ft since 2020
- Beach profile of Feb 2021 to Jul 2021 showed the elevation difference was less than 3 ft
- **History:** This area serves as a pathway from Micro Beach to the marine sports area north of Hyatt. It is eroding on the long term due to the abrasion exposing the bedrock after the September 2021 storm. The sand is pulled into the water during high wave energy conditions and pushed into the shore during lower wave energy conditions. We intend on replacing the headstake with a tree farther back.

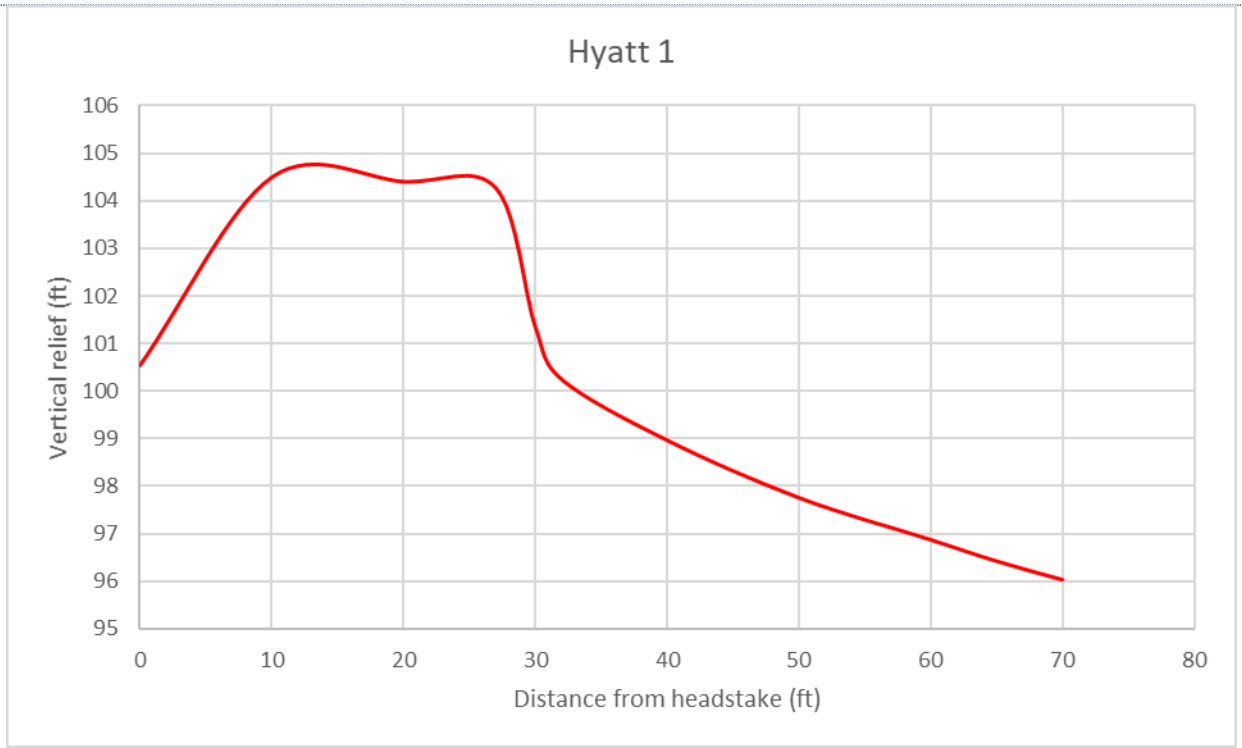


Hyatt Beach Profiles





Total Station



American Memorial Park

The AMP shoreline – short for American Memorial Park – is dynamic. The hydrodynamics is complex due to the patch reef, Smiling Cove Marina infrastructure, and the Main Channel interactions. Site-specific, smaller scaled nearshore dynamic modelling may help bring better understanding of long-shore processes. A pattern is observed: sand from the south shifts to the north with some sand returning to the south and most headed for the north. The sediment deficiency of the southern transects could be due to ongoing accretion north of Puntan Muchot). Wave energies are higher during southwest typhoon conditions given that the flows enter in through the main channel, but north-northwest conditions could drive the shift of sediment up north for this area.

American Memorial Park South 1 Highlights:

- ERODING in the long-term
- LOSS of shoreline by 35~ ft since 2020
- Elevation difference is less than 3 ft
- This area is eroding on the long term but is a highly dynamic. Sediment transport may contribute to the variation of shoreline position throughout time but the encroaching waterline and wave energy during high tide/storm events suggest this shoreline is eroding. The sand is pulled into the water during high wave energy conditions and pushed into the shore during lower wave energy conditions.

American Memorial Park South 2 Highlights:

- ERODING in the short-term with a Wrackline that ranges 37 – 70 ft with an elevation difference of more than 3 ft
- LOSS of shoreline by less than 70 ft since 2020
- In 2017, the sediment input appears to increase in the summer of 2017. The typhoon season of that year eroded the shoreline. After Super Typhoon Yutu, the berm has retreated significantly. Then the beach accreted until Feb 2021, when storms started eating away at the beach and ripped up the vegetation. Similar to AMP South 1, the seasonal sediment input may be a great contributor to a different shoreline position.

American Memorial Park Point 1 Highlights:

- ERODING in the short-term and REPLACED
- Wrackline ranges 30 – 60 ft and an ***elevation difference*** of less than 5 ft
- LOSS of shoreline is less than 70 ft since 2020
- In 2017, the sediment input appears to increase in the summer of 2017. The typhoon season of that year abraded the shoreline. After Super Typhoon Yutu, the berm has retreated significantly and the toe is deeper and closer to the waterline. Then the beach accreted until Feb 2021, when storms started eating away at the beach and ripped up the vegetation. Similar to AMP South 1, the seasonal sediment input may be a great contributor to a different shoreline position.

American Memorial Park Point 2 Highlights:

- ERODING in the short-term with a Wrackline that ranges 45– 150 ft and an ***elevation difference*** of less than 5 ft
- LOSS of shoreline is less than 70 ft since 2020
- **History:** This profile is subjected to damage by storms. It has accreted on Jan 2017 – July 2018. After Super Typhoon Yutu, the shoreline noticeably abraded. However, the September 2021 storm has eroded the shoreline by more than 50 feet. The sand in this area migrated to the northern transects. There is potential for the beach to rebuild itself.

American Memorial Park North 1 Highlights:

- ACCRETING in the short-term with an elevation difference of more than 8 ft
- GAIN of shoreline by more than 70 ft since 2018
- Sand from southern shorelines (South 1 through Point 2) may be migrating up northern as suggested by the width tripling in the last two years.

American Memorial Park North 2 Highlights:

- ACCRETING in the long-term with an elevation difference of more than 6 ft since 2017
- GAIN of shoreline by more than 110 ft since 2017
- Sand from southern shorelines (South 1 through Point 2) may be migrating up northern as suggested by the width tripling in the last two years.

American Memorial Park South 1

American Memorial Park South 2

American Memorial Park Point 1

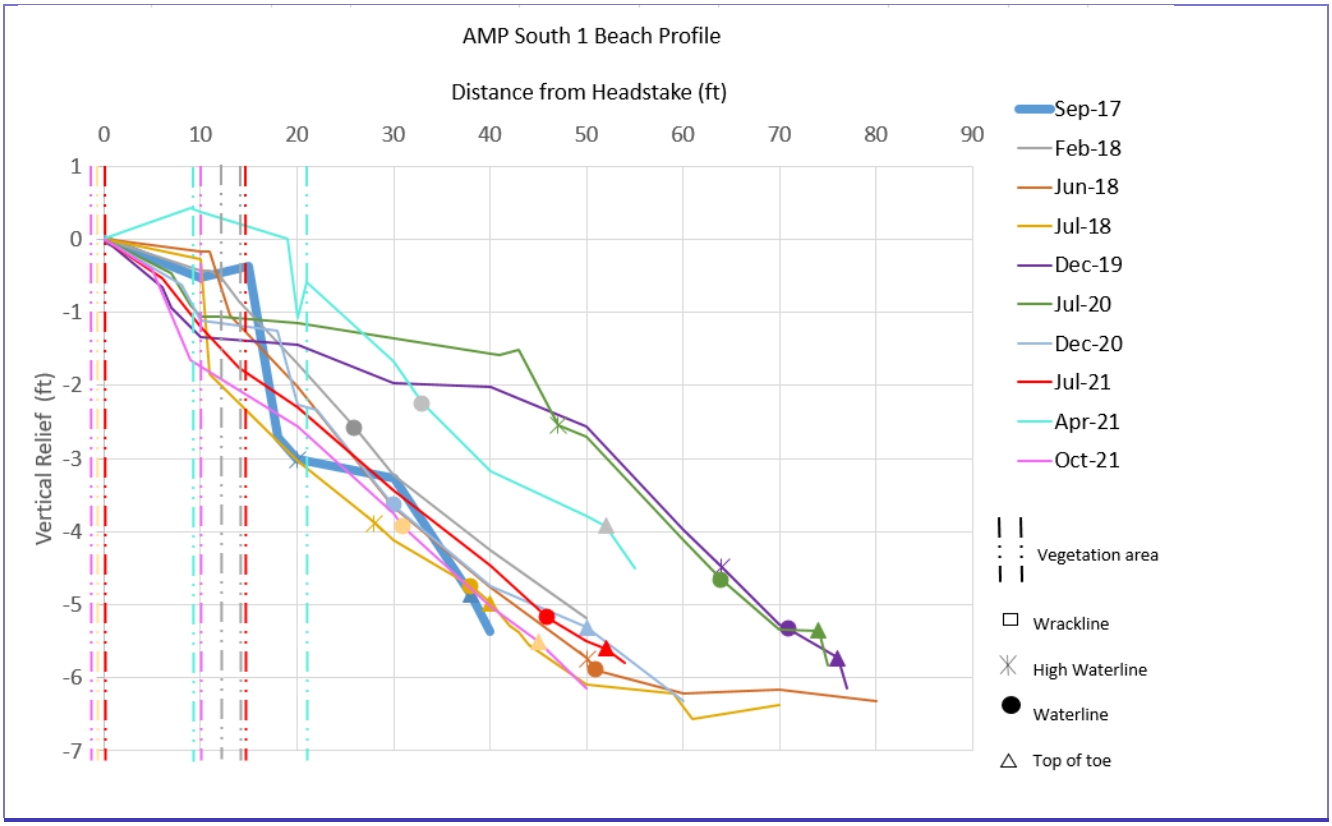
American Memorial Park Point 2

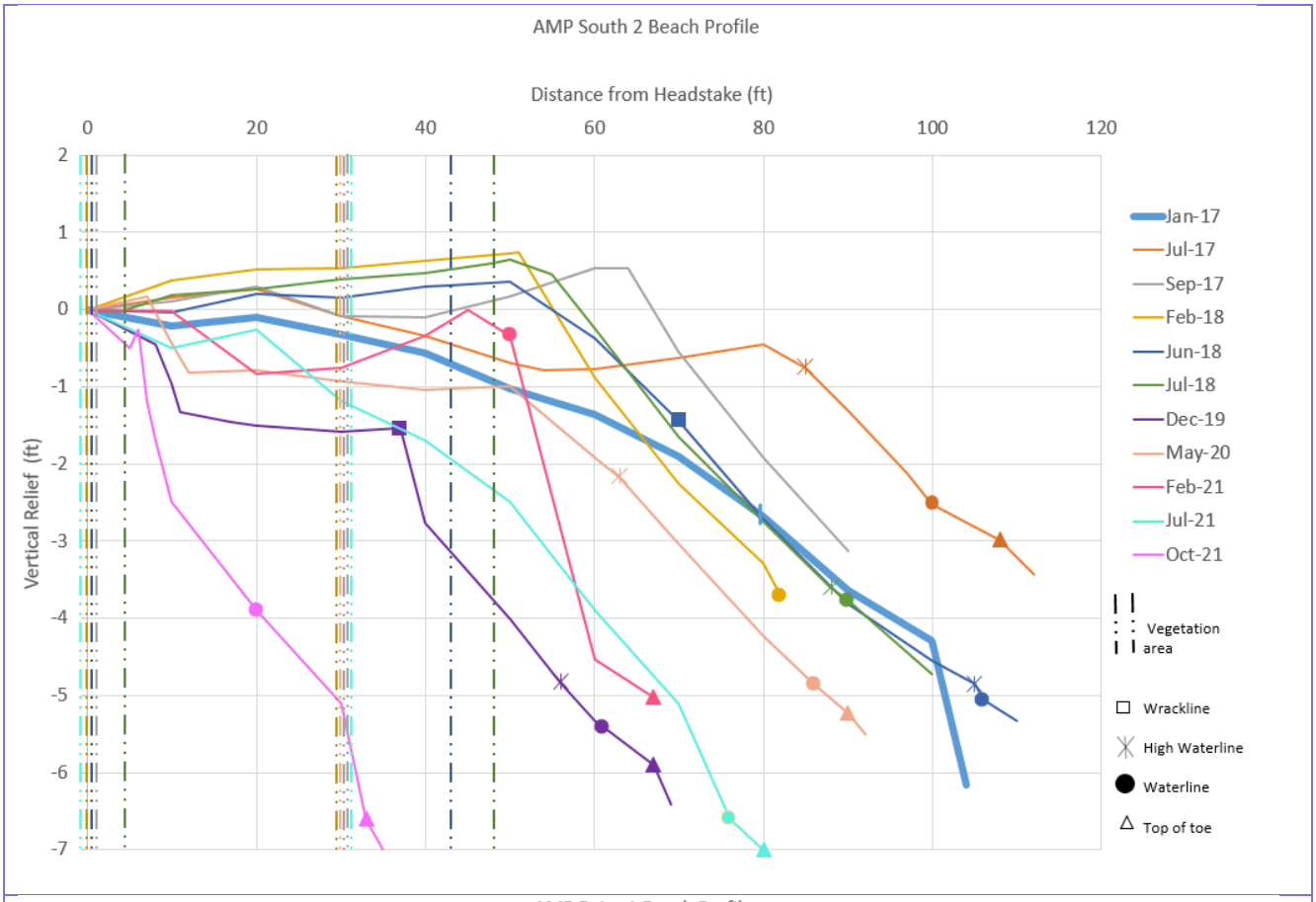
American Memorial Park North 1

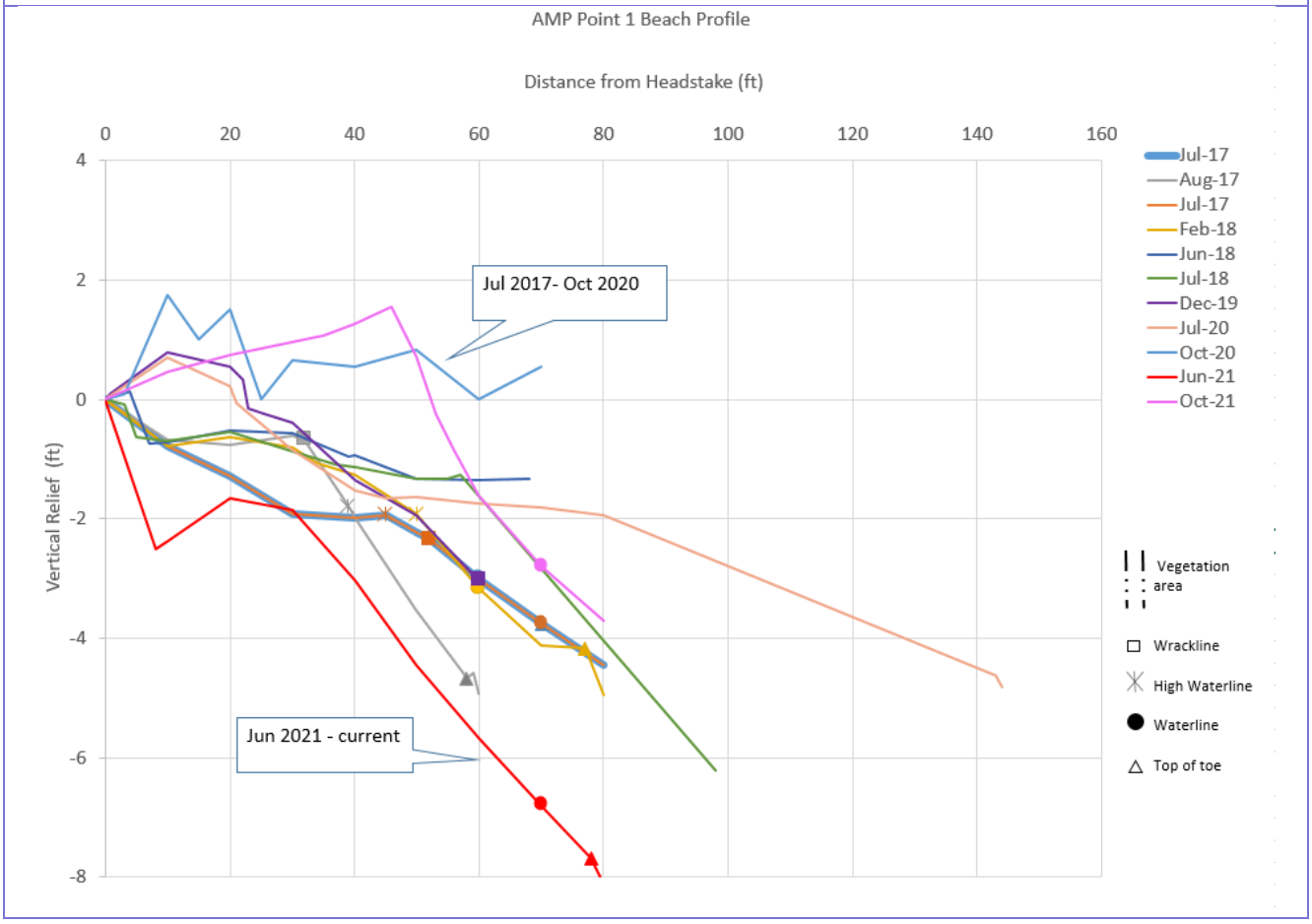
American Memorial Park North 2

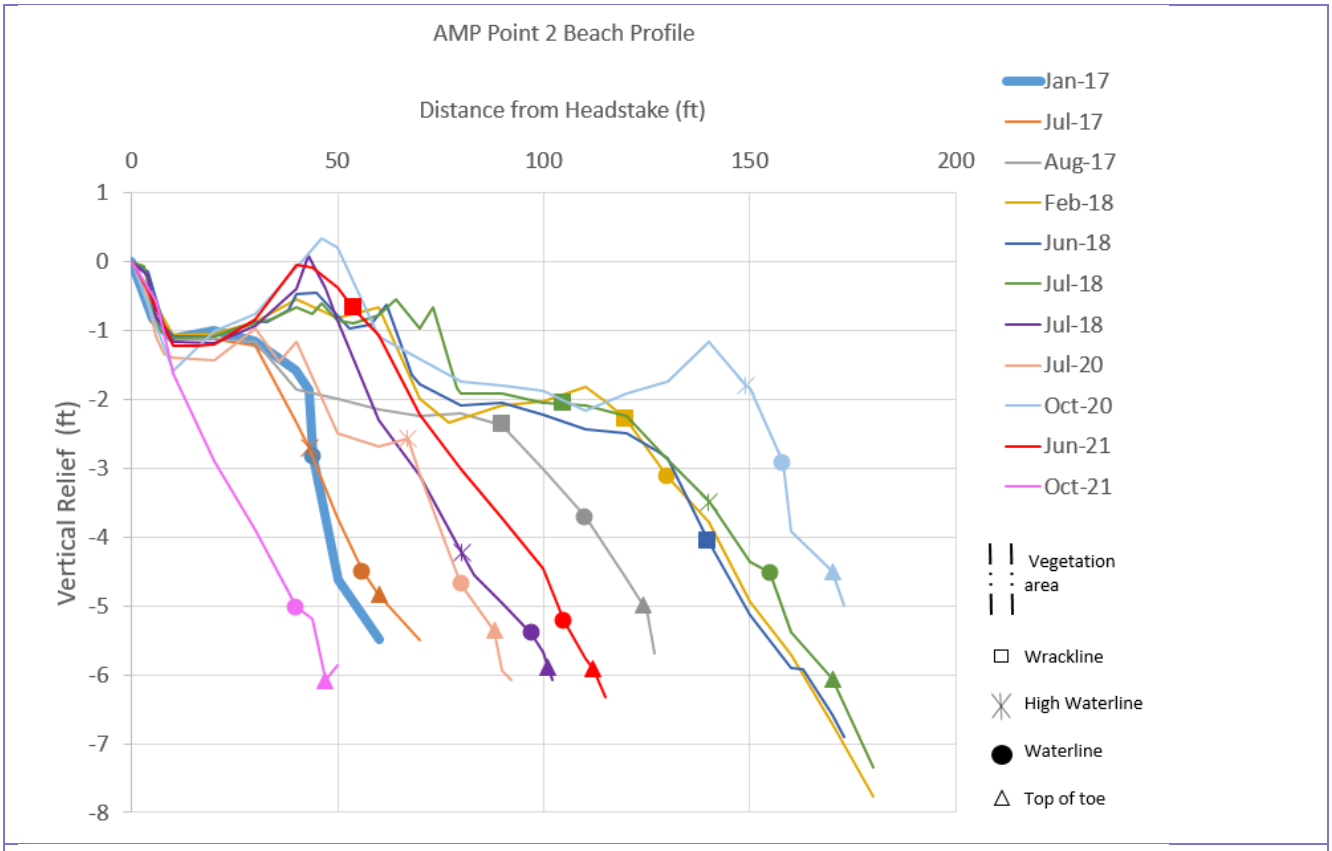
American Memorial Park North 3

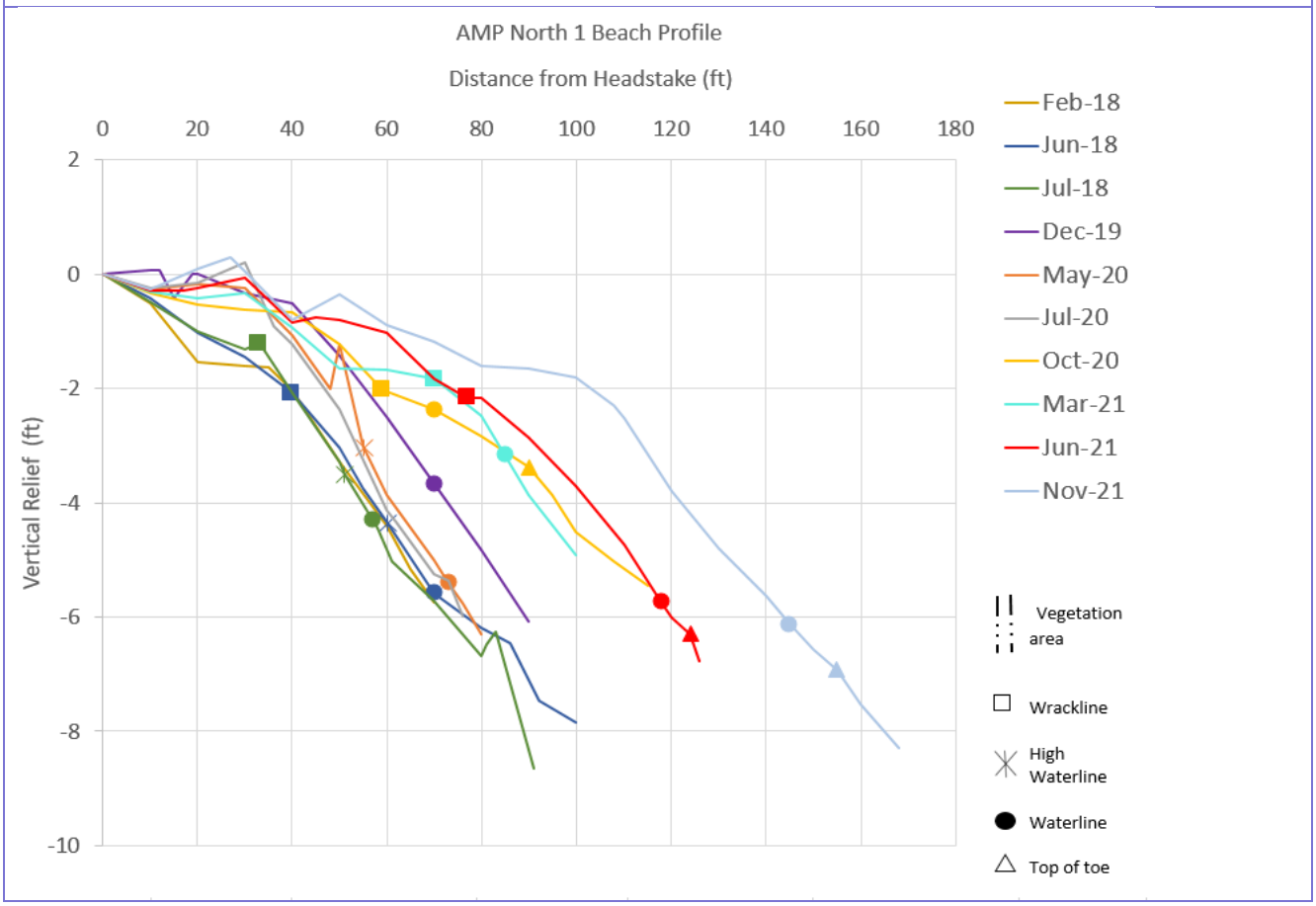
American Memorial Park Beach Profiles

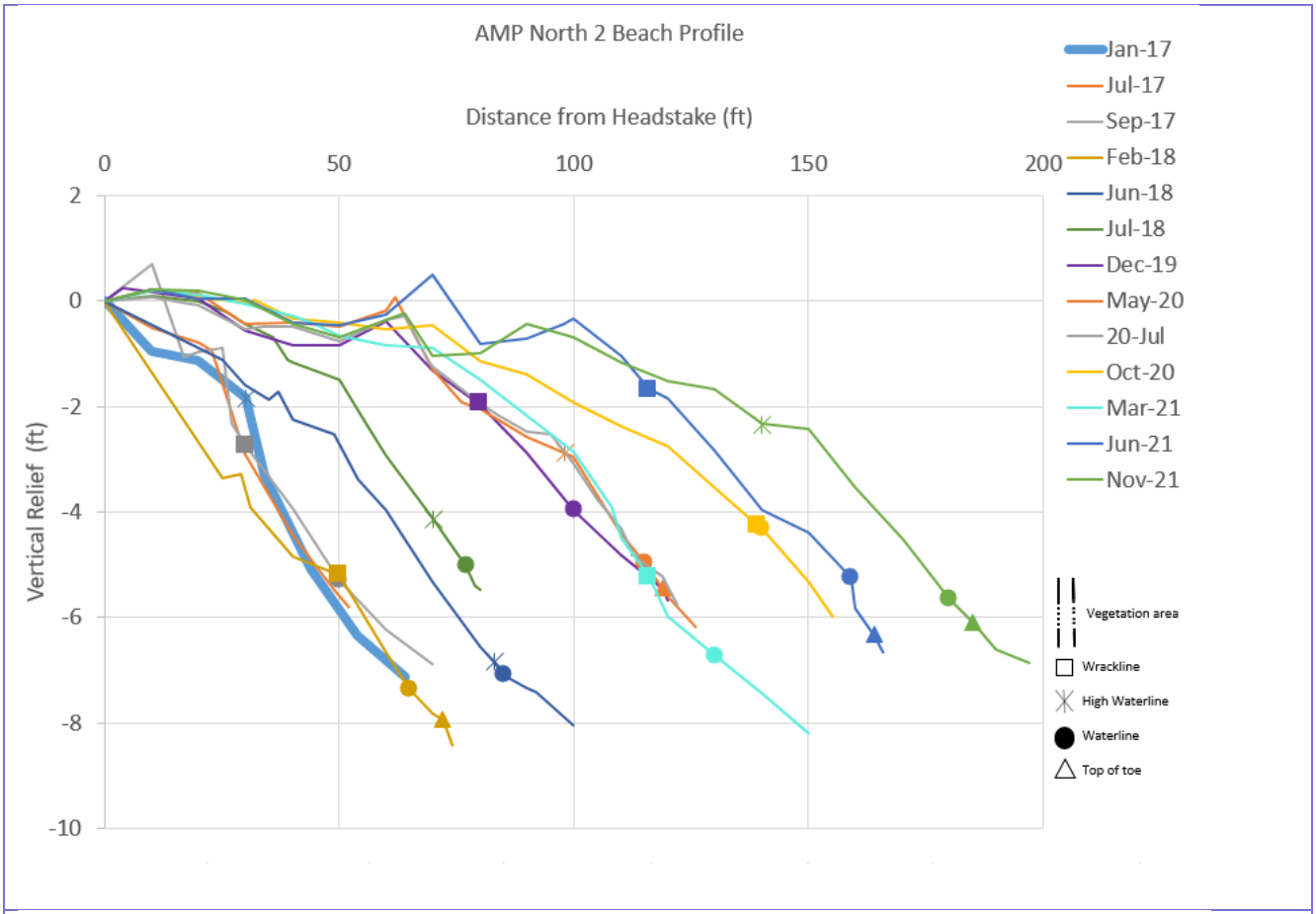


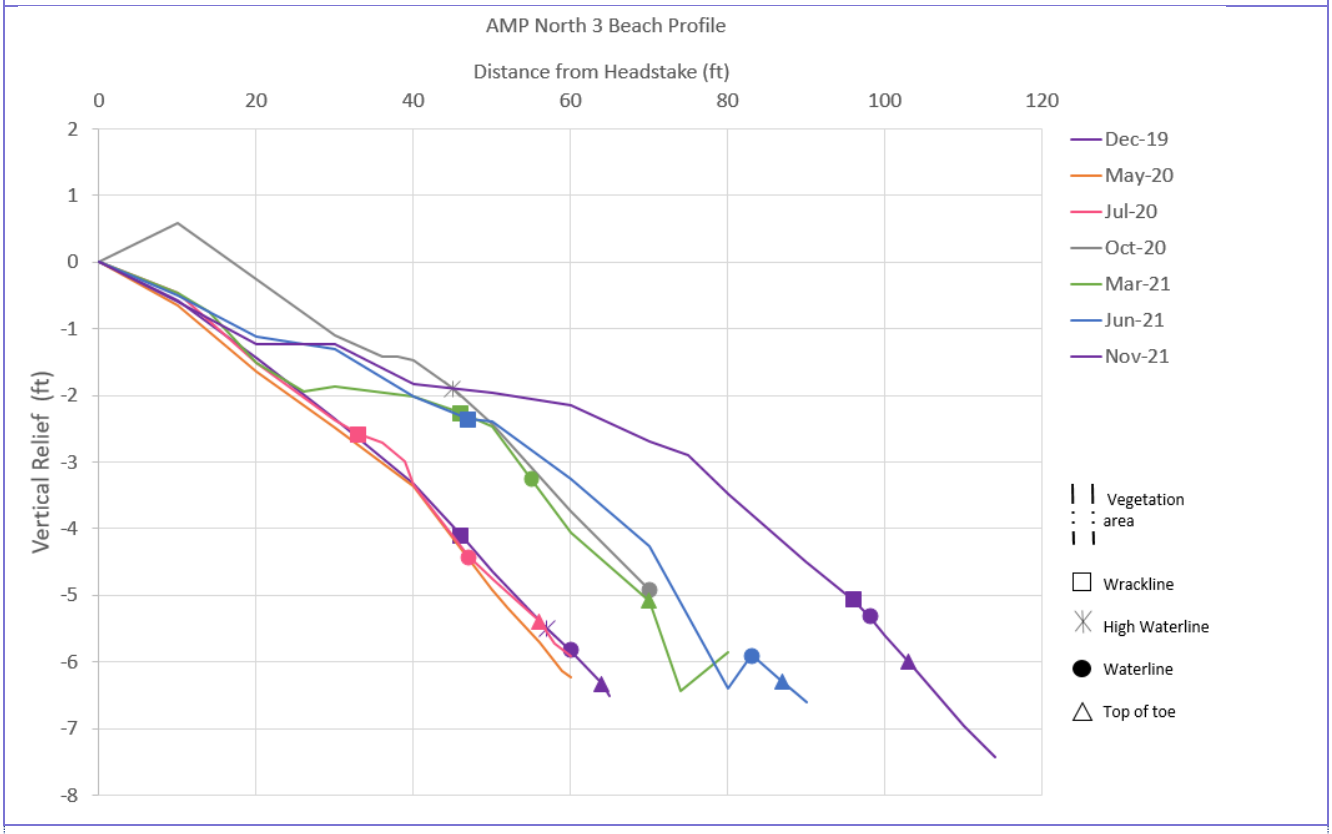

AMP South 2 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
2
1
0
-1
-2
-3
-4
-5
-6
-7
Vertical Relief (ft)
Jan-17
Jul-17
Sep-17
Feb-18
Jun-18
Jul-18
Dec-19
May-20
Feb-21
Jul-21
Oct-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


AMP Point 1 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
140
160
4
2
0
-2
-4
-6
-8
Vertical Relief (ft)
Jul 2017- Oct 2020
Jun 2021 - current
Jul-17
Aug-17
Jul-17
Feb-18
Jun-18
Jul-18
Dec-19
Jul-20
Oct-20
Jun-21
Oct-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

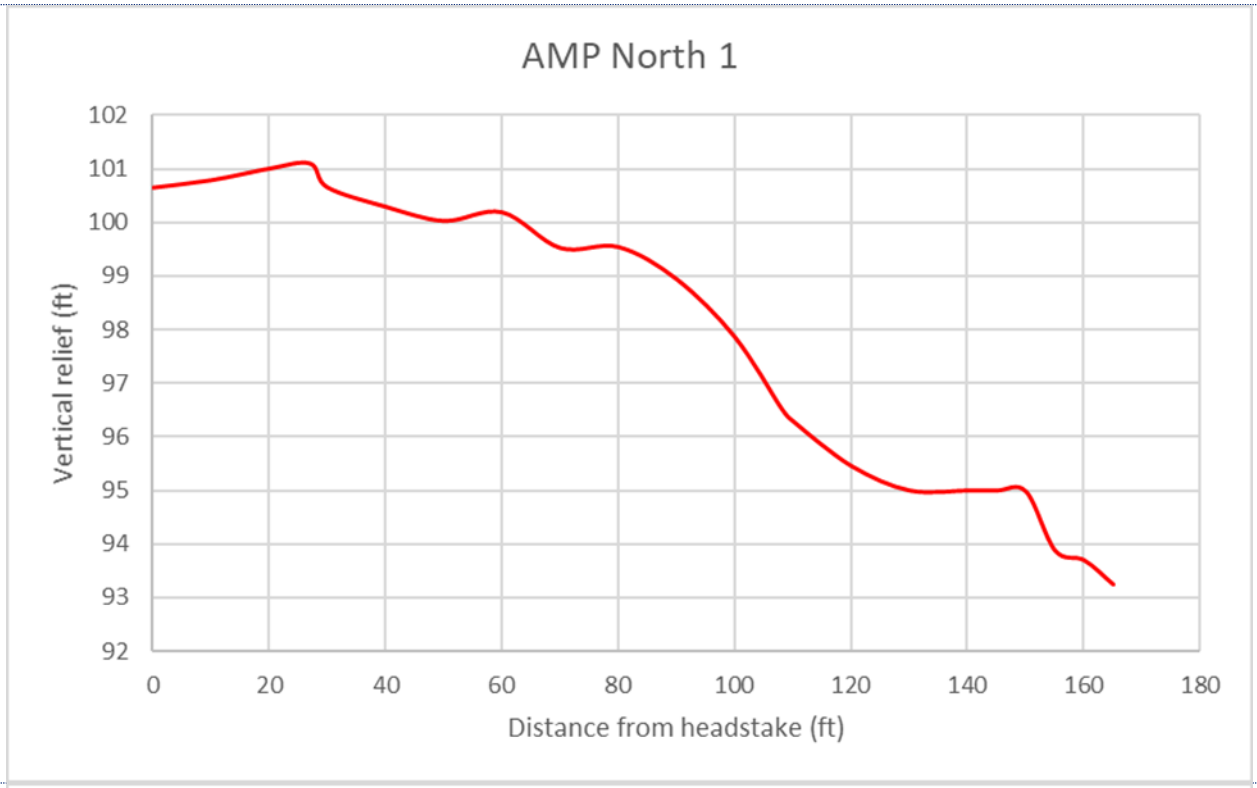

AMP Point 2 Beach Profile
Distance from Headstake (ft)
0
50
100
150
200
1
0
-1
-2
-3
-4
-5
-6
-7
-8
Vertical Relief (ft)
Jan-17
Jul-17
Aug-17
Feb-18
Jun-18
Jul-18
Jul-18
Jul-20
Oct-20
Jun-21
Oct-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

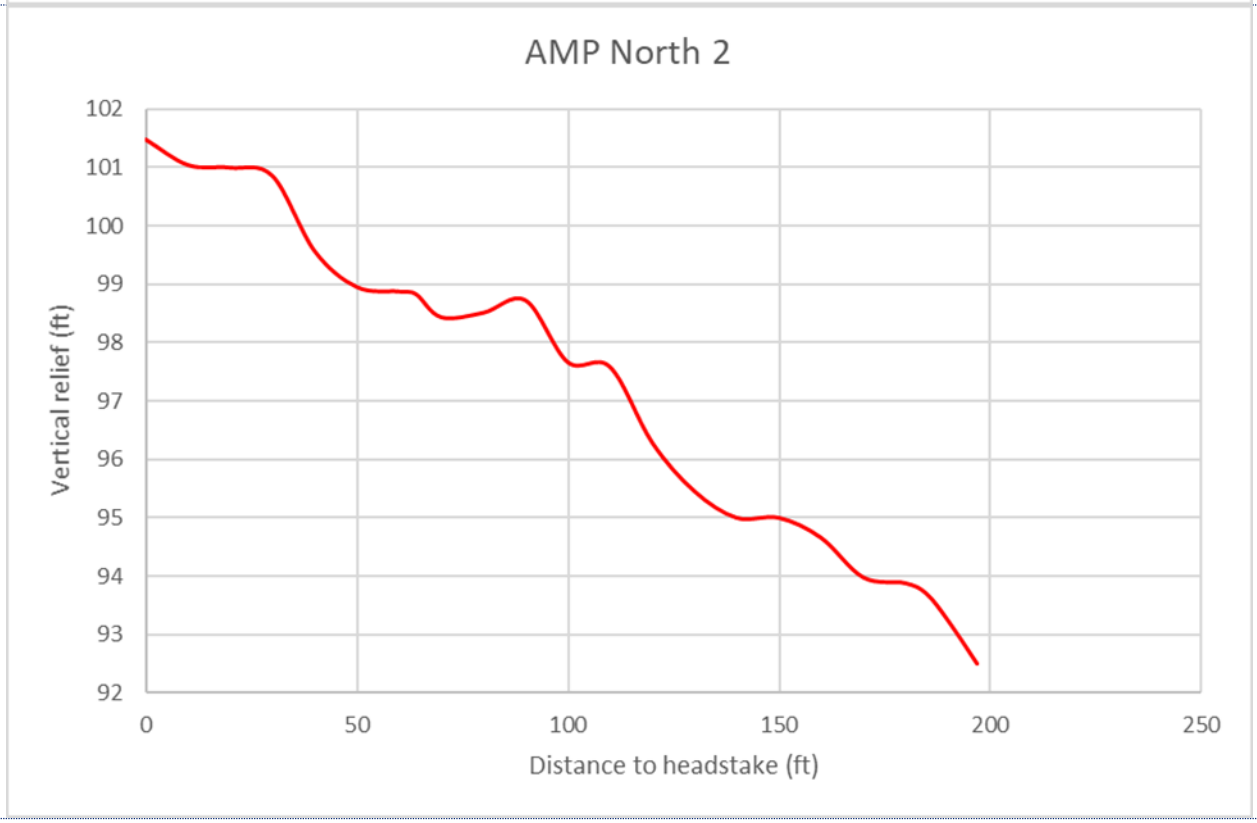

AMP North 1 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
140
160
180
2
0
-2
-4
-6
-8
-10
Vertical Relief (ft)
Feb-18
Jun-18
Jul-18
Dec-19
May-20
Jul-20
Oct-20
Mar-21
Jun-21
Nov-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

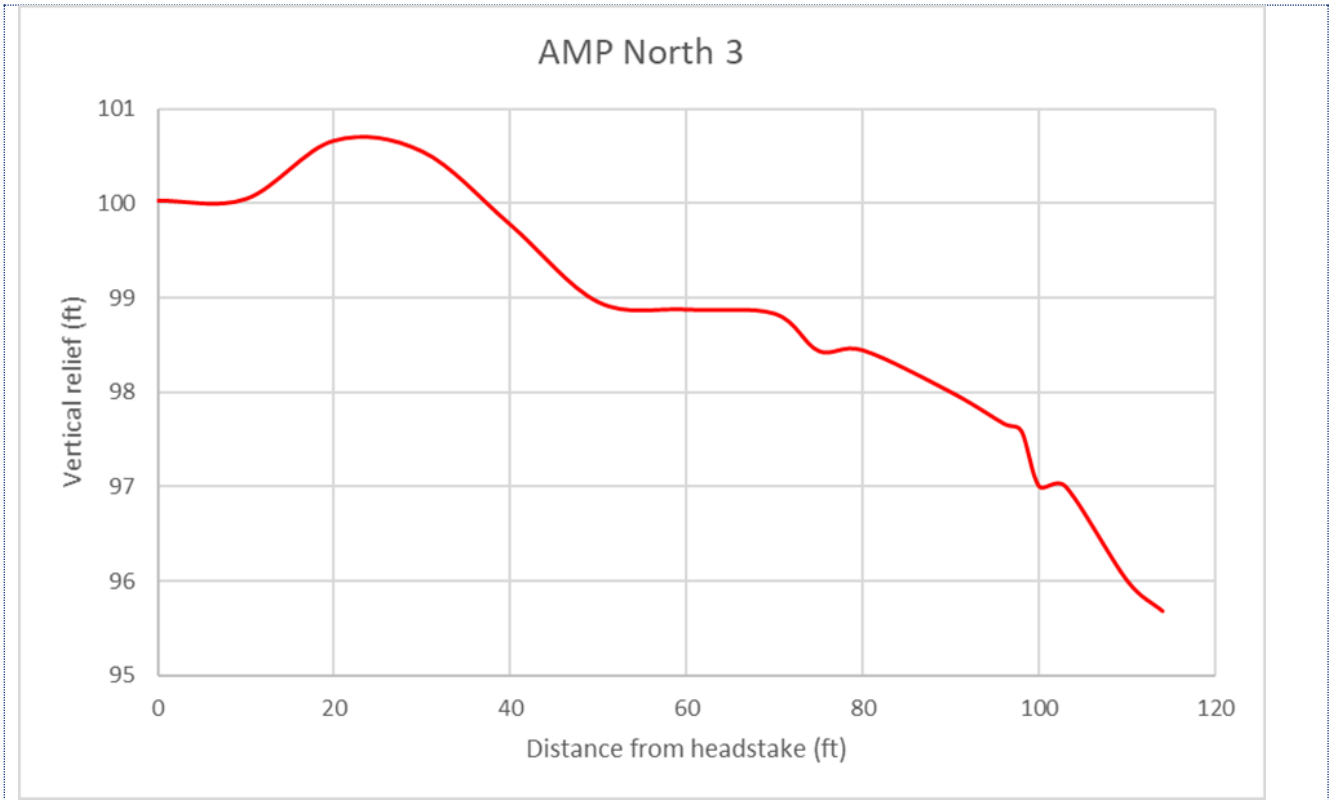

AMP North 2 Beach Profile
Distance from Headstake (ft)
0
50
100
150
200
2
0
-2
-4
-6
-8
-10
Vertical Relief (ft)
Jan-17
Jul-17
Sep-17
Feb-18
Jun-18
Jul-18
Dec-19
May-20
20-Jul
Oct-20
Mar-21
Jun-21
Nov-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


AMP North 3 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
Vertical Relief (ft)
Dec-19
May-20
Jul-20
Oct-20
Mar-21
Jun-21
Nov-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station






AMP North 3
101
100
99
98
97
96
95
Vertical relief (ft)
0
20
40
60
80
100
120
Distance from headstake (ft)

Pau Pau

Pau Pau is generally stable with the shoreline length declining from the south to north. The nearby reef attenuates wave energy but wave overtopping may contribute to short-term erosion. Sediment from nearby sources replenishes the beach. Tides may influence the length of this shoreline. For both typhoon wave conditions, this area receives high wave energy. North-northwest typhoon conditions fare worse with significant wave height potential of up to 3 m.

Pau Pau 1 Highlights:

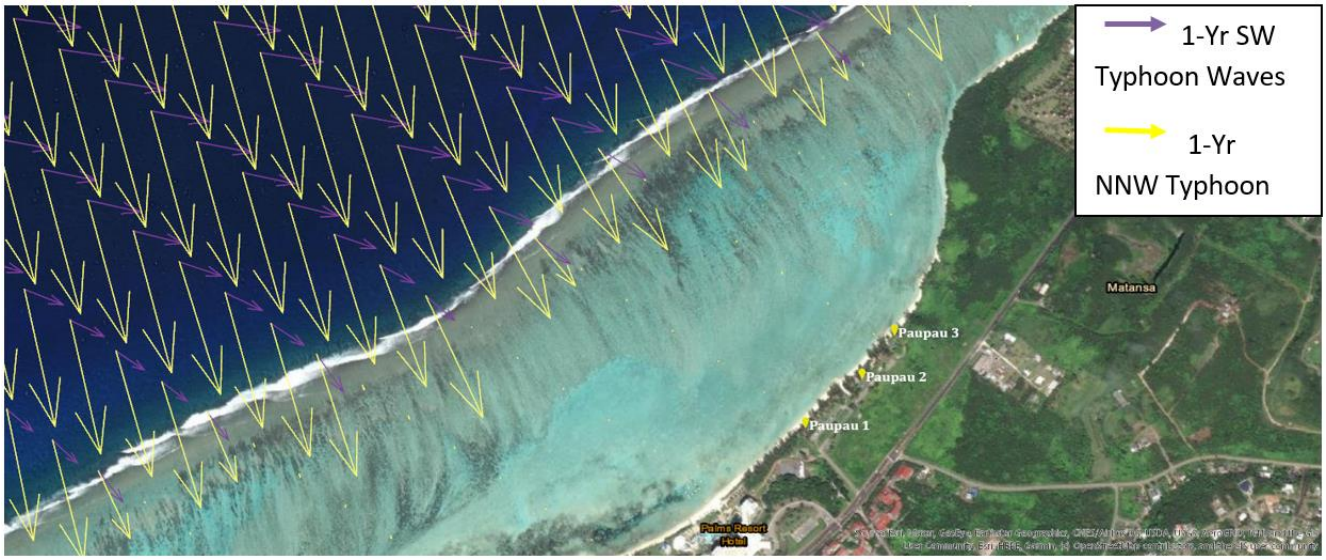
- STABLE with a Wrackline that ranges 68 – 90 ft and an elevation difference of 9 ft
- This beach profile seems to vary from time to time, dependent on deposits from the nearby reef. The headstake is at a distance in the backshore, closer to the parking lot.

Pau Pau 2 Highlights:

- STABLE with a Wrackline that ranges 40 – 60 ft with an elevation difference of 8 ft
- This beach profile has shifted in January 2017. The shoreline appears to have experienced some abrasion in Feb 2018 but then has generally stabilized over time.

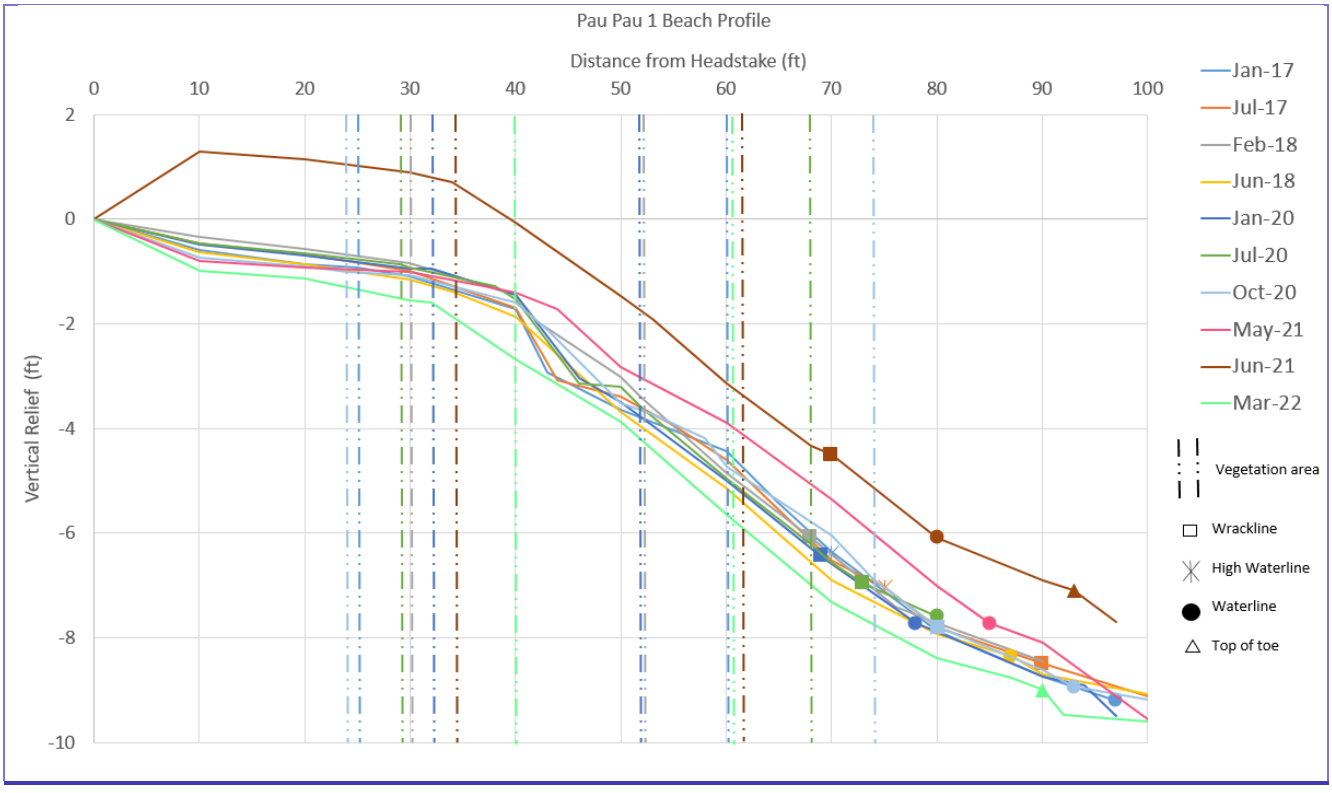
Pau Pau 3 Highlights:

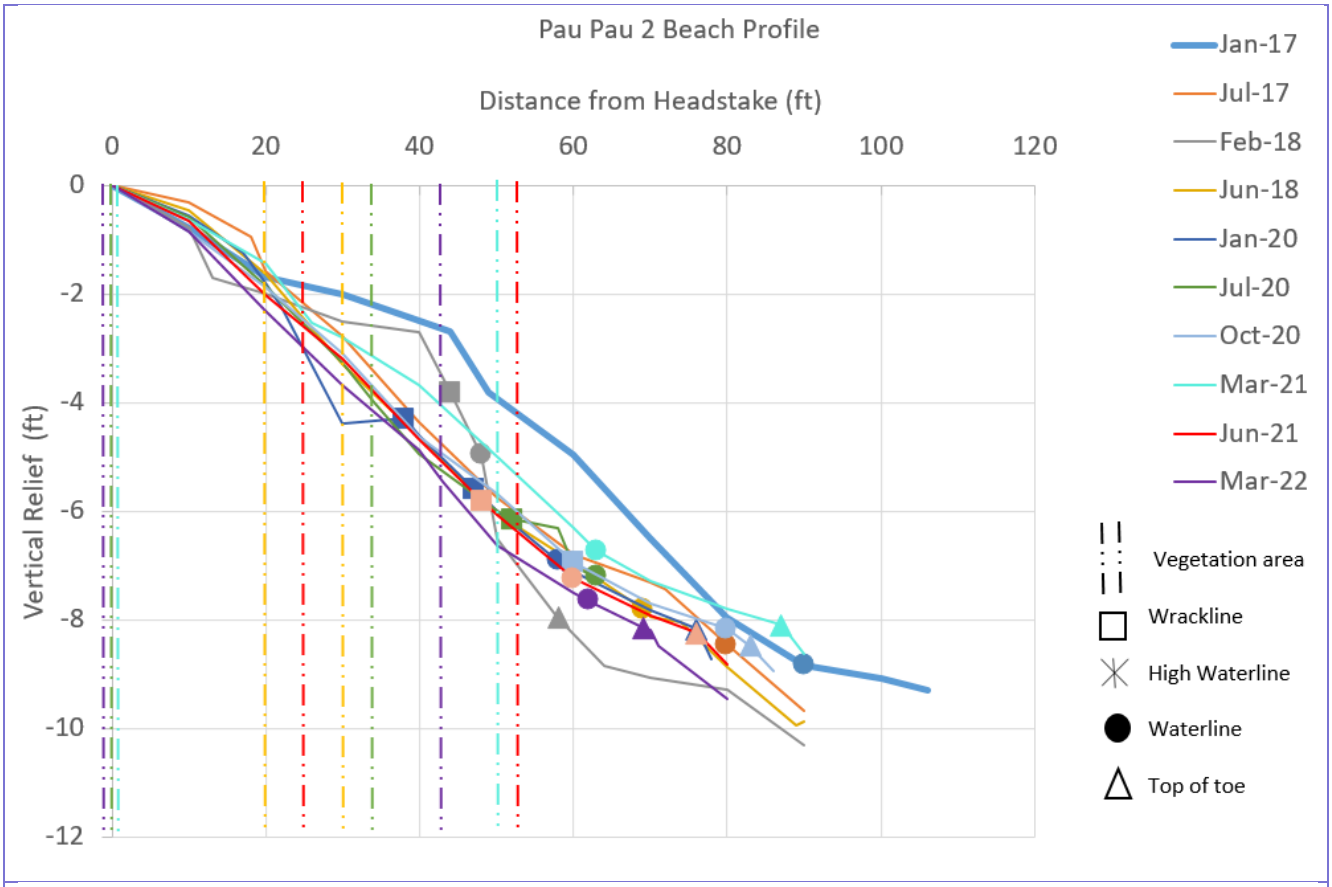
- STABLE with a Wrackline that that ranges 26 – 50 ft and an elevation difference of 9.5 ft
- This beach profile is variable compared to the other two transects in the site.

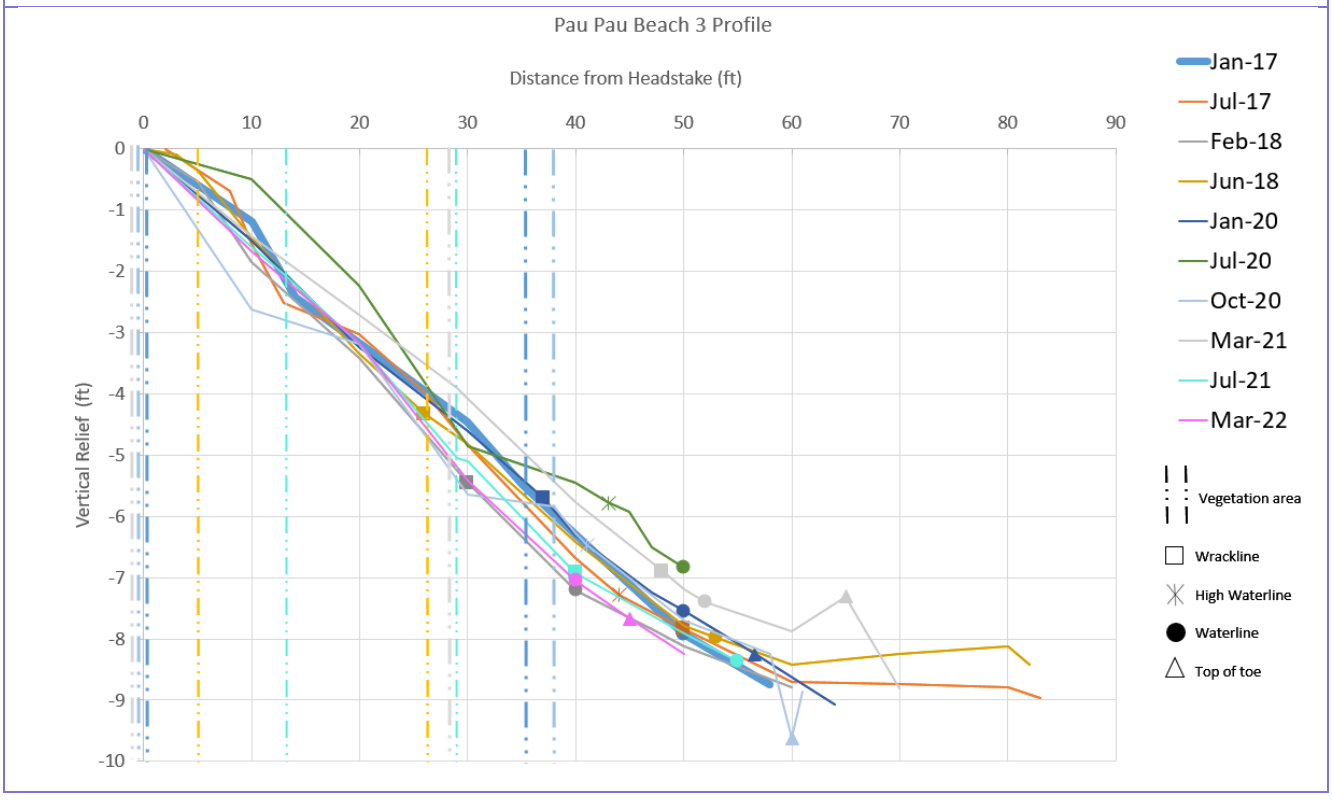


Pau Pau 1

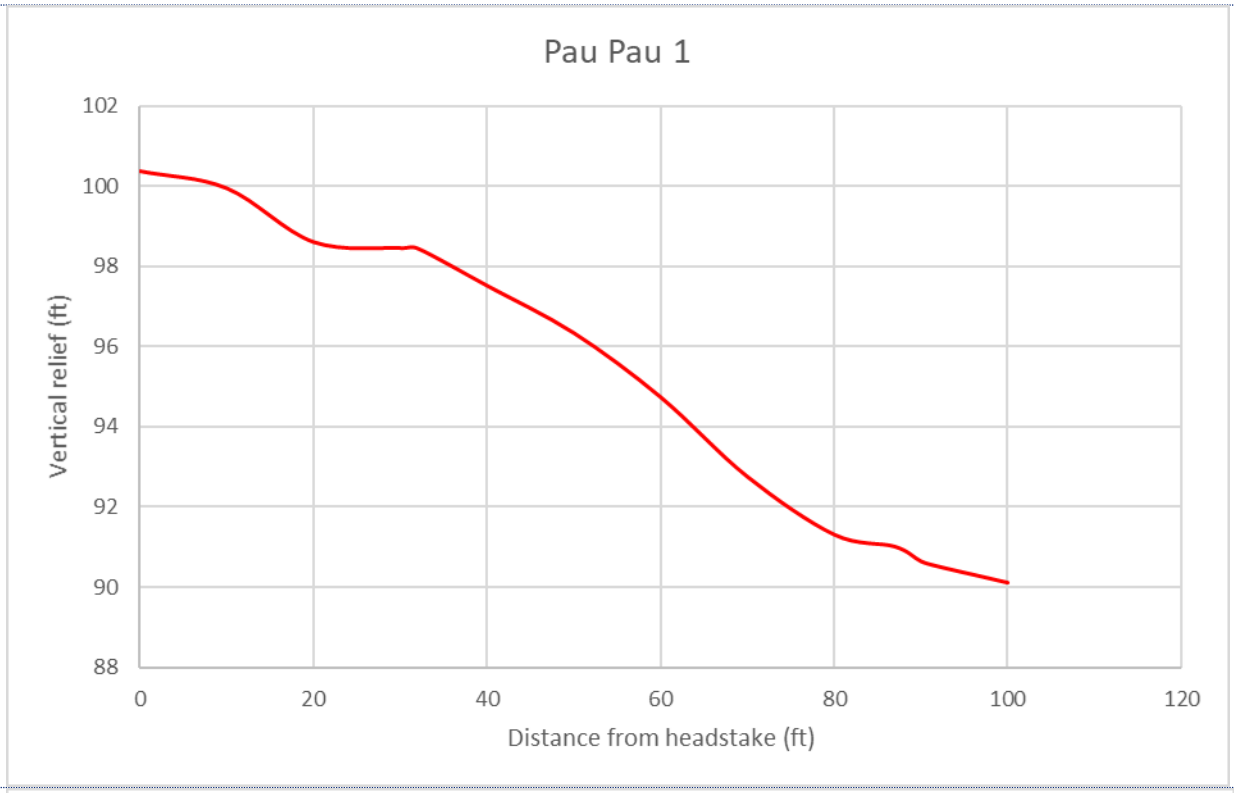
Pau Pau Beach Profiles

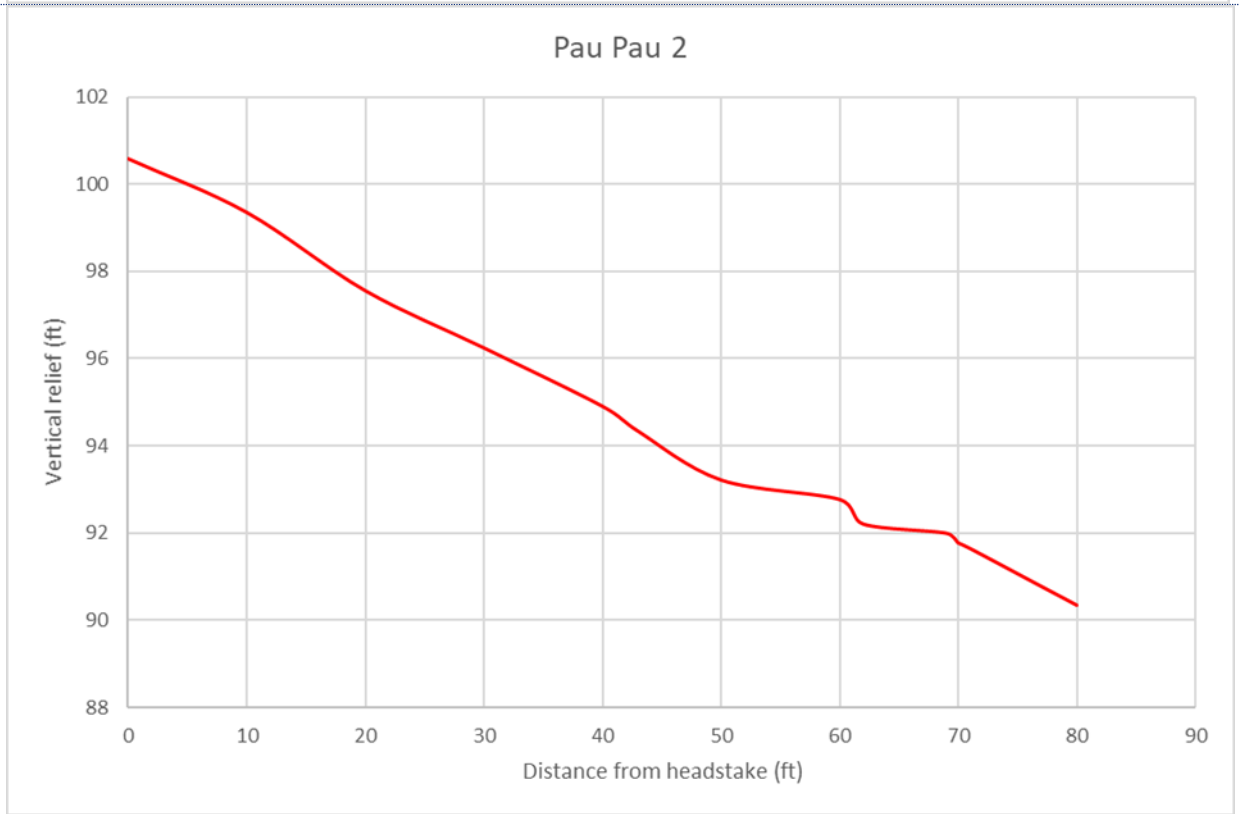


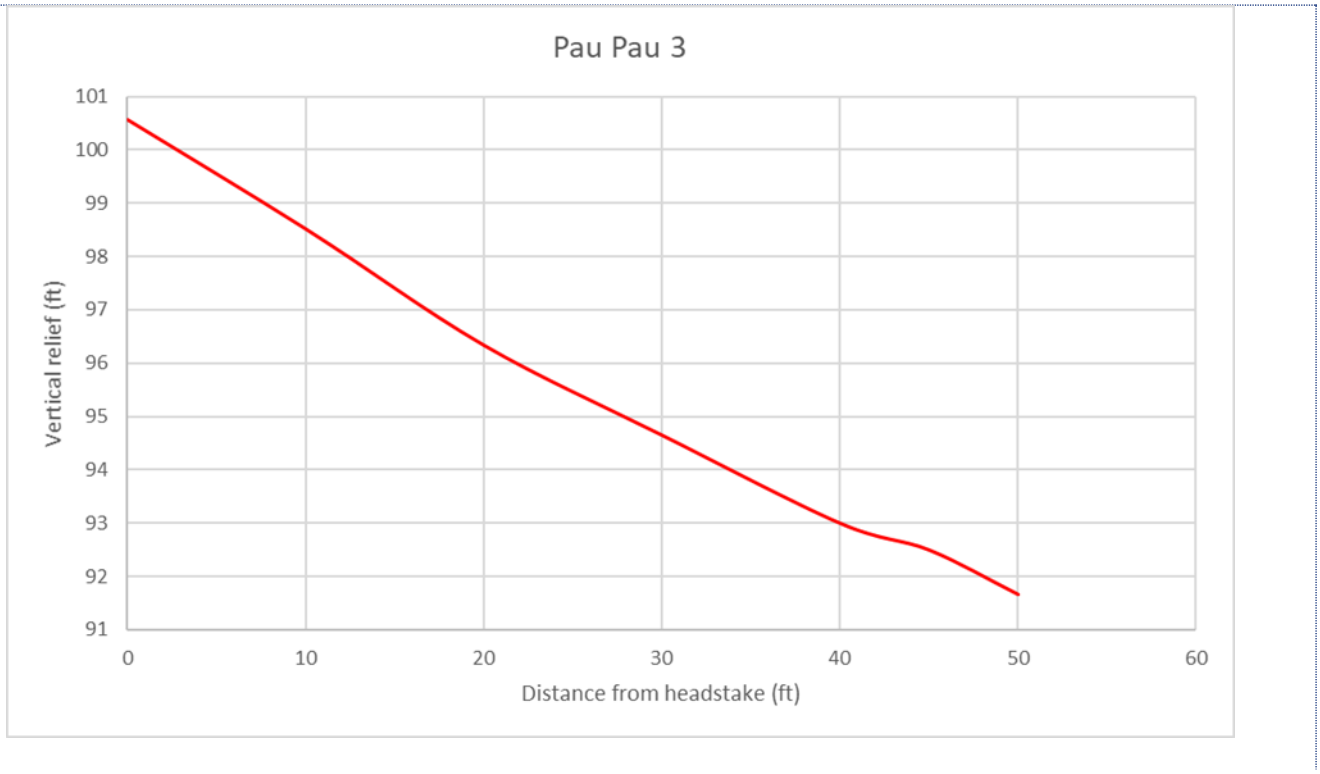

Pau Pau 2 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
Vertical Relief (ft)
0
-2
-4
-6
-8
-10
-12
Jan-17
Jul-17
Feb-18
Jun-18
Jan-20
Jul-20
Oct-20
Mar-21
Jun-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Pau Pau Beach 3 Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
90
Vertical Relief (ft)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Jan-17
Jul-17
Feb-18
Jun-18
Jan-20
Jul-20
Oct-20
Mar-21
Jul-21
Mar-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station






Pau Pau 3
Vertical relief (ft)
101
100
99
98
97
96
95
94
93
92
91
0
10
20
30
40
50
60
Distance from headstake (ft)

Wing

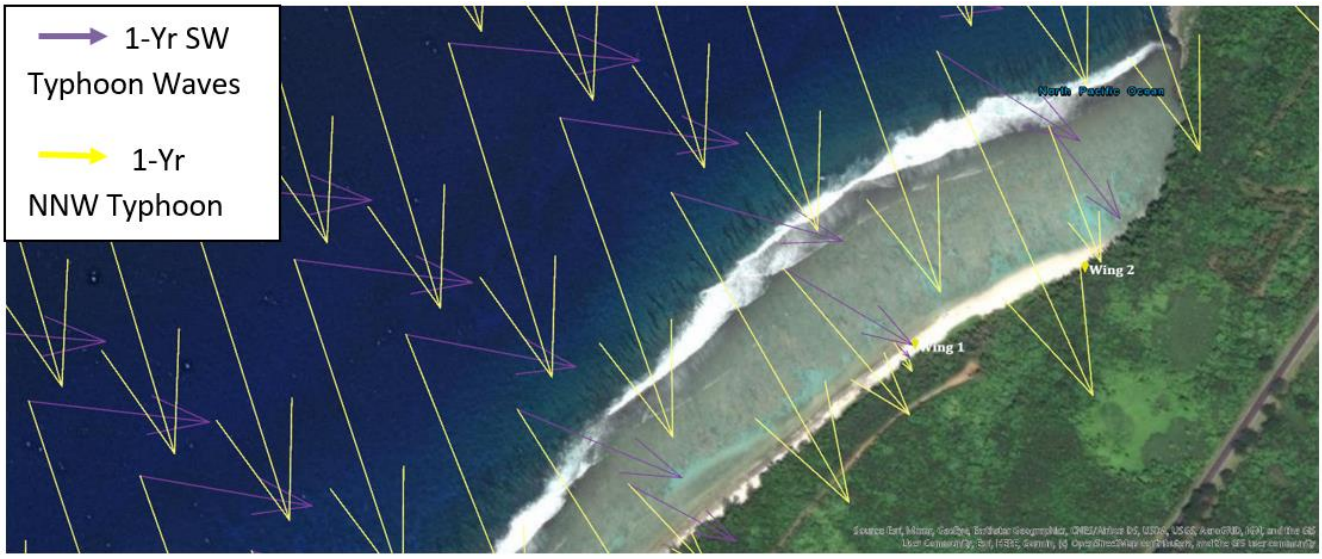
As the most northern shoreline of Saipan, Wing Beach appears to have high diversity of coastal strand species and a coral rubble shoreline. Erosion is of low concern in this area despite the high potential for strong storm-induced wave energy to beat at the shoreline. Regular sediment input may have originated from the nearby reef, pouring sand and coral rubble from inland and sea cliffs.
The southwest and northwest typhoon conditions both bring in high wave energies. The north-north wave conditions fare worse with potential of up to 4 m significant wave heights.

Wing 1 Highlights:

- STABLE with a Wrackline that ranges 58 – 91 ft and an elevation difference of 11.5 ft
- This beach profile may suggest that the shoreline experiences a good amount of sediment input and output from the influence of the nearby reef system. Feb 2018 had the most erosion while July 2017 saw the most accretion.

Wing 2 Highlights:

- DYNAMIC with an elevation difference of 11 ft
- Based on observations from the Feb-21 record shows, a high tide with a high wave event greatly abrades the berm along this transect. With the input of coral rubble from the nearby reef, recovery to the average shoreline length is anticipated.

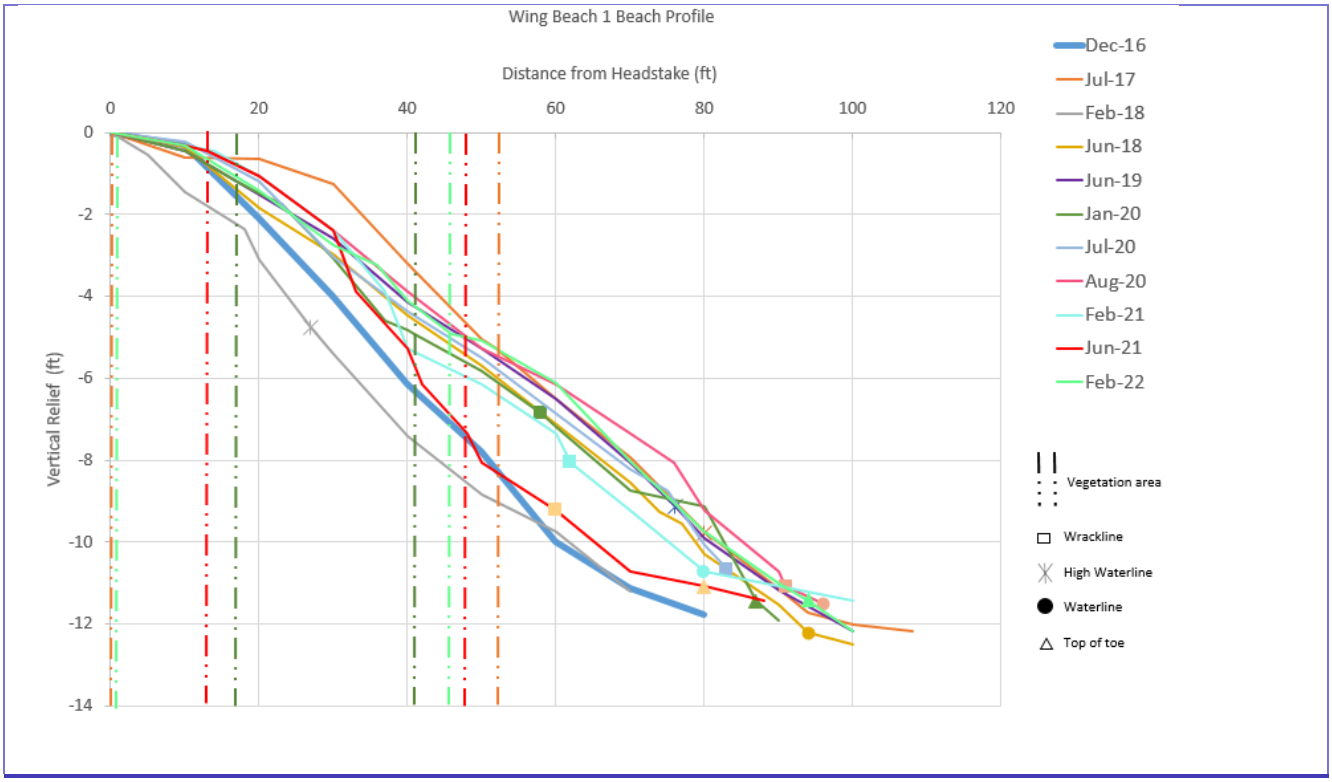


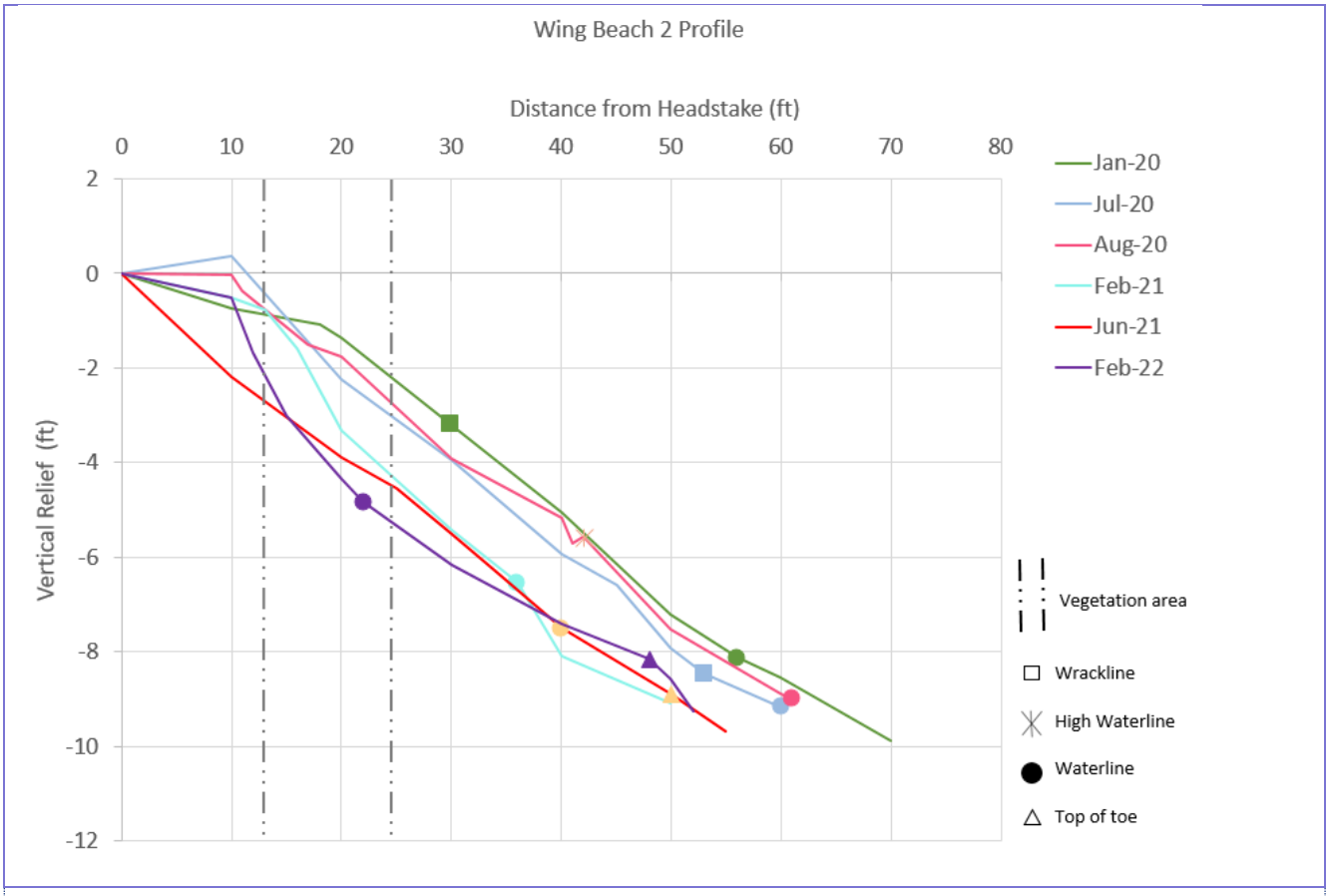
2018

2022

Wing 2

Wing Beach Profiles



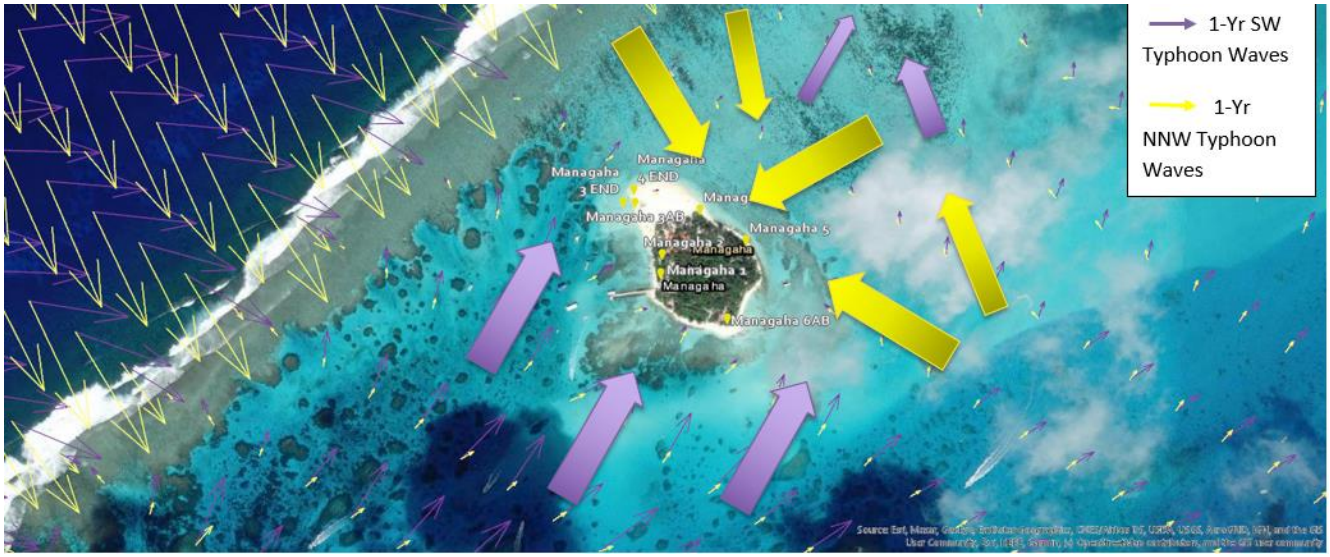

Wing Beach 2 Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
80
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Jan-20
Jul-20
Aug-20
Feb-21
Jun-21
Feb-22
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

Total Station

Mañagaha Beach Profiles and Key Findings

Mañagaha experiences ocean currents from all angles as it is situated within the Saipan Lagoon. The Saipan channel is located east of the islet with the protected barrier reef to the west.
In the 1990s, erosion was a concern expressed by users when the removal of WWII relicts caused a shift in the sediment transport. The eastern side, habitat to nesting shearwater birds, is subjected to erosion and storm surge while the northwestern side has an expanding large dune. High energy waves attacking the eastern shoreline can cause mortality of young shearwater birds nested on that side during June through October. The Division of Fish and Wildlife actively manages this nesting site, and plans to replace the deteriorating fencing.

The Mañagaha Study (Fletcher, 2007) predicted that the island may potentially stabilize in the future. In the case it may not, shoreline interventions may be necessary to protect the eastern side. The sandy nearshore remains a valuable feature of this islet.



Mañagaha shorelines interact with varying wave conditions within the Lagoon at all directions. The map above is generated using Hydrodynamic Study typhoon waves data, and large arrows were added to emphasize direction for the two conditions. The longshore transport slightly varies for the southwest and north-northwest wave conditions. During southwest conditions, longshore transport from the south is greater, which hits Transects 6A, 6B, 1, 2, 3A, and 3B. This longshore pattern seems to perpetuate the accretion occurring at Transects 3A and 3B. Transects 4 and 5 seem to be more impacted during the north-north west typhoon conditions. High wave energy occurs during the southwest typhoon condition, which appears to impact the southern part of the islet. For both conditions, the eastern side of the island appear to be eroding. Beach recovery may occur due to the sediment sources all around the island. This is DCRM's interpretation of the Mañagaha's longshore transport, in which future monitoring findings will investigate to validate these assumptions.

Mañagaha 1 Highlights:

- ERODING with a Wrackline that ranges 30 – 40 ft and an elevation difference of 8 ft
- Adjacent to this headstake is the dock infrastructure, which greatly influences how sediment moves.

Mañagaha 2 Highlights:

- STABLE with an elevation difference of 11 ft
- Variation begins past the 25 ft distance from the headstake.
- Rocky grounds are seaward.

Mañagaha 3A Highlights:

- ACCRETING in the long-term with an elevation difference of 8 ft
- Second berm is forming.

Mañagaha 3B Highlights:

- ACCRETING in the long-term with a Wrackline that ranges 90 – 100 ft and an elevation difference of 8 ft

Mañagaha 4 Highlights:

- UNDETERMINED and REPLACED previous headstake with an elevation difference of 5 ft
- Erosion down slope is observed in the long-term.

Mañagaha 5 Highlights:

- UNDETERMINED and REPLACED previous headstake
- Wrackline ranges 90 – 100 ft and an elevation difference of 11 ft

Mañagaha 6A Highlights:

- UNDETERMINED and REPLACED previous headstake
- Erosion is known and observed in the long-term.

Mañagaha 6B Highlights:

- UNDETERMINED AND REPLACED previous headstake
- Wrackline that ranges 90 – 100 ft and an elevation difference of more than 5 ft
- Erosion is known and observed in the long-term.

Mañagaha 7 Highlights:

- ERODING in the short-term with a Wrackline that ranges 0 – 11 ft and an elevation difference of 4 ft
- This current headstake receives sediment; however, it is observed that high energy and high tides have allowed the waterline to strike the headstake.

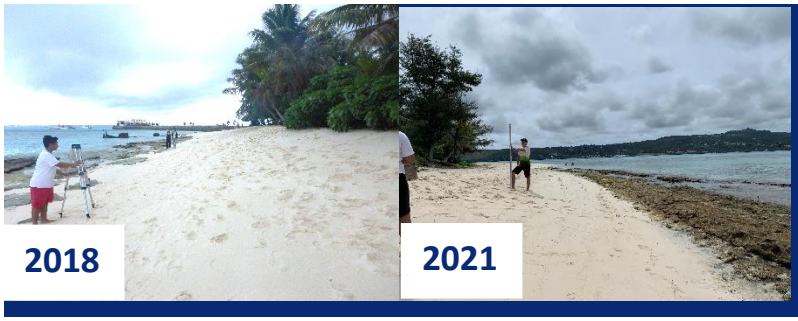
Mañagaha 1

Mañagaha 2

Mañagaha 3A

Mañagaha 3B

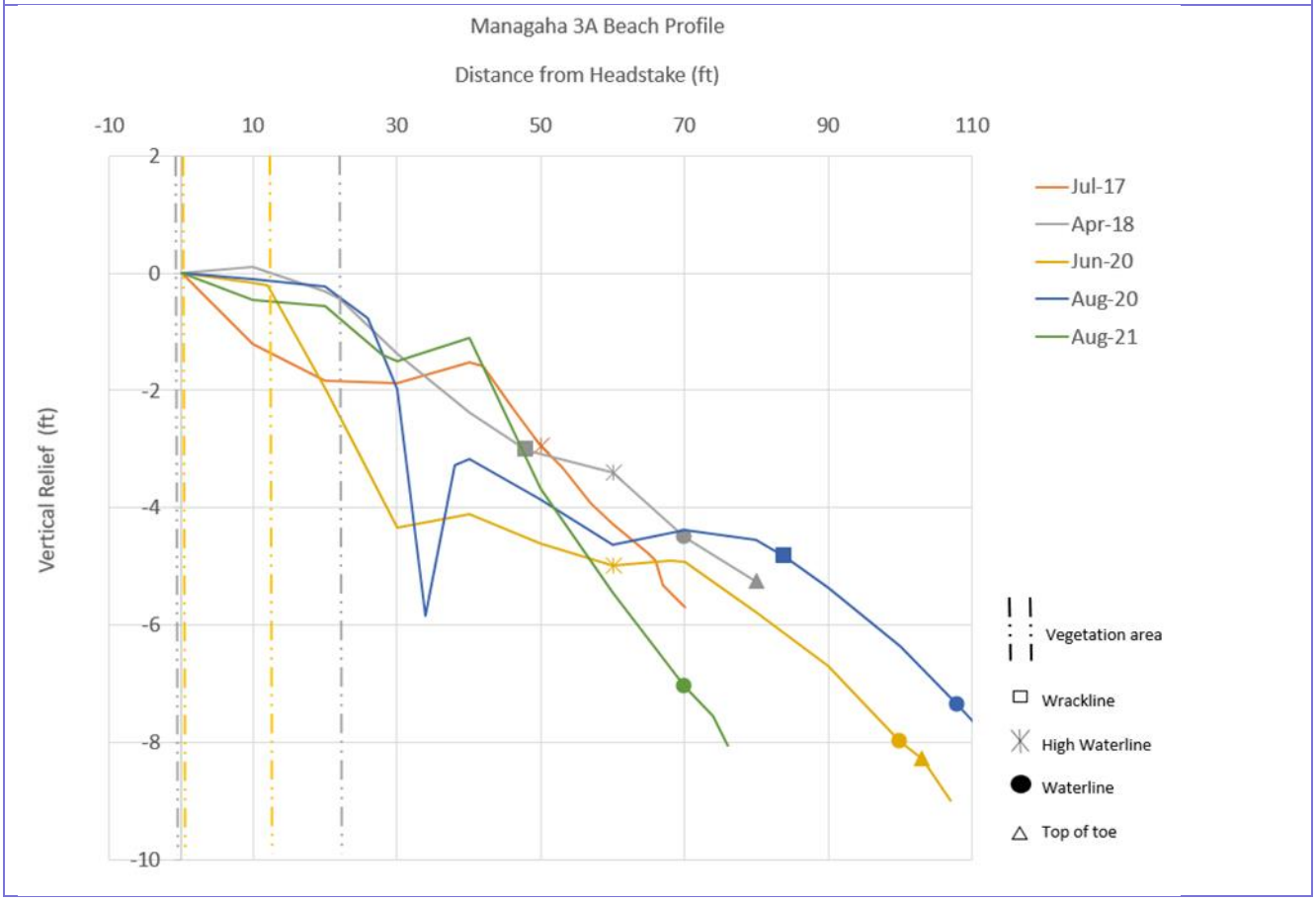
Mañagaha 4

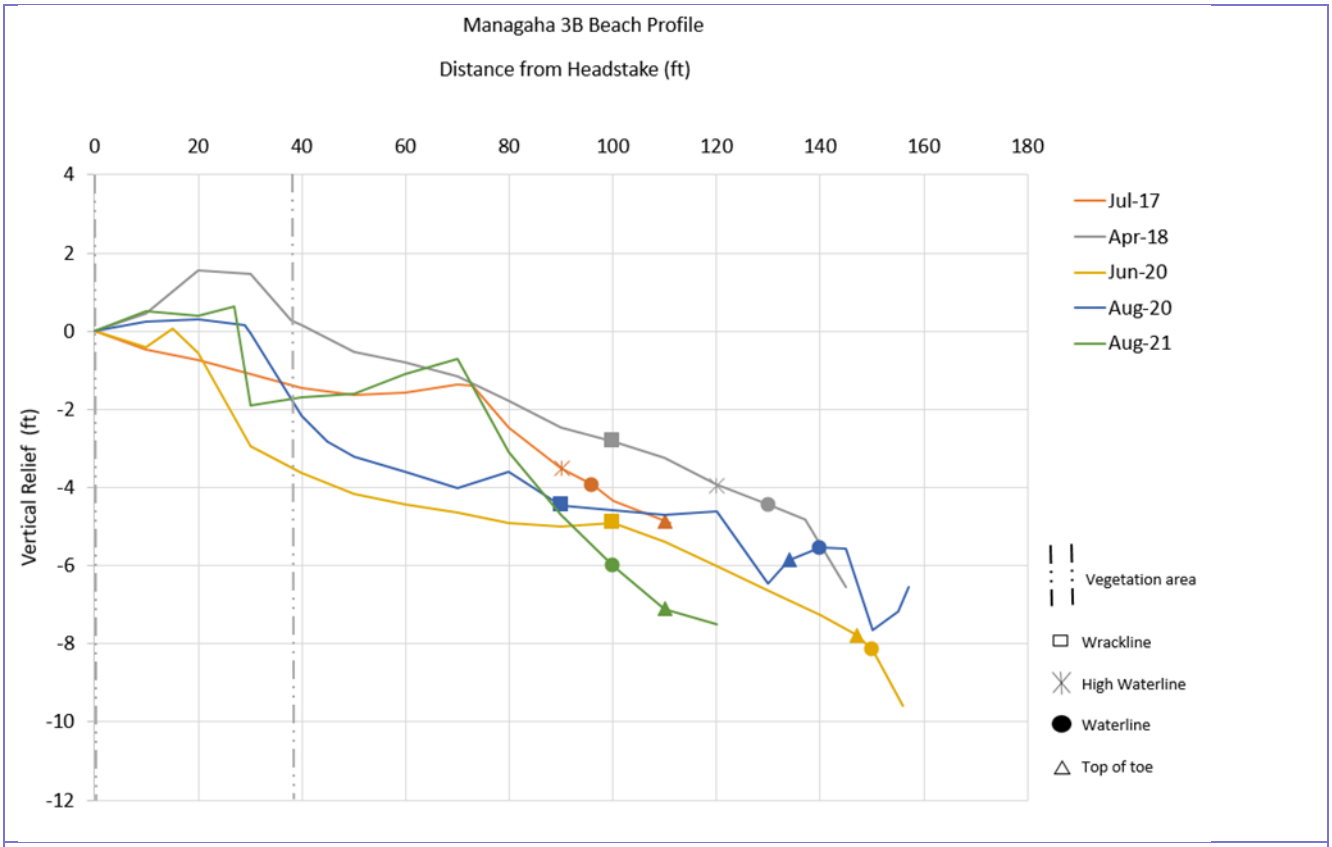


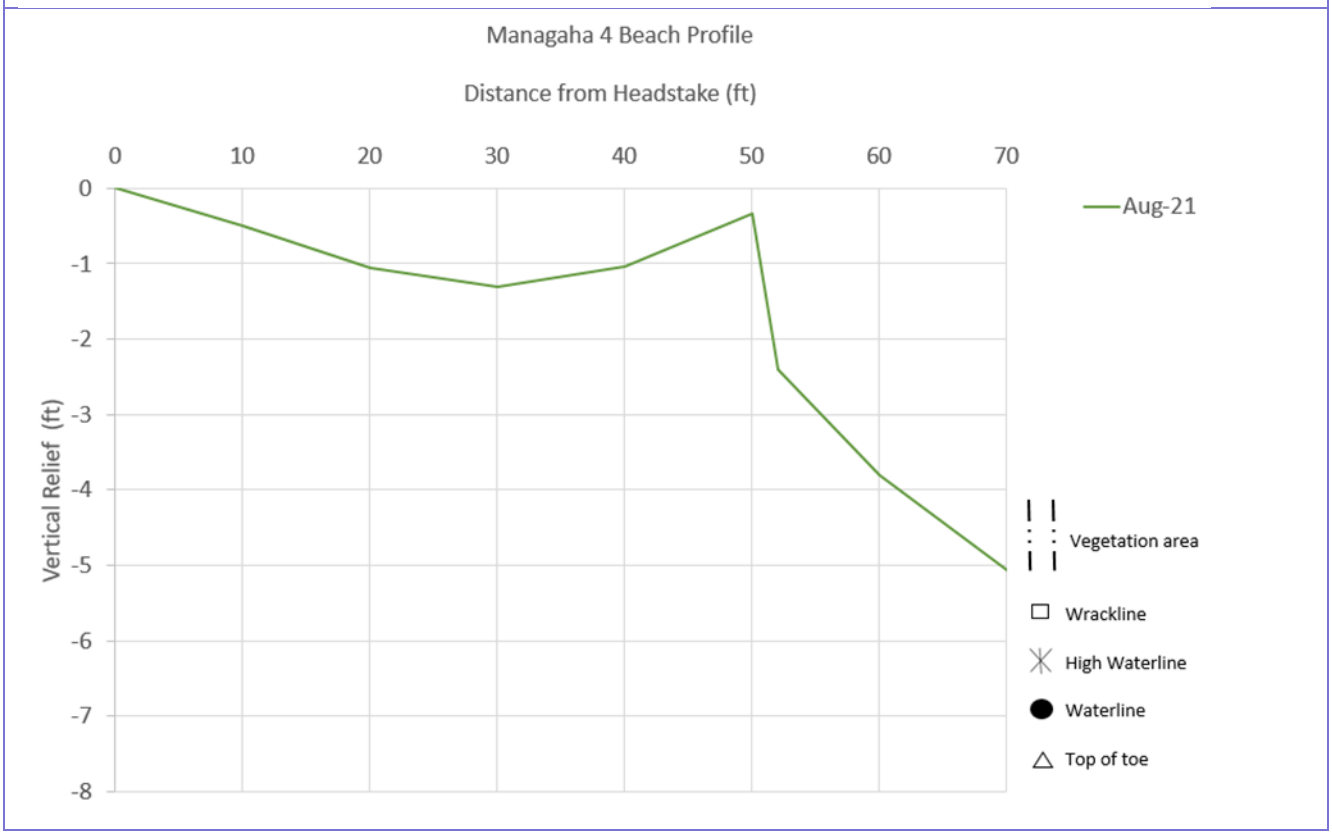
Mañagaha 7

Mañagaha Beach Profiles

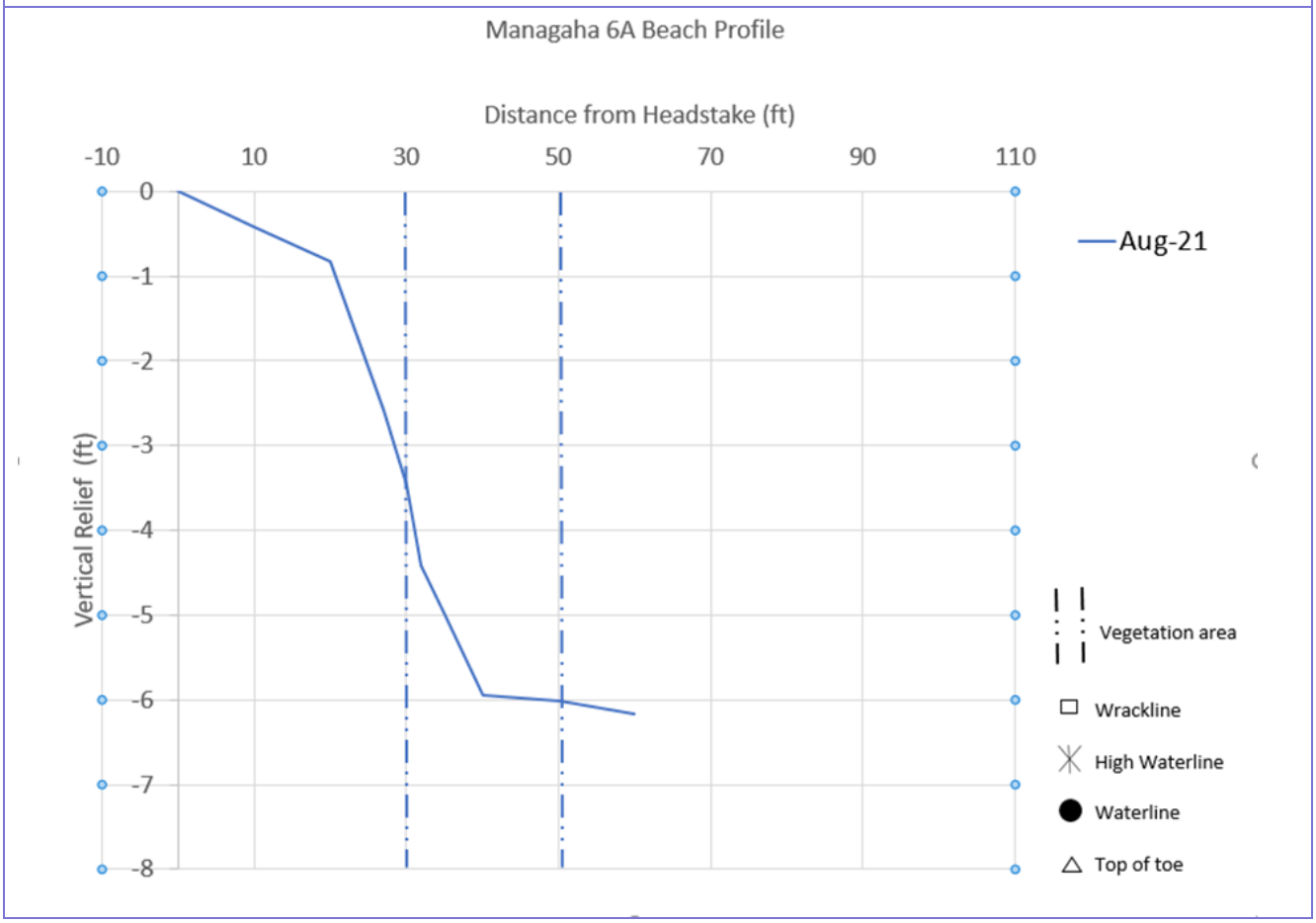

Managaha 2 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Jul-17
Apr-18
Jun-20
Aug-20
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

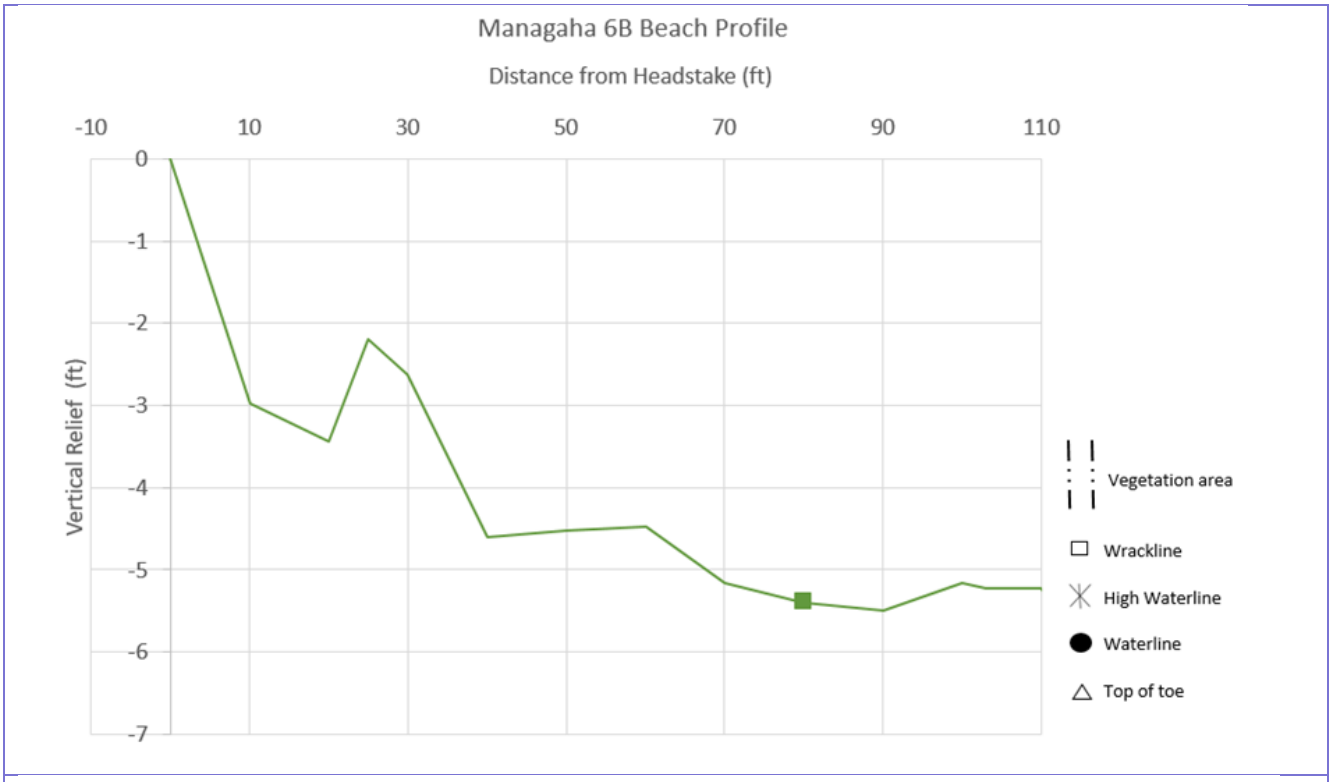

Managaha 3A Beach Profile
Distance from Headstake (ft)
-10
10
30
50
70
90
110
2
0
-2
-4
-6
-8
-10
Vertical Relief (ft)
Jul-17
Apr-18
Jun-20
Aug-20
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe

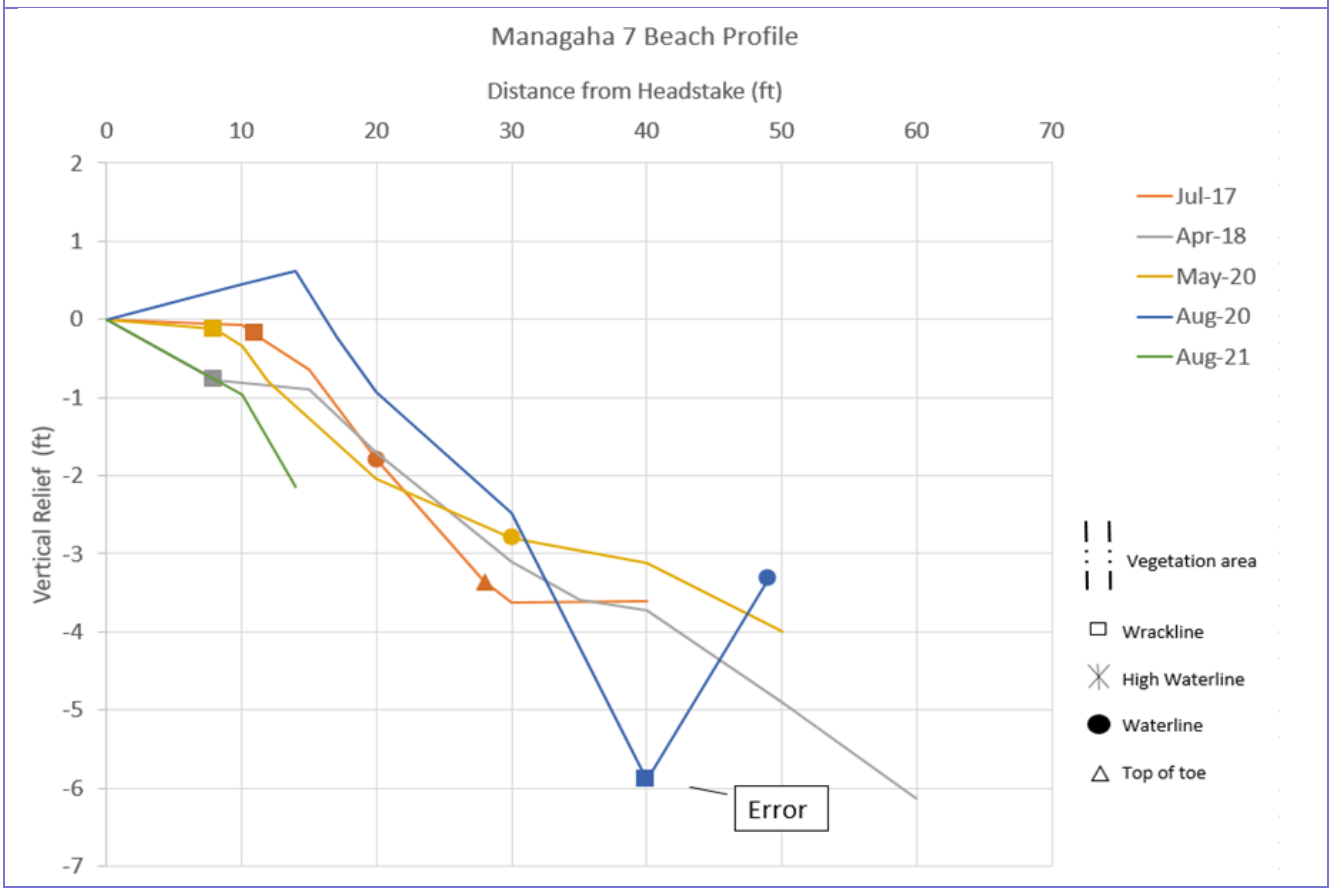

Managaha 3B Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
140
160
180
4
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Jul-17
Apr-18
Jun-20
Aug-20
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Managaha 4 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
0
-1
-2
-3
-4
-5
-6
-7
-8
Vertical Relief (ft)
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Managaha 5 Beach Profile
Distance from Headstake (ft)
0
20
40
60
80
100
120
140
2
0
-2
-4
-6
-8
-10
-12
Vertical Relief (ft)
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Managaha 6A Beach Profile
Distance from Headstake (ft)
-10
10
30
50
70
90
110
0
-1
-2
-3
-4
-5
-6
-7
-8
Vertical Relief (ft)
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Managaha 6B Beach Profile
Distance from Headstake (ft)
-10
10
30
50
70
90
110
0
-1
-2
-3
-4
-5
-6
-7
Vertical Relief (ft)
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe


Managaha 7 Beach Profile
Distance from Headstake (ft)
0
10
20
30
40
50
60
70
2
1
0
-1
-2
-3
-4
-5
-6
-7
Vertical Relief (ft)
Jul-17
Apr-18
May-20
Aug-20
Aug-21
Vegetation area
Wrackline
High Waterline
Waterline
Top of toe
Error

Recommendations for Management

Shoreline Monitoring continues to improve in capturing seasonal conditions and data accuracy. DCRM site-specific shoreline set backs is still in progress. The previous report for August 2018 – February 2021 recommended the following, which still applies:

1. Developing a long term planning strategy to address Garapan shoreline's ongoing erosion

Re-evaluate potential management actions and plan a long-term strategy.
What uses may actually be threatened by the erosion? What restoration actions could be considered? The following plans and studies recommended some potential management actions:

- SLUMP Recommendations–

  #6 Improve public access infrastructure
  6.1 Work with partners on priority improvements to Outer Cove Marina, Sugar Dock, and beach barbeque areas
  6.2 Determine if there is a benefit to moving concessionaires off the beaches and into hotels
  6.3 Ensure developers/hotels maintain a clearly marked, publicly-accessible passage to the shoreline

  #10 Evaluate and implement appropriate shoreline stabilization and erosion control projects
  10.1 Require that public infrastructure improvement projects constructed a certain distance from an eroding shoreline implement viable shoreline stabilization and/or beach re-nourishment projects
  10.2 Secure grant funding for shoreline enhancement and stabilization projects not covered by CIP funds
  10.3 As part of APC permit review, ensure that private applicants have considered shoreline stabilization concerns and needs
  10.4 Consider allowing shoreline projects as part of permit mitigation alternatives
  10.5 Incorporate education and outreach components into shoreline protection and climate adaptation projects
  10.6 Collaborate with DFW in re-vegetation efforts at Mañagaha
  10.7 Condition as part of permitting that beach re-nourishment projects use clean, uncontaminated sand

- SASEA Recommendations –

  A(i): Establish a program to monitor long-term shoreline change. – Shoreline Monitoring Program can adopt the Digital Shoreline Assessment System, as described, into future shoreline monitoring work with UAV captured aerial imagery. 2017 – 2022 analysis could be conducted in the near future.
  B(i): Methodology to monitor sea level rise
  B(ii): Require development projects to account for sea level rise
  B(iii): Consider future sea level rise in establishing shoreline setbacks
  C(i): Reference a physical feature as the baseline for shoreline setbacks – Eroding berms are recommended.
  D(i): Consider adopting erosion rate-based shoreline setbacks
  E(i): Identify and map littoral cells to inform management priorities
  E(ii): Comprehensive management plans for high priority areas – Garapan stretch may undergo project scoping for a mitigation grant.
  F(i): Establish criteria for removal of shoreline vegetation
  F(ii): Remove encroaching vegetation that limits shoreline access.

What could we do to address vehicular compaction and parking at sandy stretches that are eroding?

- The active retreat of the shoreline based on the loss of Fiesta 2 & 3 headstakes calls for a shift in the current shoreline setbacks. Currently, driving and parking are compacting the loose sandy beach due to the unavailability of the Crowne Plaza Hotel's parking lot and its on-going construction. There following points indicate why the parking areas should shift in-land as well:

  Parking areas should not be allowed 35 – 100 ft. Shoreline Setbacks in DCRM §15-10-350 states:
  "Shoreline setback B, from 35-100 feet. No vertical construction, which will obstruct the visual openness and continuity of the shoreline area, is permitted. Open space, rest and recreation areas, swimming pools, terraces, landscaping and related outdoor improvements are allowed. Parking areas are not permitted."

- Driving and parking on the loose sandy ground close to the berm can worsen erosion from the next storm.
- Vehicles are at risk of getting stuck and posing safety concerns.

2. Encouraging affected entities to consider nature-based solution options rather than hardening when appropriate

- ❖ Constructing a seawall will drown out the sandy beach. Seawalls should be considered last after analysis of nature-based solutions.
- ❖ Consider the littoral drift processes and examine first nature-based solution options rather than harden the shoreline.

3. Acquiring storm surge modelling data to integrate into shoreline set back requirements

- ❖ Storm surge could take away huge volumes of sand at one time.
- ❖ UAV capture should help in modelling shorelines after big storm events.

4. Minimizing beach grooming maintenance at berms of eroding shorelines

- ❖ Removal of stabilizing elements, such as live vegetation, may exacerbate erosion.
- ❖ Research beach grooming and develop a strategy to minimize beach grooming.

5. Developing and implementing shoreline erosion outreach to affected stakeholders

- ❖ Shoreline science is not well-known in the CNMI.
- ❖ Shoreline erosion outreach should target the marine sports operators and hotel managers who maintain and use the beach.

Conclusion

The DCRM Shoreline Monitoring team has monitored 62 transects on Saipan and Mañagaha. 18 transects have exhibited erosion from longshore transport during this time while 11 appear to be accreting. Given the dynamic nature of shoreline morphology and sediment transport, there are 25 'stable' and 8 'undetermined.' See 'Trends of Shoreline Monitoring Transects'. These trends only reflect on beach profile contour interpretations and do not directly account for sea level rise. As the program approaches a decade, sea level rise may be more detectable with the decreasing distance of the recorded wrackline data.

The stretch from Micro Beach to Fiesta is highly eroded from high wave conditions generated during "typhoon" wave conditions, presenting itself as a priority for management and planning actions. Hafa Adai and AMP North transects (within the National Park Service vicinity) received sand deposition from ongoing longshore transport process. Sand migration from the south of AMP to the northern area facing Smiling Cove was evident after the September 2021 storm. As for down south, erosion has temporarily impacted parts of Kilili Beach while an erosion hotspot in PIC seems to have done well this cycle.

Surveying has improved through the continued use of compass direction to reduce inaccuracies when laying the transect and considering seasonal variation. The total station was deployed at several sites. In the next reports, the program expects to integrate LiDAR for capturing sediment volumes pre- and post- storms.

The beach profiles document the dynamic nature/trends of our shorelines so we can better address site-specific shoreline erosion through management actions and policies to prevent detrimental hardening of our sandy shoreline areas. DCRM plans to move forward with shoreline outreach and management actions.

Other Resources

Cooper, N. J., Leggett, D. J., & Lowe, J. P. (2000). Beach-Profile Measurement, Theory and Analysis: Practical Guidance and Applied Case Studies. Water and Environment Journal, 14(2), 79-88.

Division of Coastal Resources Management., 2021. Shoreline Profile Monitoring Data Report., 2021., 115 p. https://dcrm.gov.mp/wp-content/uploads/crm/DCRM-Shoreline-Profile-Monitoring-Data-Report-2018-2021_Final.pdf

Fletcher, C.H., Barbee, M., Dyer, M., Genz, A., Vitousek, S., 2007. Mañagaha Island Shoreline Stability Assessment, Report to the Coastal Resources Management Office, Commonwealth of the Northern Mariana Islands, Saipan, 90 p. https://dcrm.gov.mp/wp-content/uploads/crm/Managaha-Island-Shoreline-Stability-Assessment.pdf

Sea Engineering, Inc., 2019. Hydrodynamic Study of Saipan's Western Lagoon, Prepared for Commonwealth of the Northern Mariana Islands, Bureau of Environmental Coastal Quality, Commonwealth of the Northern Mariana Islands, Saipan, 127 p. https://dcrm.gov.mp/wp-content/uploads/crm/25582_Hydrodynamic-Study-of-Saipans-Western-Lagoon-02-25-19.pdf

Sea Engineering, Inc., 2018. Saipan Shoreline Access and Shoreline Enhancement Assessment (SASEA), Prepared for Commonwealth of the Northern Mariana Islands, Bureau of Environmental Coastal Quality, Commonwealth of the Northern Mariana Islands, Saipan, 281 p. https://dcrm.gov.mp/wp-content/uploads/SEI-25573-SASEA-Final-Report-3-15-2018.pdf