Living Shoreline Site Suitability Integrated Model Technical Report

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Introduction

The Harte Research Institute (HRI) at Texas A&M Corpus Christi has generated geospatial information on the suitability of applying Living Shoreline (LS) solutions for erosion control and environmental enhancement along bay shorelines of the Texas coast. HRI compiled geospatial and environmental data to build a rule-based model that classifies the suitability of bay shorelines for various living shoreline stabilization techniques. The specific classes and LS types were determined in collaboration with the Texas General Land Office (GLO) and the Galveston Bay Foundation (GBF), which has conducted a similar analysis for Galveston Bay. The original HRI model and the GBF model have been integrated to create one comprehensive LS site suitability model for the entire Texas coastline. The outcomes of the suitability model will be made available as an online viewer to help stakeholders determine where along the coast of Texas LS techniques are viable options as well as recommendations for which type of LS features might be most appropriate. The new data layers regarding LS will also be packaged, documented, and made available for download via a webpage to be hosted by the GLO. HRI has also produced an ArcGIS Story Map to highlight living shoreline types to accommodate varying shoreline conditions along with the model outputs shown on a GIS based map.

Methods

Living Shoreline Suitability Integrated Model

The original HRI Living Shoreline Suitability Model and the Galveston Bay Foundation Living Shoreline Protection Model were integrated into a single, comprehensive site suitability model for living shoreline techniques that covers all bay shorelines along the coast of Texas. To begin this effort, the two models were compared for similarities and differences with regards to the input variables, data layers and sources used, and outcome recommendations. An advisory team comprised of HRI, GBF, and GLO experts then collaborated on the combining the relevant aspects of each model to create a plan for an integrated model that would be appropriate for the entire coast. This process began by compiling a list of input layers and sources, identifying the desired outcome categories, and then creating a decision tree flowchart to conceptualize the model components (Figures 1, 2, and 3).

The original HRI model used bathymetry, wave exposure, shoreline type, shoreline change rate, and proximity to shipping channels as inputs that were used to recommend outcomes of Soft Stabilization, Hybrid Stabilization, Retrofit: Hybrid Stabilization, Retrofit: Soft Stabilization, or Not Suitable for Living Shorelines. The GBF model had output options of High Profile Breakwater with Marsh Plantings, Low Profile Breakwater

with Marsh Plantings, Marsh Plantings with or without Shoreline Grading, Revetment or Bulkhead with Optional Rock Toe, Beach Nourishment as Needed, No Action Needed, and Stop- Seek Expert Advice.

To prepare the integrated model, the first step was to import the Environmental Sensitivity Index shoreline layer (HRI), which classifies the entire coast of Texas based on shoreline type (e.g, sand vs gravel beach, seawall, revetment, marsh). The ESI layer then simplified, processed to split the shoreline into segments of 50 m or less, and classified based on shoreline type (Shoreline = 1 where beach or marsh present; Scarp = 1 where scarp present; Hard = 1 where shoreline is hardened). In addition to scarp presence, bank height was measured for the entire coast using 2m bathymetric LiDAR data collected in 2017-2019 for use in the Texas Coastal Resiliency Master Plan. The bathymetric digital elevation model (DEM) was converted from meters to feet, classified into 5 ft elevation bands and then converted to polygons from its original raster format. A new field was added to its attribute table, and the elevations within this column were classified into three categories: 0-5 ft, 5-10 ft, and >10 ft. A 25 ft buffer was created around the shoreline layer, converted to a polyline, and then intersected with elevation polygon layer. The bathymetry data was also used to classify the nearshore water depth as either shallow or deep by converting the raster layer to 1 m contours. Where the water was measured as 1 m depth more than 10 m from shore (<10% shoreline gradient), the depth was considered shallow. Water depth was classified as deep where it was measured as 1 m deep within 10 m from shore (>10% gradient). For subaquatic vegetation (SAV), a 30 ft buffer was created around the shoreline layer, and the identity tool was used to find where SAV was present within 30 ft of the shoreline. A field was added to the attribute table and calculated for whether or not SAV was present. The tidal creek layer was created by using the riverine classification of the NWI Texas Wetlands layer, which was clipped to the coastal region, merged into a single polyline, intersected with a 100 ft buffer created around the shoreline layer, and then intersected with the shoreline to show tidal creeks within 100 ft of the shoreline. A new field was then added to the attribute table and coded to show whether a tidal creek was present for each segment of the shoreline. As the boat ramp data layer was a point layer, a 100 ft buffer was created around this layer, intersected with the shoreline layer, and then coded for the presence or absence of boat ramps within 100 ft of the shoreline. Conservation areas were a combination of a wildlife management layer and a state parks layer, both from the Texas Parks and Wildlife Department (TPWD). These two layers were merged and then intersected with the shoreline layer and then coded in the attribute table for presence or absence of designated conservation areas. The presence or absence of oysters was coded by using the oyster presence layer from the Oyster Habitat Suitability Index (OSHI v.6) (GLO). The 100 ft buffer was again used to intersect with the oyster polygon layer, the output of which was then intersected with the shoreline and merged to show oyster presence within 100 ft of the shoreline. Since the oyster layer was ranked from not suitable-highest habitat suitability, a new attribute field was created with ranks not suitable – low suitability coded as absence of oysters and moderate – high suitability coded as oysters present. Shipping channels were previously mapped by HRI and were used to classify segments of the shoreline as either bordering ($\leq$ 30 m) or near ($\leq$ 50 m) a shipping channel.

Wave exposure was calculated using the USGS Fetch Model and was coded as either having a fetch suitable for soft stabilization or a fetch suitable for hybrid stabilization. Finally, the shoreline change rates were calculated using Bureau of Economic Geology (BEG) historic shoreline and the Analyzing Moving Boundaries Using R (AMBUR) package. Transects of 500 m were cast every 50 m along the shoreline, spatially joined to the shoreline layer, and then the coded as having erosion rates suitable for either soft or hybrid stabilization techniques. A final shoreline layer with all of the above mentioned attributes was then used as the input layer for the decision support model.

To create the model, six distinct recommendations were identified and used as the outputs: "Soft Stabilization," "Hybrid Stabilization," "Retrofit Stabilization: Hybrid," "Retrofit Stabilization for Existing Bulkhead Structures," "Retrofit Stabilization for Existing Revetment Structures," and "Stop. Seek Expert Advice." Based on the decision trees (Figures 1-3) created for undefended shorelines, shorelines with existing bulkhead features, and shorelines with existing revetment structures, each recommended model outcome was coded based on the shoreline attributes. The required criteria for each recommendation output can be found in Table 1. The model is created and run using the Model Builder tool in ESRI's ArcMap 10.8. Once the model has been run, the final product is a polyline shapefile of the coast of Texas with each segment coded for one of the six living shoreline technique recommendations. For the integrated model, the shoreline characteristics used to define each recommended output can be found in Table 1 of this appendix. Steps needed to run the full model are detailed in the following section.

<u>Steps to run the full Living Shoreline Suitability Integrated Model:</u>

1.) <u>Run the following steps to prepare the shoreline file:</u>

- ESI shoreline type is clipped to the study area and classified based on shoreline type (Shoreline = 1 where beach or marsh present; Scarp = 1 where scarp present; Hard = 1 where shoreline is hardened).
    - ESI shoreline type shapefile used in model has already been split using ET Geowizard into 50 m (or smaller) segments.
- Bathymetry points from ADCIRC Mesh are clipped to study area, a tin is created (using the shoreline as a hard line and the bay polygon as a soft clip), and then contours are derived.
- Shoreline where the 1m contour is at least 10 m away are deemed shallow (Bathy = 1).
- Land/water raster for the fetch model is generated (landwater_c) (will use later in USGS Fetch Model).
- Shoreline segments are classified based on proximity to channels (chan_bord = 1 where channel <=30 m; chan_near = 1 where channel <= 50m).
    - **NOTE:** channels are not categorized into type
- Tributaries are joined to the shoreline using a buffer of 100 ft and coded TidalCreek = 1 where tributaries are present.
- Boat ramps are intersected with a 100 ft buffer on the shoreline and merged with the shoreline layer. Where ramps are present, boatramp = 1.
- Conservation areas are intersected with the shoreline and coded CnsrvArea = 1 where they are present.
- Oyster suitability data is intersected with a 100 ft buffer around the shoreline and merged with the shoreline. Rank of "not suitable" – "low suitability" is coded oysterpres = 0, and rank "moderate suitability" – "high suitability" is coded as oysterpres = 1.

- Subaquatic vegetation is intersected with a 30 ft buffer around the shoreline, and then merged with the shoreline. Where SAV is present, code SAVpres = 1.

2. Simplify the shoreline:

- Is the landmass connected to other landmasses (i.e. part of the mainland)?
- Is the shoreline located on "internal" waters? Is it sheltered by other landmasses?
- If the landmass is an island, is it reasonably large and stable? Is it vegetated or a sand spit? Is there an upland area? Or would a habitat restoration project be more suitable?

3. Derive wave exposure index using the USGS Fetch Model:

- User Guide: https://umesc.usgs.gov/management/dss/wind_fetch_wave/wind_fetch_wave_2012update/wind_wave_2012_update_070814.pdf
- Burrows, M.T., Harvey, R. and Robb, L. (2008). Wave exposure indices from digital coastlines and the prediction of rocky shore community structure. *Marine Ecology Progress Series*, 353, 1-12.
- Create a text file based on the wind rose data for the study area
  - Wind rose data: See excel files in "Input" folder
- Obtain wind speed data from corresponding NOAA buoy for 2007-2017 – calculate the average for each direction (every 22.5 degrees) in knots
- Land/water raster is derived in the above model (landwater_c)
- Add model to toolbox (Waves2012)
- Use Raster Calculator to generate wave exposure index
  - Wind energy = % time of wind in that sector * average wind speed (knots) squared in that sector
  - Wave exposure index is equal to the sum of fetch in each direction * wind energy in each direction
  - Example code: Log10(((("fet_022"*0.0608*150) + ("fet_045" * 0.0670 * 164)+ ("fet_067"*0.0415*114.19) + ("fet_090"*0.0614*121) + ("fet_112"*0.1018*116) + ("fet_135"*0.1723*165) + ("fet_157"*0.1989*157) + ("fet_180"*0.077 * 97) + ("fet_202"* 0.0187 * 118) + ("fet_225"*0.018*117) + ("fet_247"*0.0097* 144) + ("fet_270"* 0.0076*154) + ("fet_292"+ 0.0121 * 333) + ("fet_315"* 0.027 * 168) + ("fet_337" * 0.0650 * 238) + ("fet_000"* 0.0666 * 150))*0.001)
    - First number is proportion of wind in that direction; second number is average wind speed (knots) in that direction squared
- Symbolize the raster into 3 categories using quartiles 1st category will be Low (0-25), 2nd will be Moderate (25-75), 3rd will be High (75-100)– compare to wave exposure index for corpus Christi for validation
- Reclassify the raster (first category = 1, etc.)
- Convert the raster into a polygon
- Use spatial join to add the wave exposure index to the shoreline shapefile
- Add Field called "Wave_log" & use Field Calculator with code:

```
def myfunct(GRIDCODE):
  if (GRIDCODE == 1):
    return "Low"
  if (GRIDCODE == 2):
    return "Moderate"
  if (GRIDCODE == 3):
    return "High"
  else:
    return "NA"
```

- Add Field called "Fetch_soft" & use Field Calculator with code:

```
def myfunct(Wave_log):
  if "Low" in Wave_log:
    return 1
  else:
    return 0
```

- Add Field called "Fetch_hybr" & use Field Calculator with code:

```
def myfunct(Wave_log):
  if "Moderate" in Wave_log:
    return 1
  if "High" in Wave_log:
    return 1
  else:
    return 0
```

4. Calculate shoreline change rates:

- Historic shoreline source: http://www.beg.utexas.edu/coastal/zip_shoreline/zone14_up10.htm
  - Merge shoreline type shapefile to historic shoreline shapefile for modern shoreline data (date: 02/01/2012)
  - Used the date "07/01/year" when the exact date for a given year wasn't given
- Create a baseline and follow AMBUR user guide to format shapefile and calculate shoreline change rates: http://ambur.r-forge.r-project.org/user/ambur%20basic%20user%20guide%201_0a.pdf
  - Cast transects every 50 m with a length of 500 m
  - Excluded 1880 in the analysis
- Use Spatial Join to join envelope_transects_analysis to shoreline shapefile – join field LRR
- Add field called "Erosion" & use Field Calculator with code:

```
def myfunct(LRR):
  if (LRR <= -6.5):
    return "High"
  if (-3.2 >= LRR > -6.5):
    return "Moderate"
  if (0 >= LRR > -3.2):
    return "Low"
  if (LR_FT > 0):
    return "Accretion"
  else:
    return "NA"
```

- Select by attributes, Join_count = 0 & use Field Calculator on selection to change Erosion = Unknown
- Add Field called "Erode_soft" & use Field Calculator with code:

```
def myfunct(Erosion):
  if "Low" in Erosion:
    return 1
  if "Accretion" in Erosion:
    return 1
  else:
    return 0
```

- Add Field called "Erode_hybr" & use Field Calculator with code:

```
def myfunct(Erosion)
  if "Moderate" in Erosion:
    return 1
  if "High" in Erosion:
```

```
            return 1
         else:
            return 0
```

- Add Field called "Unknown" & use Field Calculator with code:
  ```
  def myfunct(Erosion):
   if "Unknown" in Erosion:
    return 1
   else:
    return 0
  ```


5.) Use the following codes to classify the final shoreline layer:

Soft Stabilization:
Shoreline = 1 AND Bathy = 1 AND fetch_soft = 1 AND Scarp = 0 AND Erode_soft = 1 AND chan_bord = 0 AND chan_near = 0 AND Hard = 0 AND TidalCreek = 0 AND "BoatRamp" = '0' AND "CnsvtnArea" = '0' AND "OysterPres" = '0' AND "SAV_pres" = 0

Hybrid Stabilization:
("Shoreline" = 1 AND "Bathy" = 1 AND "chan_bord" = 0 AND "Erode_hybr" = 1 AND "Erode_soft" = 0 AND "Fetch_hybr" = 1 AND "OysterPrs1" = 0 AND "SAVpres1" = 0 AND "CnsvtnAr_1" = 0) OR ("Shoreline" = 1 AND "Bathy" = 1 AND "chan_bord" = 0 AND "Erode_soft" = 1 AND "Erode_hybr" = 0 AND "Fetch_soft" = 1 AND "chan_near" = 1 AND "OysterPrs1" = 0 AND "SAVpres1" = 0 AND "CnsvtnAr_1" = 0) OR ("Shoreline" = 1 AND "Bathy" = 1 AND "chan_bord" = 0 AND "Unknown" = 1 AND "OysterPrs1" = 0 AND "SAVpres1" = 0 AND "CnsvtnAr_1" = 0) OR ("Shoreline" = 1 AND "Scarp" = 0 AND "Hard" = 0 AND "Bathy" = 1 AND "chan_bord" = 0 AND "chan_near" = 0 AND "Erode_hybr" = 1 AND "Erode_soft" = 0 AND "Fetch_soft" = 1 AND "OysterPrs1" = 0 AND "SAVpres1" = 0 AND "CnsvtnAr_1" = 0) OR ("Shoreline" = 1 AND "Scarp" = 0 AND "Hard" = 0 AND "Bathy" = 1 AND "chan_bord" = 0 AND "chan_near" = 0 AND ("Erode_hybr" = 0 AND "Erode_soft" = 0) AND "Fetch_soft" = 1 AND "OysterPrs1" = 0 AND "SAVpres1" = 0 AND "CnsvtnAr_1" = 0) OR ("Shoreline" = 1 AND "Scarp" = 0 AND "Hard" = 0 AND "Bathy" = 1 AND "Erode_soft" = 1 AND "Erode_hybr" = 0 AND "Fetch_hybr" = 1 AND "OysterPrs1" = 0 AND "CnsvtnAr_1" = 0)

Retrofit: Soft Stabilization:
"Bathy" = 1 AND "Fetch_soft" = 1 AND "Erode_soft" = 1 AND "Scarp" = 0 AND "chan_bord" = 0 AND "chan_near" = 0 AND "Hard" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0

Retrofit for Existing Bulkhead Structures: Hybrid Stabilization:
("Hard" = 1 AND ("ESI_F" = '1' OR "ESI_F" = '8A') AND "Bathy" = 1 AND "chan_bord" = 0 AND "Erode_soft" = 1 AND "Fetch_hybr" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0) OR ("Hard" = 1 AND ("ESI_F" = '1' OR "ESI_F" = '8A') AND "Bathy" = 1 AND "chan_bord" = 0 AND "Erode_soft" = 1 AND "Fetch_hybr" = 1 AND "chan_near" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0) OR ("Hard" = 1 AND ("ESI_F" = '1' OR "ESI_F" = '8A') AND "Bathy" = 1 AND "chan_bord" = 0 AND "Fetch_hybr" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0)

Retrofit for Existing Revetment Structures: Hybrid Stabilization:
("Hard" = 1 AND ("ESI_F" = '6B' OR "ESI_F" = '8B') AND "Bathy" = 1 AND "chan_bord" = 0 AND "Erode_soft" = 1 AND "Fetch_hybr" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0) OR ("Hard" = 1 AND ("ESI_F" = '6B' OR "ESI_F" = '8B') AND "Bathy" = 1 AND

"chan_bord" = 0 AND "Erode_soft" = 1 AND "Fetch_hybr" = 1 AND "chan_near" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0) OR ("Hard" = 1 AND ("ESI_F" = '6B' OR "ESI_F" = '8B') AND "Bathy" = 1 AND "chan_bord" = 0 AND "Fetch_hybr" = 1 AND "BoatRamp1" = 0 AND "CnsvtnAr_1" = 0 AND "OysterPrs1" = 0 AND "SAVpres1" = 0)

Seek Expert Advice:
Scarp =1 OR Shoreline = 0 OR OysterPres = 1 OR BoatRamp = 1 OR TidalCreek = 1 OR CnstvnArea = 1 OR Bathy = 0 OR TidalCreek = 1 OR SAV_pres = 1

Decision Support Tool

Using the same decision trees as used in the site suitability model, a self-guided assessment tool was created to accompany the model tool. This decision support tool uses if- then- else statements to walk users through yes or no questions to arrive at a recommendation for which type of living shoreline technique would be appropriate for their section of the Texas coastline. Each question has an information icon that opens a pop-up window with more information on that specific topic to make the application more accessible to non-expert users. The tool also has a restart option, and the choices can be changed once the user clicks on an option to reroute to a new set of conditions if needed. The outcomes of the tool are the same six recommendations as in the model tool with an accompanying brief description of each recommendation.
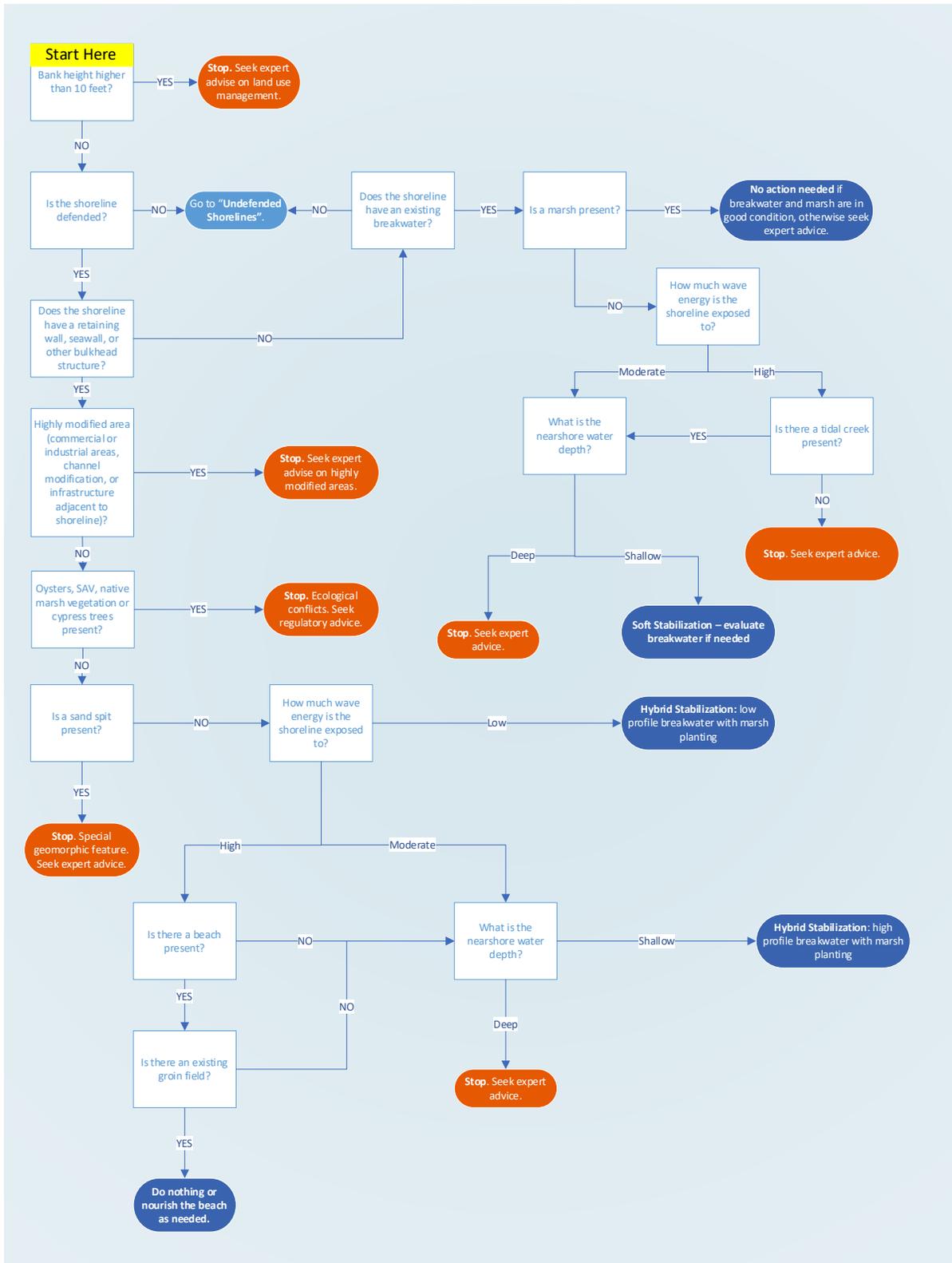
Figure 1 Decision tree designed to guide the geospatial model for shoreline stabilization techniques to be used for sections of the coast that *do not currently have hardened structures* in place along the shore.

Figure 2 Decision tree designed to guide the geospatial model for shoreline stabilization techniques to be used for sections of the coast that *currently have a seawall or bulkhead structure* in place along the shore.
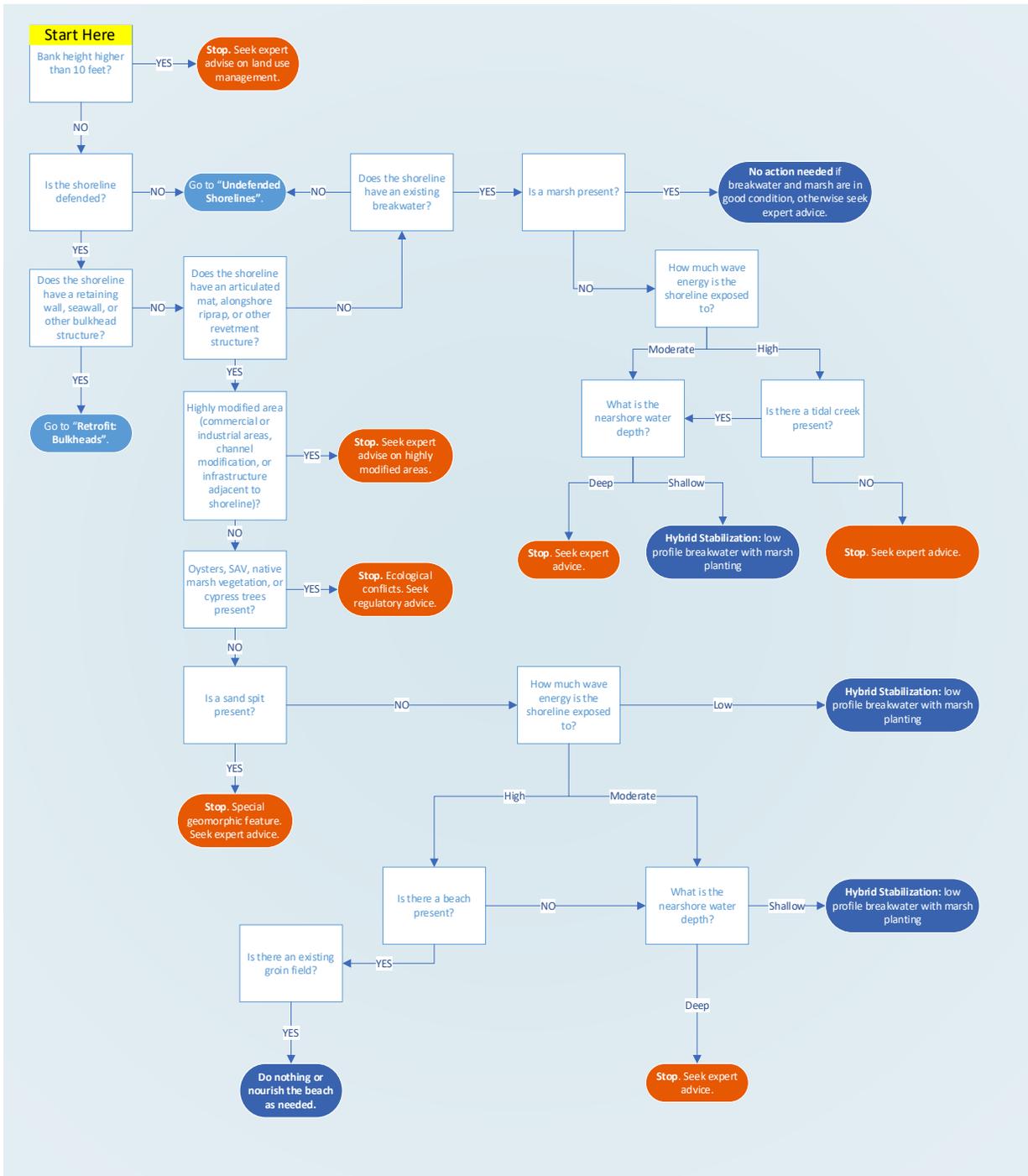
Figure 3 Decision tree designed to guide the geospatial model for shoreline stabilization techniques to be used for sections of the coast that *currently have revetment or riprap structures* in place along the shore.

Results

The outputs from the Living Shoreline Site Suitability Integrated Model provide recommendations for five different living shoreline techniques as well as one recommendation for scenarios in which living shorelines may not be appropriate without expert advice (Figure 4). Of the nearly 4,446 miles of shoreline that were analyzed across the entire state of Texas, roughly 75% of the coast was determined to be appropriate for some type of living shoreline project, with only 25% being classified as needing expert advice due to the shoreline conditions present in these areas (Figure 5, Table 2). Strictly soft stabilization techniques were determined to be suitable for over 1300 miles of shoreline, comprising nearly 30% of the coast mapped. 35% of the coast was suitable for hybrid stabilization, where a combination of soft and hardened features would be used. Where hardened structures already were constructed along the shoreline, roughly 3% were appropriate for retrofit with hybrid techniques for existing revetment structures and another 3% for existing bulkhead structures. In areas with an existing breakwater offshore of the shoreline, retrofit with soft stabilization was recommended for 4% of the coast.
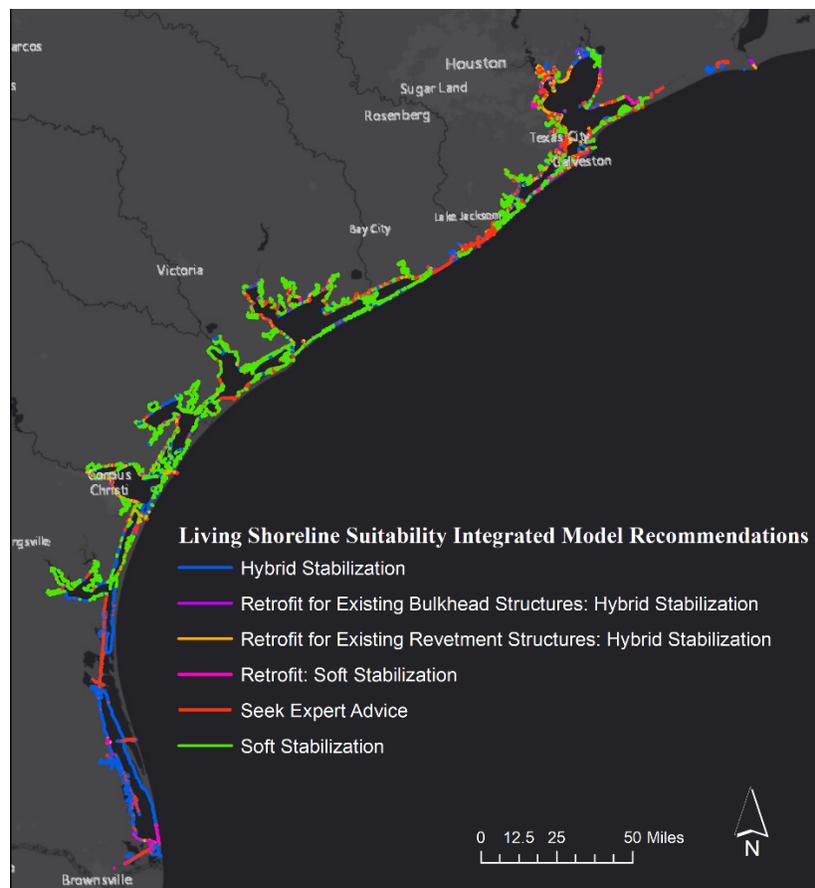

Figure 4 Model output showing the 6 different living shoreline recommendations based on shoreline characteristics for the Texas coast.
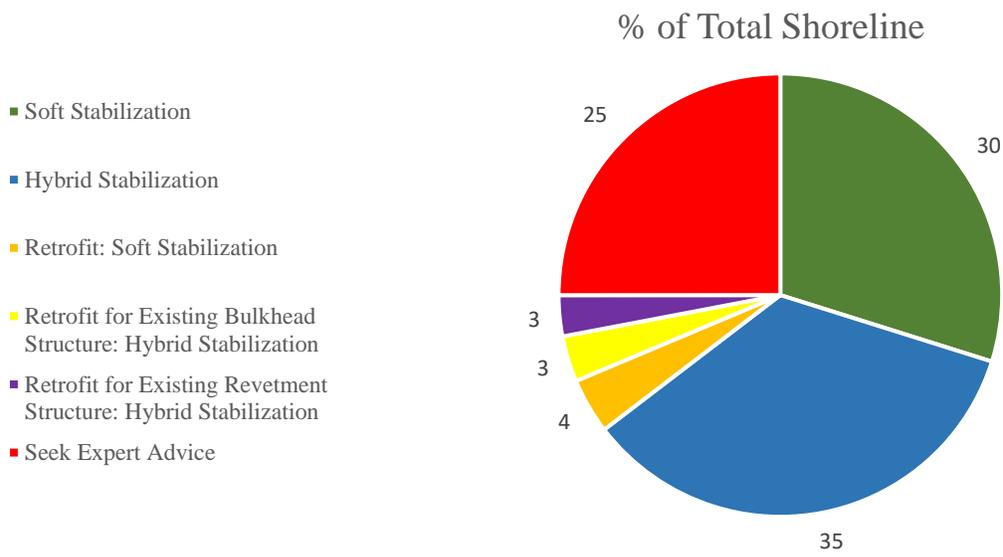
Figure 5 Percent of the total shoreline analyzed that was classified as being suitable for each of the six shoreline stabilization outcomes using the Living Shoreline Suitability Integrated Model.

Table 1: Recommended stabilization techniques classified by each combination of shoreline characteristics

	Nearshore Water Depth	Fetch	Erosion Rates	Scarp Present	Distance from Shipping Channel	Hardened Shoreline	Ecologically Sensitive Feature Present	Tidal Creek Present
Soft Stabilization	Shallow	Low	Low	No	Far	No	Beach or Marsh	No
Hybrid Stabilization	Shallow	Moderate-High	Moderate-High	Yes or No	Near, Bordering, or Far	Permanent Structure Close to Shore (ie groin)	Marsh	Yes with Beach or Marsh
Retrofit: Soft Stabilization	Shallow	Low	Low-Accreting	No	Far	Permanent Structure Close to Shore (ie breakwater)	No	No
Retrofit for Existing Bulkhead Structure: Hybrid Stabilization	Shallow	Moderate-High	Moderate-High	Yes or No	Near, Bordering, or Far	Bulkhead or Sea Wall	No	No
Retrofit for Existing Revetment Structure: Hybrid Stabilization	Shallow	Moderate-High	Moderate-High	Yes or No	Near, Bordering, or Far	Revetment or Rip Rap	No	No
Seek Expert Advice	Deep	Moderate-High (in combination w/ other factors)	High	>10 ft	Bordering	Highly Modified	Oysters, SAV, or Extensive Native Marsh	Yes with No Beach or Marsh

Table 2: Length of the shoreline recommended for each type of living shoreline technique and the percent of the entire coastline for each classification.

	Shoreline Length (m)	Shoreline Length (mi)	% of Total Shoreline
Soft Stabilization	2135714.02	1327.13	29.85
Hybrid Stabilization	2487239.93	1545.50	34.76
Retrofit: Soft Stabilization	289848.42	180.13	4.05
Retrofit for Existing Bulkhead Structure: Hybrid Stabilization	239316.29	148.70	3.34
Retrofit for Existing Revetment Structure: Hybrid Stabilization	213715.10	132.80	2.99
Seek Expert Advice	1789095.98	1111.72	25.01
Total Shoreline	7154929.74	4445.98	100