TIFF Recommendation #2: Priority Areas along the Texas Coast for Bathymetry Data Acquisition

Project Name: Priority Areas along the Texas coast for Bathymetry Data Acquisition

Scope: Collecting bathymetry data in areas with a high priority need to enhance the performance of various modeling efforts

Schedule: Varies

Estimated Budget: Varies depending on the water type, size of project, and the data collection methodology

Potential implementation Agency: TWDB, NOAA, USGS, and others (varies)

Explanation of Benefits: Significantly increase accuracy of coastal flood modeling and forecasting.

Priority Areas along the Texas Coast for Bathymetry Data Acquisition

Background

Bathymetric data is one of the most important datasets for coastal modeling, but there are obstacles to collecting high-quality data. Bathymetry represents the three-dimensional features of underwater terrain, or bed elevation, which is highly dynamic and frequently changes with natural and anthropogenic influences. Thus, data must be collected regularly to ensure it is current, accurate, and useful for coastal modeling. Additionally, bathymetry data is generally costly to collect, and agencies collecting bathymetry data could improve collaboration to better coordinate data acquisitions and leverage limited funding resources.

While numerous agencies collect and share bathymetry data, it can be difficult for end-users, like modelers or the general public, to access the data. To address this, The Texas Integrated Flooding Framework (TIFF) utilized insights from Technical Advisory Team (TAT) members and other experts to identify the highest priority areas for bathymetric data needs along the coast of Texas. The TIFF recommendation for priority areas considers only the feedback from survey participants; thus, is limited with respect to representing a broad stakeholder community.

TIFF Bathymetry Workshop

The TIFF Steering Committee hosted a virtual bathymetry workshop with 90 participants (Appendix A) on May 18, 2022, to improve statewide collaboration and expand bathymetry data collection in Texas. The workshop focused on gathering insights from the TIFF TAT members, other bathymetry experts, and end-users to develop a statewide priority map for bathymetry acquisition needs and target available resources.

To provide attendees with a broad overview of the bathymetry data landscape in Texas, the workshop opened with a screening of nine pre-recorded presentations from bathymetry data experts. Each presenter described the tools and data sets available from their respective agencies and their organization's plans for bathymetry data in the coming years. The TIFF Steering Committee allowed attendees to view the pre-recorded presentations before the workshop, which collected a total of 98 views across the nine presentations before the event. The links to view the pre-recorded presentations are provided in Appendix A.

The second half of the workshop focused on the needs for bathymetry data in Texas, current obstacles for data acquisition and management, and how TIFF could address these issues for the state, followed by an open discussion.

Attendees were instructed to use an online Bathymetry Mapping Survey (developed by Texas Water Development Board (TWDB)) to submit information about areas where they have the highest need for bathymetry data. The TIFF Steering Committee also asked attendees to send any bathymetry data files that they have available.

TIFF used this information to conduct an inventory and gap analysis for bathymetry data, which resulted in a TIFF recommendation for the areas needing immediate bathymetry data acquisition and the estimated costs to complete the work, as presented in the next sections.

Inventory Analysis

Survey Results

After receiving the participants' responses to the provided survey, results were exported as a shapefile to be analyzed. A total of 15 Areas of Interests (AOIs) were received: 13 through the survey, and two via email. Among the 15 AOIs, one was not along the coast, so it was sent to the TWDB's River Science and Hydrosurvey departments for future reference. Figure 1 shows all received AOIs along the coast of Texas. The justification for bathymetry acquisition for each AOI, as well as any information provided by the participants of the TIFF Bathymetry Workshop are shown in Table 1.

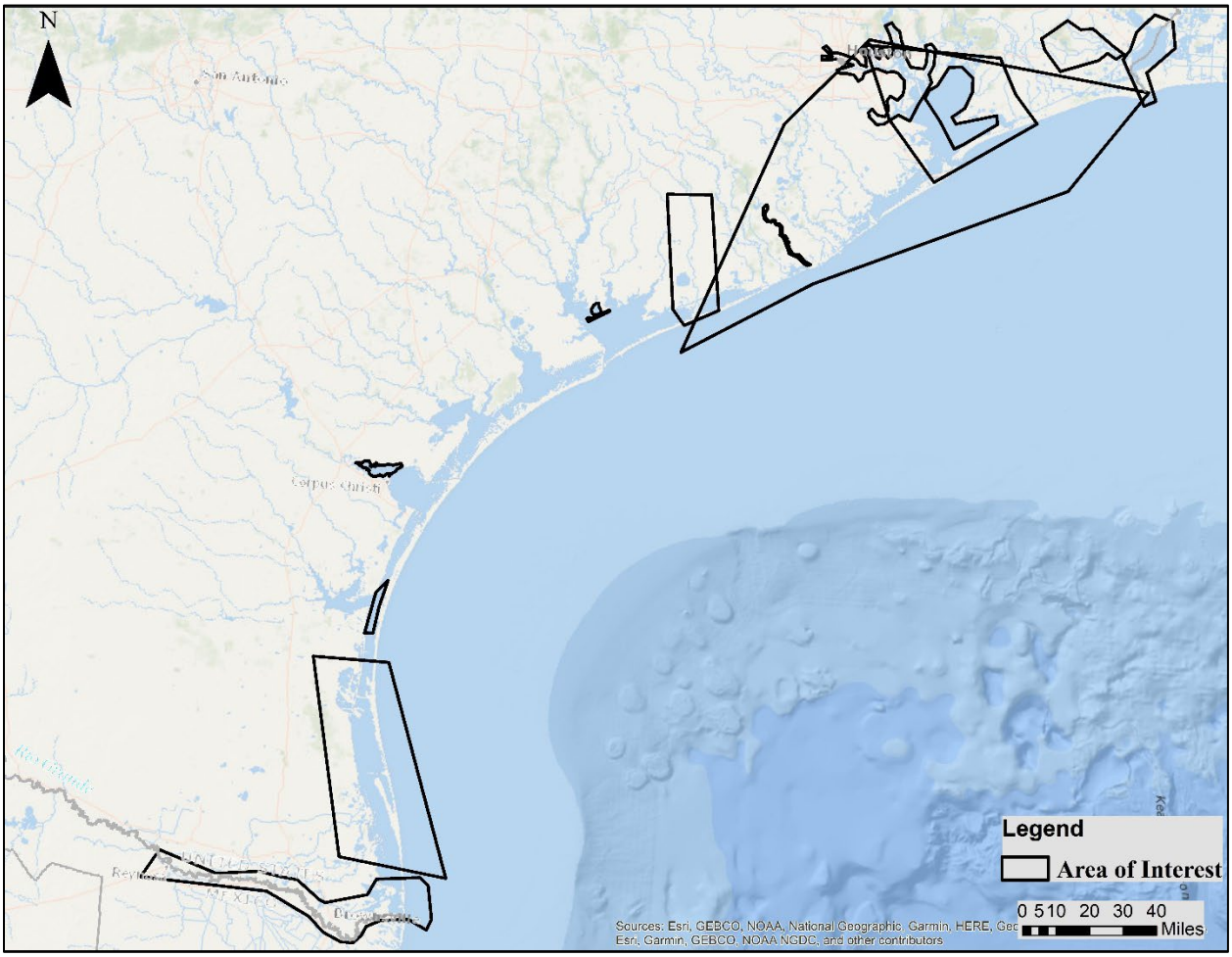

Figure 1. Areas of Interests (AOIs) along the coast of Texas identified by the participants of the TIFF Bathymetry Workshop.

Table1. Areas of Interests (AOIs) identified by the participants of the TIFF Bathymetry Workshop and their comments to justify the need for bathymetry acquisition.

AOI	Why should bathymetry data be collected in this location?	Information to narrow or expand the selected area	Is the water in the selected area transparent enough (low turbidity) to use LiDAR for bathymetry collection
AOI1	We have a GLO project and San Bernard River bathymetry (Below water where USGS Elevation maps do not capture) has been very hard to find.	Lower Reach of San Bernard	I don't know
AOI2	Very poor representation of the Rio Grande River and nearby floodplains.		I don't know
AOI3	There is an active design project by TAMU that requires survey ASAP and will lead to a permitted construction project. Project is included in the USACE TX Coastal Plan and has been submitted for Tier 1 status in GLO TX coastal plan.	Could expand further into Matagorda Bay and Keller/Lavaca for other interests, if needed.	No
AOI4	Support design modeling and flood forecast modeling efforts in the region. HCFCD currently runs riverine flood forecast models that do not take into consideration the coastal boundary and have diminishing performance in tidally influenced areas.	Goal is to include tidally influenced portions of major channels that drain through Harris County.	I don't know
AOI5	Sedimentation deposits from Baffin Bay	Expand area downstream based on tidal flows.	I don't know
AOI6	Ongoing H&H characterization of primary drainage pathways (TWDB) and coastal (Laguna) hydrodynamic circulation (TGLO/CMP) and water quality (TCEQ)	LRGVDC/Cameron County	No
AOI7	On-going in-shore HF-Radar coastal circulation study (TGLO/CMP)		Yes
AOI8	On-going HF-Radar in-shore hydrodynamic circulation study (TGLO/CMP)		Yes

AOI	Why should bathymetry data be collected in this location?	Information to narrow or expand the selected area	Is the water in the selected area transparent enough (low turbidity) to use LiDAR for bathymetry collection
AOI9	Not the whole area, but hydrography of channels in this area seems to be hard to find. These areas were heavily impacted by Harvey and also chemical contamination in this area is a problem.	Generally, where NOAA's NCEI Elevation data and USGS DEMs lack below water definition.	I don't know
AOI10	In order to support total water level forecasting and the NextGen initiative of the NWM, bathymetry data along the Colorado River would be extremely useful. Multiple partners would benefit from this data.	Colorado River from GIWW to at least Matagorda but ideally Bay City	I don't know
AOI11	High risk zone for surge and rainfall and sediment movement.	More resolution is needed at the interface between coastline and further into ocean and also at the interface with Galveston Bay	Yes
AOI12	Bay bathy is old, currently developing a 2D model to look at sediment transport, so having the Keller Bay would be helpful for that analysis	Entire Keller Bay	No
AOI13	Bathymetry data in this area would be extremely useful for total water level forecasting for Trinity River and for surge modeling on the back side of Bolivar Island	The area can be split into two zones. The priority is Bolivar Island and then Lake Anahuac	I don't know
AOI14	There is no bathymetry data available for this area		Mostly No

Bathymetry Inventory Acquisition

The inventory analysis was based on the available data by National Oceanic and Atmospheric Administration's (NOAA) BlueTopo program, TWDB, and Texas Parks & Wildlife Department (TPWD). The BlueTopo product is "a compilation of the nation's best available bathymetric data." To find and download the best available bathymetric data within each identified AOI, a Python script developed by NOAA was used. A brief guideline on how to use this script to acquire bathymetry data for a given area was provided in Appendix B. For some of the AOIs, additional bathymetric data were acquired from various sources (details provided in the following sections) based on the TIFF steering committee members knowledge of the area and available data. For each AOI, three separate ArcMap files were generated; in the "Bathy" files, all Elevation raster layers

downloaded for the associated AOI were imported and formatted while in the "Year" files, the Contributor raster layers were loaded and formatted. Finally, the "Gap" files include the initial suggested areas for each AOI. Some of the AOIs were spatially very close to each other so they were merged into a single file. All the GIS files can be found here.

Gap Analysis

A gap analysis was conducted manually for each AOI. Two main criteria were used to suggest areas for bathymetry acquisition: 1) existing data availability, and 2) year of last measurement. In other words, an area was suggested if there was no bathymetric data available (based on the analysis conducted in this effort) or the last effort to collect bathymetric data was more than 20 years ago. For the suggested areas (with no or old bathymetric data), various tools and datasets were used to have a more accurate representation of the area. For rivers in particular, the assessment units provided by the Texas Commission on Environmental Quality (TCEQ) that provide a detailed shapefile for the shapes of the rivers were used. A buffer tool with a linear width of 50 m was used to represent the entire river waterbody. This estimate may cause under- or over-estimation of suggested areas for rivers. As mentioned earlier, a separate GIS file was generated for each AOI that contains the suggested areas.

Priority Analysis

Once the areas with an immediate need for bathymetry acquisition within the Areas of Interest had been identified by workshop participants, a follow up survey was sent to the participants to prioritize the identified areas considering funding and resource limitations. The participants were asked to fill a brief survey out to rank (1 to 5) the areas they believe to have the highest needs for data collection. As noted before, the TIFF recommendation for priority areas considers only the feedback from survey participants; thus, is limited with respect to representing a broad stakeholder community. A total of 13 responses were received, and the importance of each area was calculated using a relative weighted sum method:

$$Importance_i = \frac{\sum_{j=1}^{13} W_{i,j}}{Maximum\ AOI\ Weight}$$

Where i is the location of interest, j is the participant's number, and W is the weight which is defined as follow:

- Priority 1: 5 points
- Priority 2: 4 points
- Priority 3: 3 points
- Priority 4: 2 points
- Priority 5: 1 point
- Not included: 0 points

In other words, the importance for a specific location was calculated as the sum of number of responses for Priority 1 multiplied to 5, number of responses for Priority 2 multiplied to 4, and so on for each AOI divided by the maximum weight among all AOIs.

In addition to the TIFF post-survey results, we used the results of the nationwide Spatial Priorities Studies (SPS) conducted by NOAA's Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM) working group in December 2021. The IWG-OCM SPS was conducted amongst several federal agencies including:

1. Bureau of Ocean Energy Management
2. Department of Energy -Water Power Technologies Office
3. United States Environmental Protection Agency -Ocean Dumping Program
4. National Oceanic and Atmospheric Administration
5. United States National Park Service
6. United States Coast Guard
7. United States Department of Agriculture -Natural Resources Conservation Service
8. United States Geological Survey

Organizations were limited to selecting 10% of the submission area, using a 10 km fishnet grid, as "High", 25% as "Medium", and 50% as "Low." Using the “Spatial Join” tool in ArcMap, the average values of Weighted Score were calculated within each of TIFF suggested areas.

The IWG-OCM SPS used a similar method in calculating the weighted sum scores using the following criteria:

- High Priority: 3 points
- Medium Priority: 2 points
- Low Priority: 1 point

Thus, a similar approach was used to normalize the scores and calculate the importance of each suggested area based on the maximum reported score.

Estimated Cost

Although the cost of bathymetry acquisition depends on the type of water body, size of project, and method of collection we estimate, on average, it would cost $6,000-$9,000 (2021 U.S. dollars) to collect bathymetry data per square mile ($9-$14 per acre) using sonar techniques in shallow waterbodies. This estimate is based on some of the previous contracts managed by the TWDB in 2021. We used the same estimate for all types of water (shallow, deep, and rivers) but the cost could be significantly different for various types of waterbodies. The actual cost of the project could be significantly different from the estimated cost provided here because of the aforementioned reasons.

Results

The summary of the gap analysis for the received AOIs is provided in Table 2. The location of suggested areas can be seen in Figure 2. More details on each of the AOI as well as the maps are presented in the following sections. For further investigations and acquiring the collected datasets, all the GIS files can be found here.

Table 2. Summary of the gap analysis for the received AOIs.

AOI	Area Description	Waterbody Type	Reason for Suggestion	Suggested Area (mi^2)	Estimated Cost*
1	San Bernard River Tidal	River	no data	1.16	$7-11 K
2	Rio Grande River	River	no data	13.62	$82-123 K
		Shallow Water	no data	56.91	$342-512 K
3	Part of Matagorda Bay	Shallow Bay	old data (1991-1992)	5.11	$31-46 K
4	HSC[1] System and part of the Upper GB[1]	River	no data	15.80	$95-142 K
		Shallow Water	old data (SJR delta (1984 & 1995), Burnet Bay (1931), Crystal Bay (1931), Scott Bay (1931 & 1965), SJR Bay (1965 & 1996), Black Duck Bay (No data in some areas,1931 & 1965), and Tabbs Bay (1965)))	13.97	$84-126 K
5	Baffin Bay Entrance	Shallow Waters	no data	48.44	$291-436 K
6	Laguna Madre[2]	Shallow Waters	no data	446.18	$2.7-4.0 M
7	HSC[1]-SJR[1]-GB[1]-TB[1]-EB[1] system and GOM[1] entrance [3]	Shallow Waters Upper GB	old data (1995-1996)	139.05	$835 K -1.25 M
		Shallow Waters Lower GB	old data (1962 and 1995-1996)	110.23	$661-992 K
		Deep Waters GOM Entrance	old data (1963, 1965, and 1995)	69.30	$416-624 K

AOI	Area Description	Waterbody Type	Reason for Suggestion	Suggested Area (mi^2)	Estimated Cost*
8	Sabine Lake system[4]	Shallow Waters	no and old data (shallower parts of Sabine Lake on the Texas side: 1885)	51.43	$309-463 K
9	Taylor and Hillebrandt Bayous[5]	Rivers	no data	10.19	$61-92 K
10	Colorado River	River	no data	2.17	$13-20 K
11	HSC[1]-SJR[1]-GB[1]-TB[1]-EB[1] system and GOM[1] entrance [6]	Shallow Waters	old data (East Bay (1965))	76.16	$457-685 K
		Small Lakes	no data	9.96	$60-90 K
12	Keller Bay	Shallow Bay	old data (1935)	10.14	$61-92 K
13	TB[1]-EB[1] system	Shallow Bay	old data (Trinity Bay (1965))	167.61	$1.00-1.51 M
		Lakes, and Rivers	no data and old data (Lake Anahuac and Trinity River delta (1933))	46.28	$278-417 K
14	Nueces Bay	Shallow Bay	no data	42.30	$254-381 K

* The actual cost of the project could be significantly different from the estimated cost provided here because bathymetry acquisition cost depends on the type of water body, size of project, and method of collection. we estimate, on average, it would cost $6,000-$9,000 (2021 US. dollars) to collect bathymetry data per square mile ($9-$14 per acre) using sonar techniques in shallow waterbodies. This estimate is based on some of the previous contracts managed by the TWDB in 2021.

[1] Houston Ship Channel (HSC), Galveston Bay (GB), San Jacinto River (SJR), Trinity Bay (TB), East Bay (EB), Gulf of Mexico (GOM).

[2] The suggested areas are very shallow, and the new LiDAR study funded by the TWDB might cover some of the suggested areas.

[3] Please also see AOI 4, 11, and 13.

[4] Sabine Lake bathymetry is an important subject for the Sabine to Galveston project conducted by USACE so more bathymetric data might become available or be collected in the near future.

[5] USACE-Galveston District might have some data for the Taylor and Hillebrandt Bayous (AOI9). An active search is being performed at the time of writing this report.

[6] Please also see AOI 4, 7, and 13.

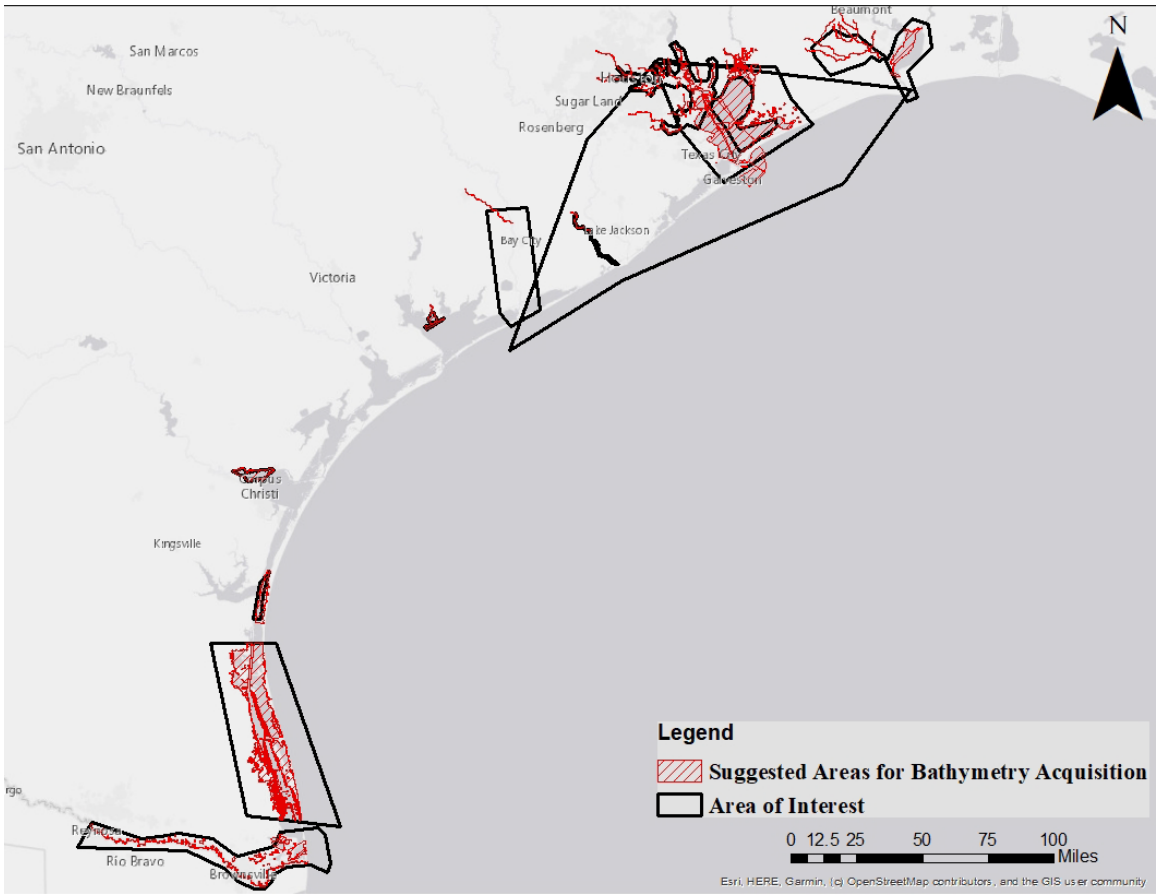

Figure 2. Areas of Interests (AOIs) provided by the participants of the TIFF Bathymetry Workshop overlayed with the suggested areas identified in the gap analysis with a need for bathymetric data collection within the AOIs.

Summary of suggestion

AOI 1 Summary of suggestion

- Area Description: San Bernard River Tidal
- Waterbody Type: River
- Reason for suggestion: No data is available (based on the analysis conducted in this effort) for this tidally-influenced portion of the river that is important for coastal modeling.
- Suggested Area=1.16 mi^2
- Estimated Cost: $7,000-$11,000

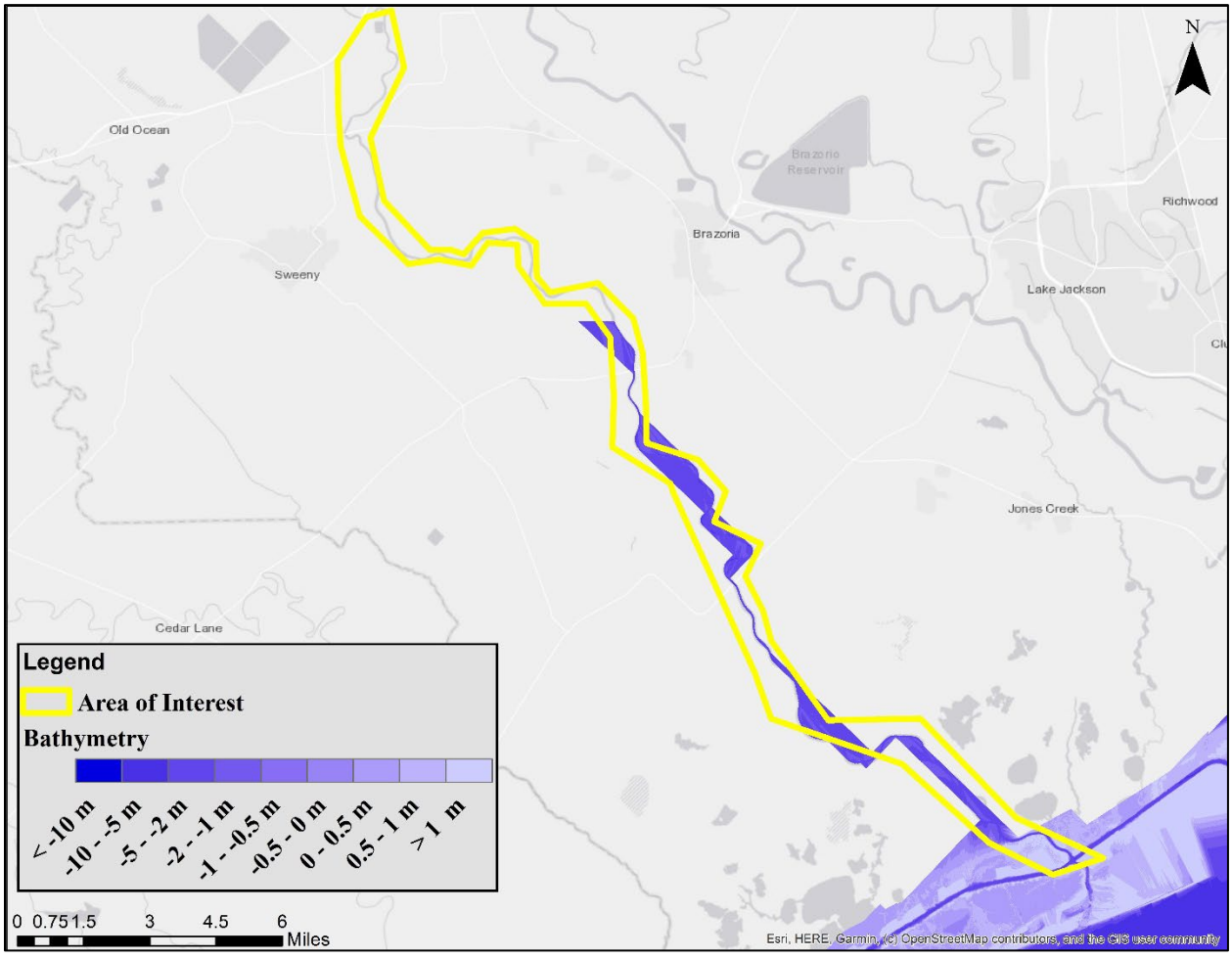

Figure 3. Bathymetry of AOI1 using the BlueTopo database.

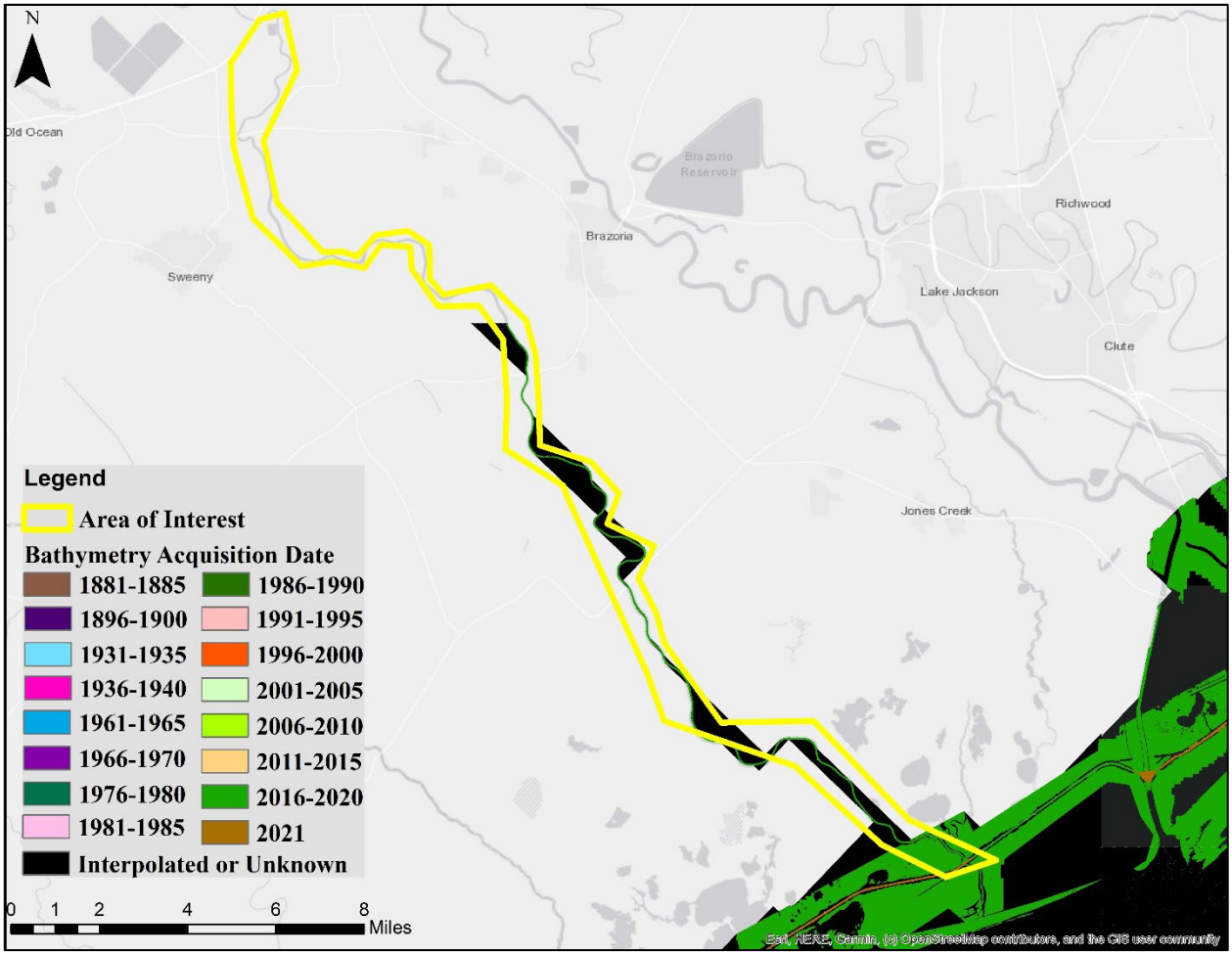

Figure 4. Latest bathymetry acquisition date for AOI1 using the BlueTopo database.

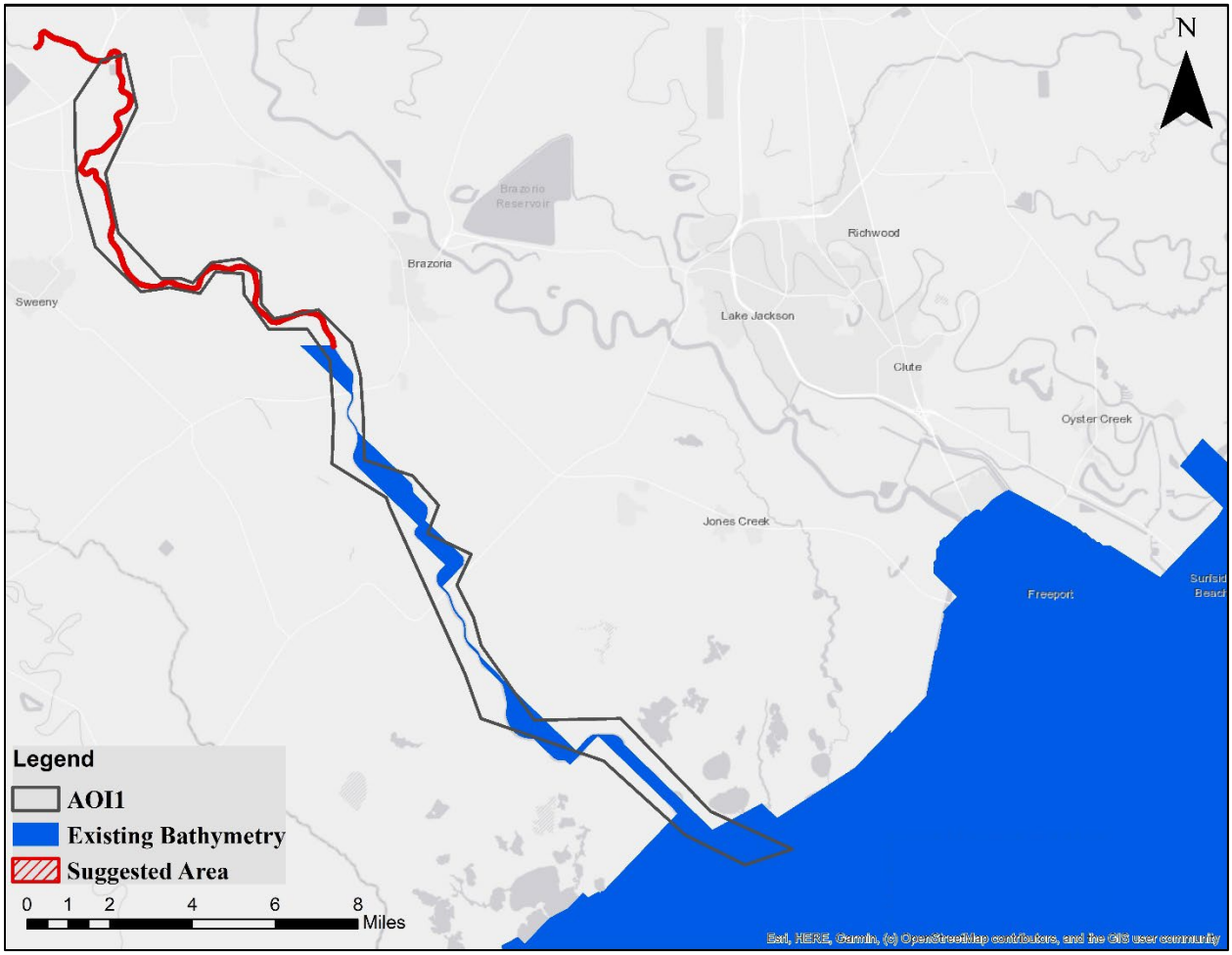

Figure 5. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI1.

AOI 2 Summary of suggestion

- Area Description: Rio Grande River floodplain
- Waterbody Type: River and shallow waters
- Reason for suggestion: No data is available (based on the analysis conducted in this effort)
- Suggested Area
  - River: 13.62 mi^2
  - Waterbodies: 56.91 mi^2
- Estimated Cost
  - River: $82,000-$123,000
  - Waterbodies: $342,000-$512,000

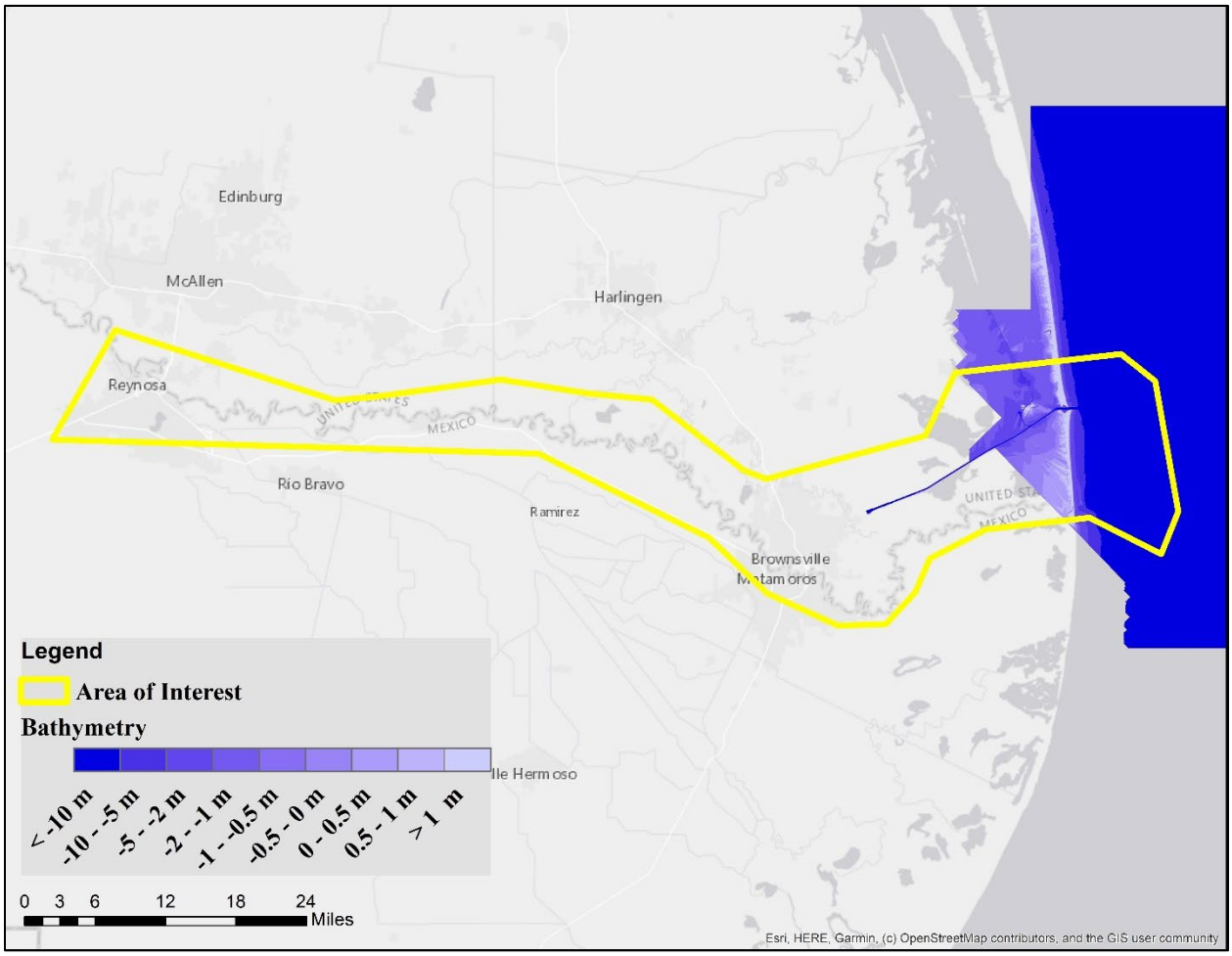

Figure 6. Bathymetry of AOI2 using the BlueTopo database.

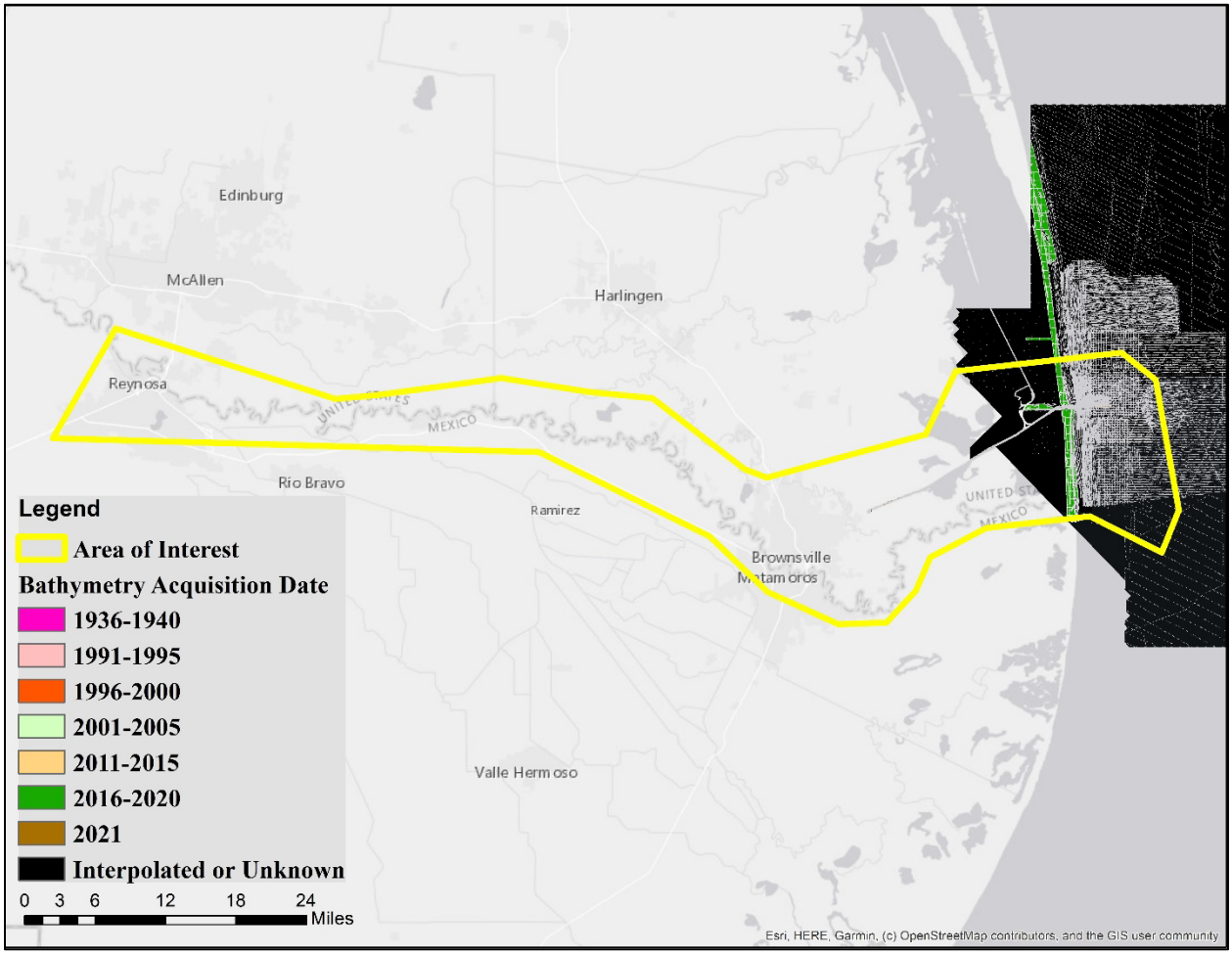

Figure 7. Latest bathymetry acquisition date for AOI2 using the BlueTopo database.

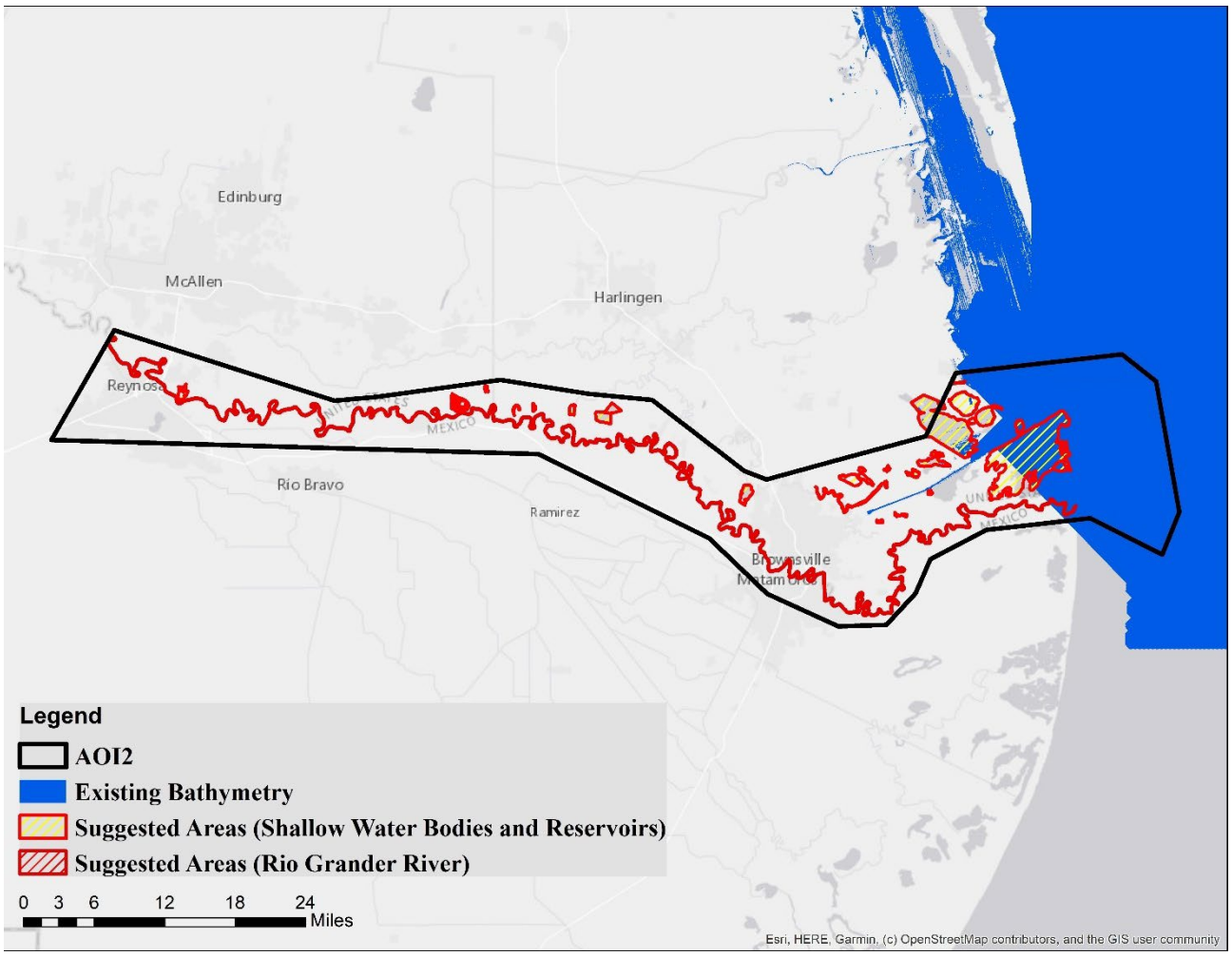

Figure 8. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI2.

AOI 3 and 12 Summary of suggestion

- Area Description: Part of Matagorda Bay (AOI 3) and Keller Bay (AOI 12)
- Waterbody Type: Shallow Bays
- Reason for suggestion: Old bathymetry data (based on the analysis conducted in this effort)
    - AOI 3: 1991-1992
    - AOI 12: 1935
- Suggested Area
    - AOI 3: 5.11 mi^2
    - AOI 12: 10.14 mi^2
- Estimated Cost
    - River: $31,000-$46,000
    - Waterbodies: $61,000-$92,000

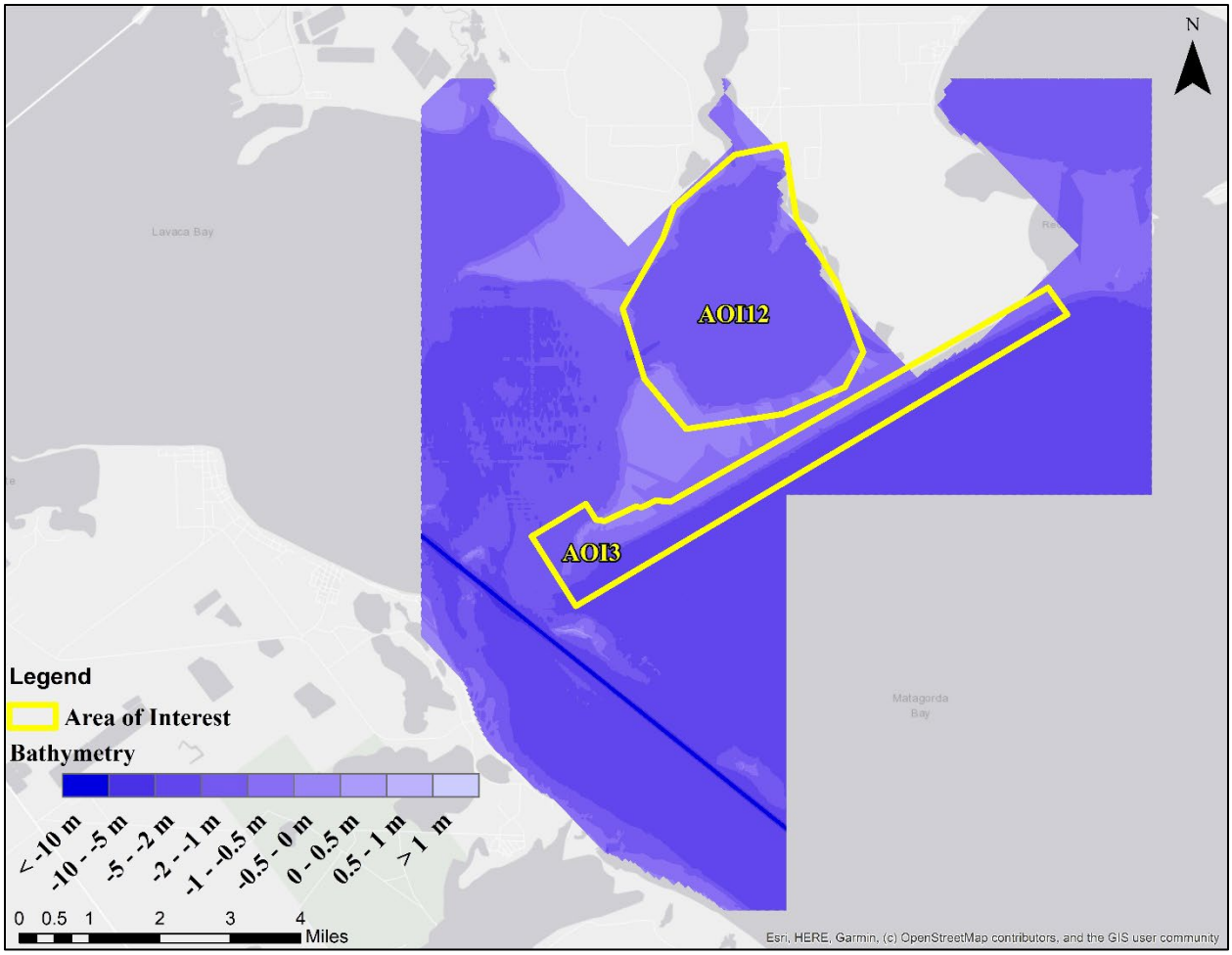

Figure 9. Bathymetry of AOI 3 and 12 using the BlueTopo database.

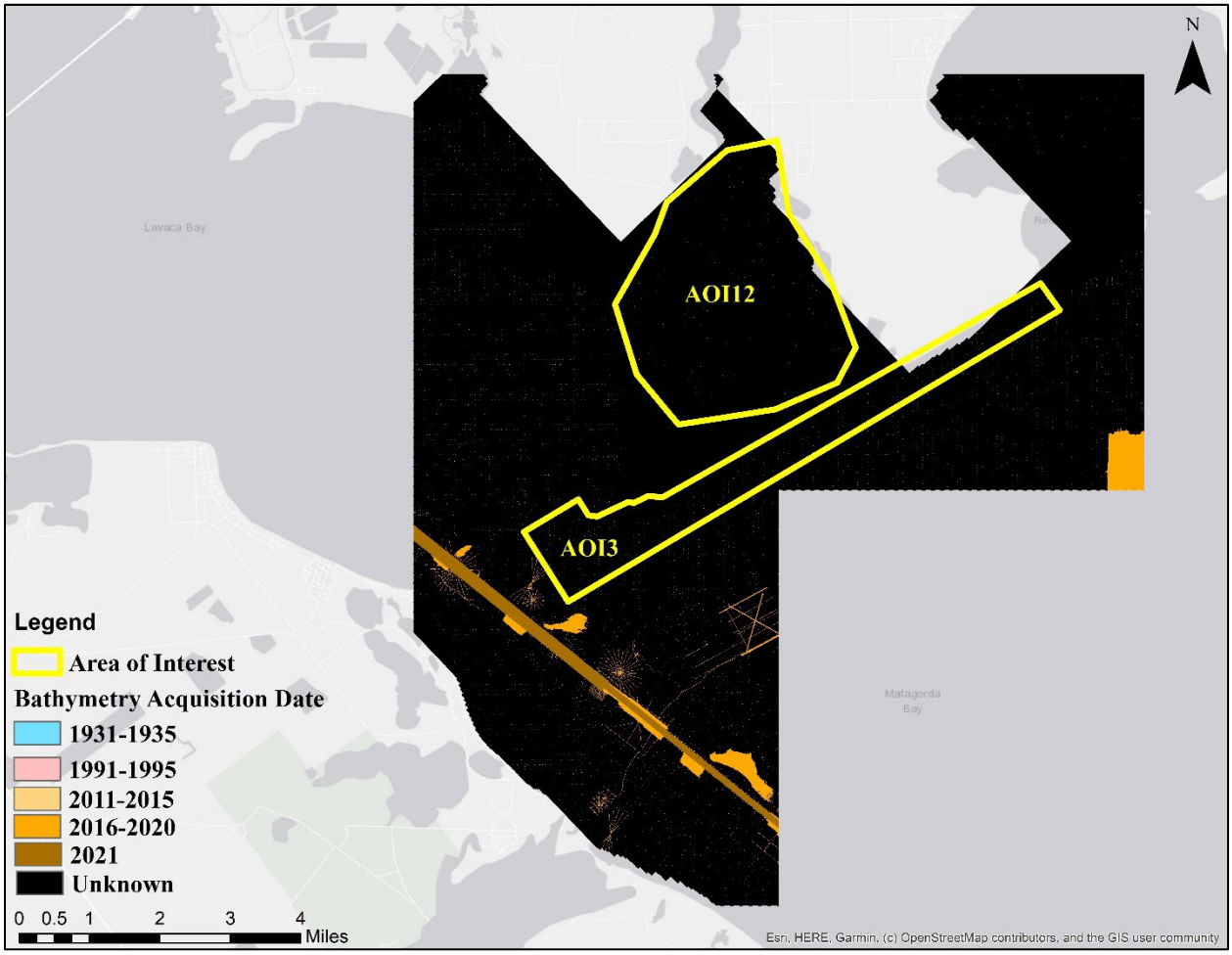

Figure 10. Latest bathymetry acquisition date for AOI 3 and 12 using the BlueTopo database.

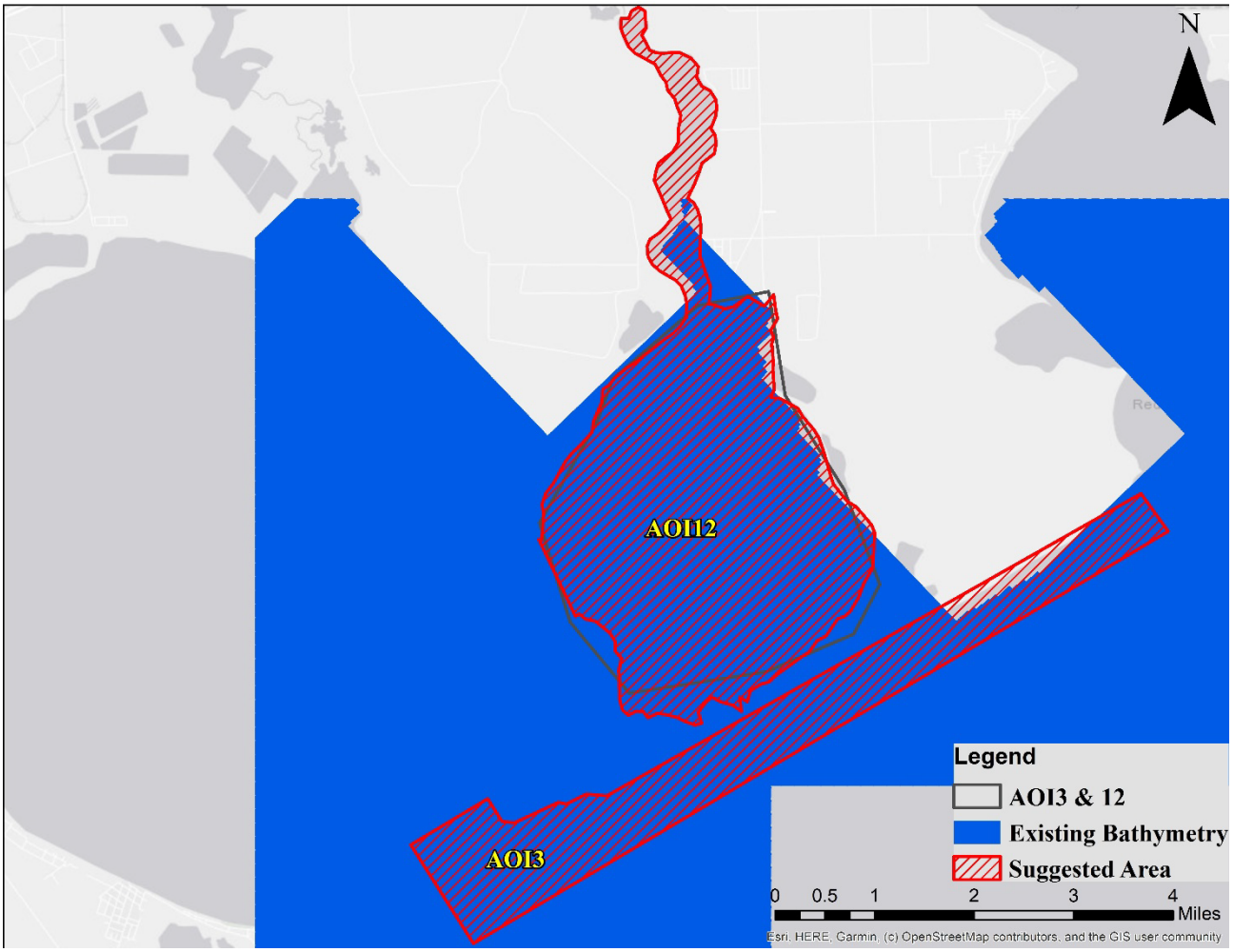

Figure 11. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 3 and 12.

AOI 4 Summary of suggestion

- Area Description: Houston Ship Channel System and part of the Upper Galveston Bay
- Waterbody Type: Rivers and Shallow Waters
- Reason for suggestion: Old bathymetry data for the Shallow Waters (SJR delta (1984 & 1995), Burnet Bay (1931), Crystal Bay (1931), Scott Bay (1931 & 1965), SJR Bay (1965 & 1996), Black Duck Bay (No data in some areas,1931 & 1965), and Tabbs Bay (1965)), and no data for the rivers (based on the analysis conducted in this effort)
- Suggested Area
    - Rivers: 15.80 mi^2
    - Shallow Waters: 13.97 mi^2
- Estimated Cost
    - River: $95,000-$142,000
    - Shallow Waterbodies: $84,000-$126,000

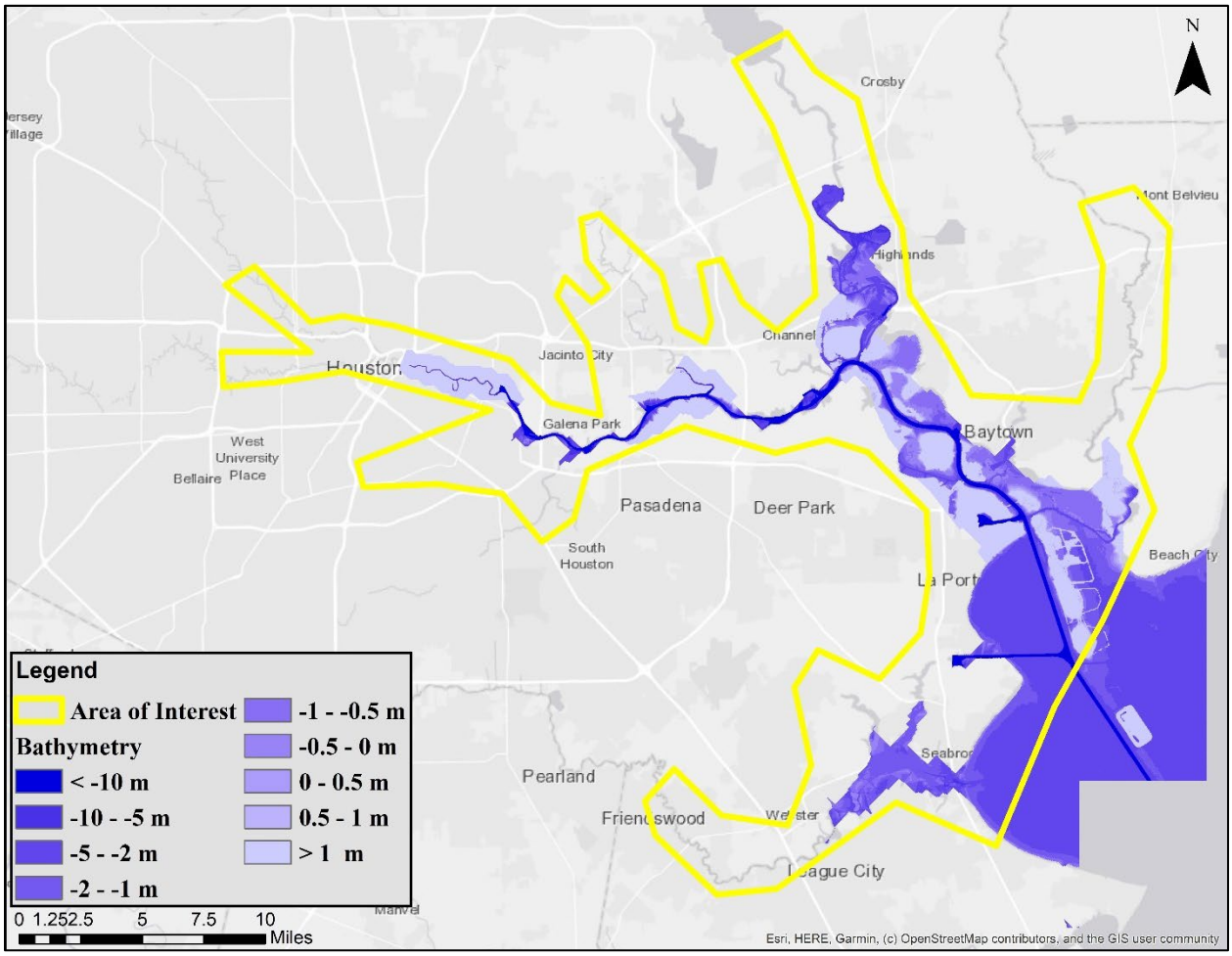

Figure 12. Bathymetry of AOI 4 using the BlueTopo database.

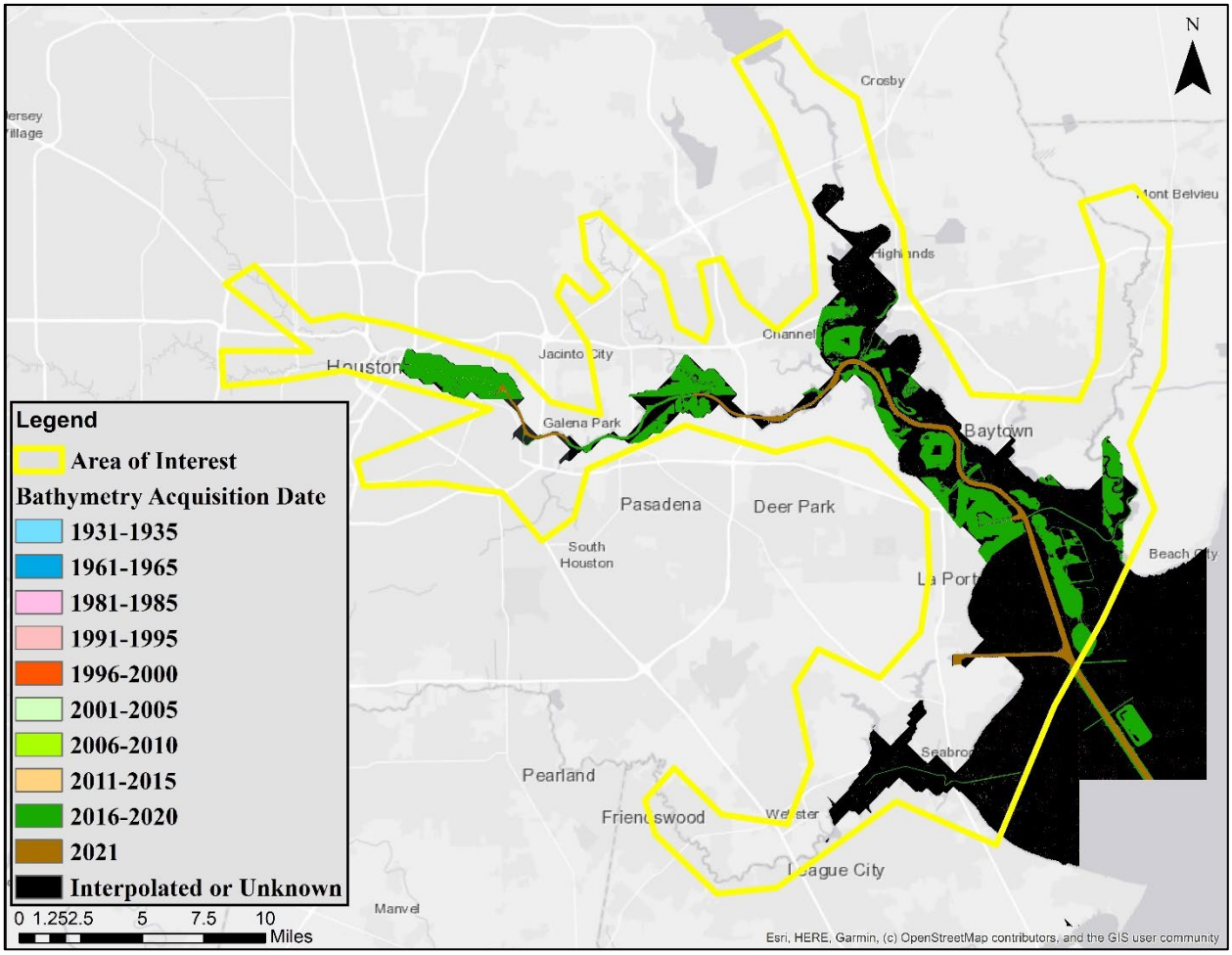

Figure 13. Latest bathymetry acquisition date for AOI 4 using the BlueTopo database.

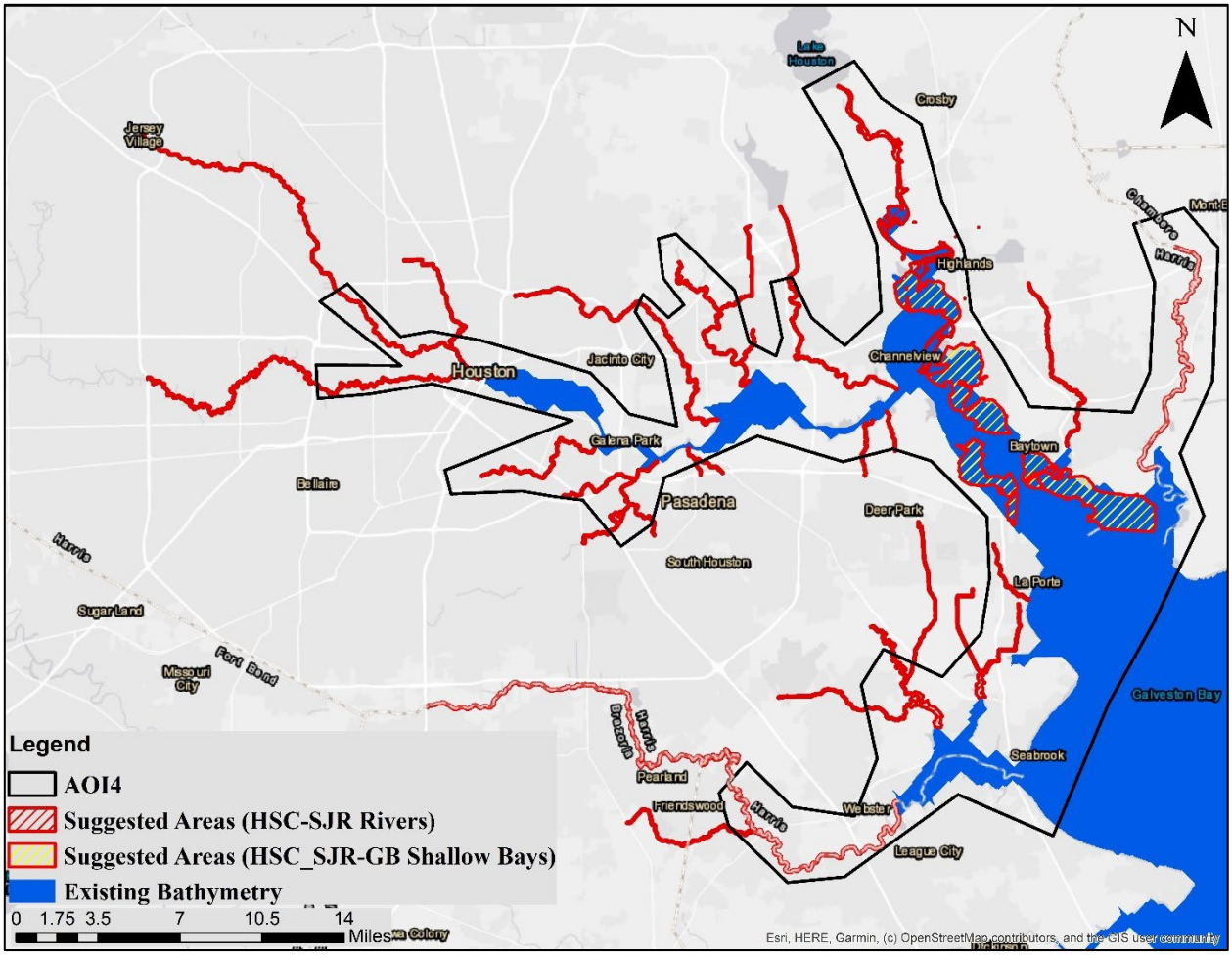

Figure 14. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 4.

AOI 5 Summary of suggestion

- Area Description: Baffin Bay Entrance
- Waterbody Type: Shallow Waters
- Reason for suggestion: No data is available (based on the analysis conducted in this effort)
- Suggested Area: 48.44 mi^2
- Estimated Cost: $291,000-$436,000

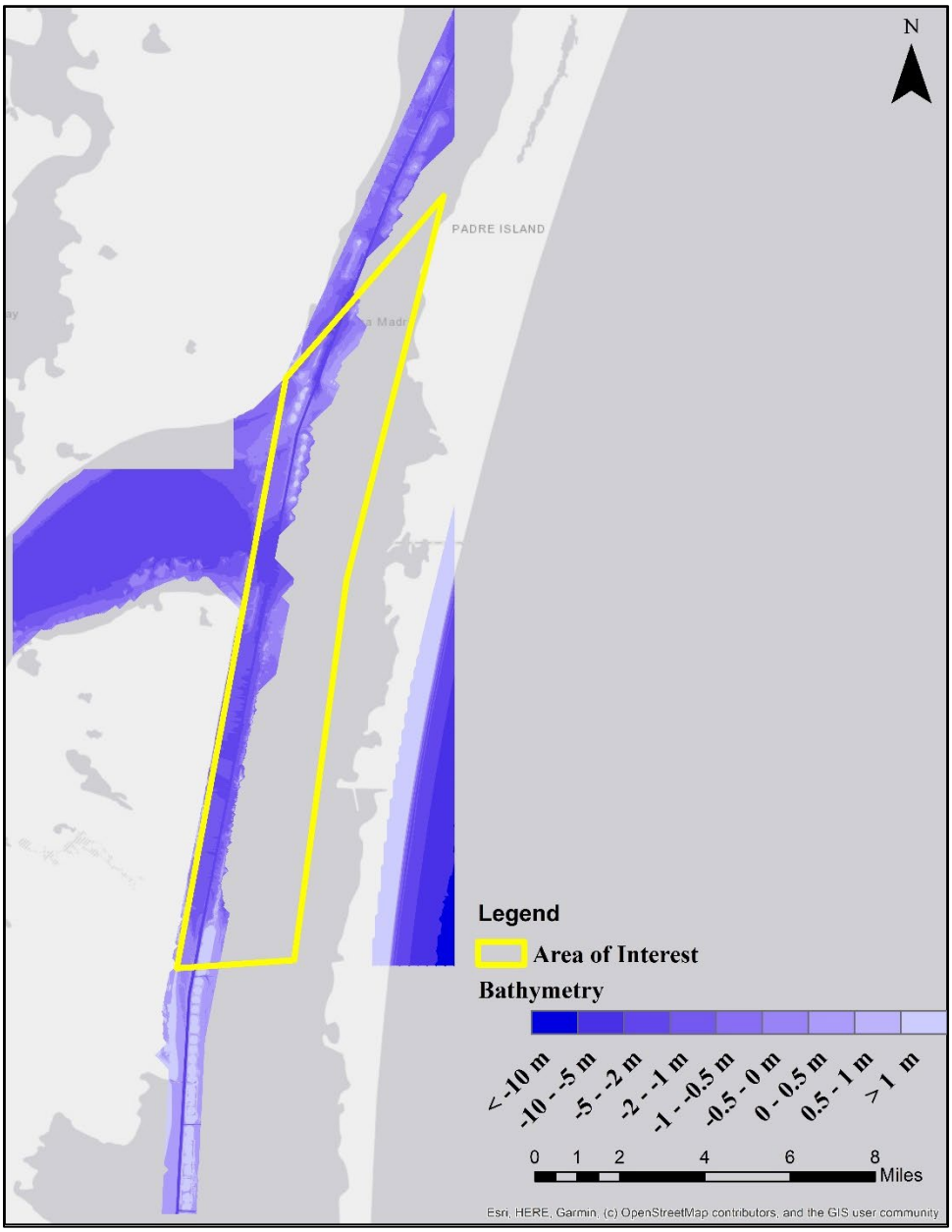

Figure 15. Bathymetry of AOI 5 using the BlueTopo database.

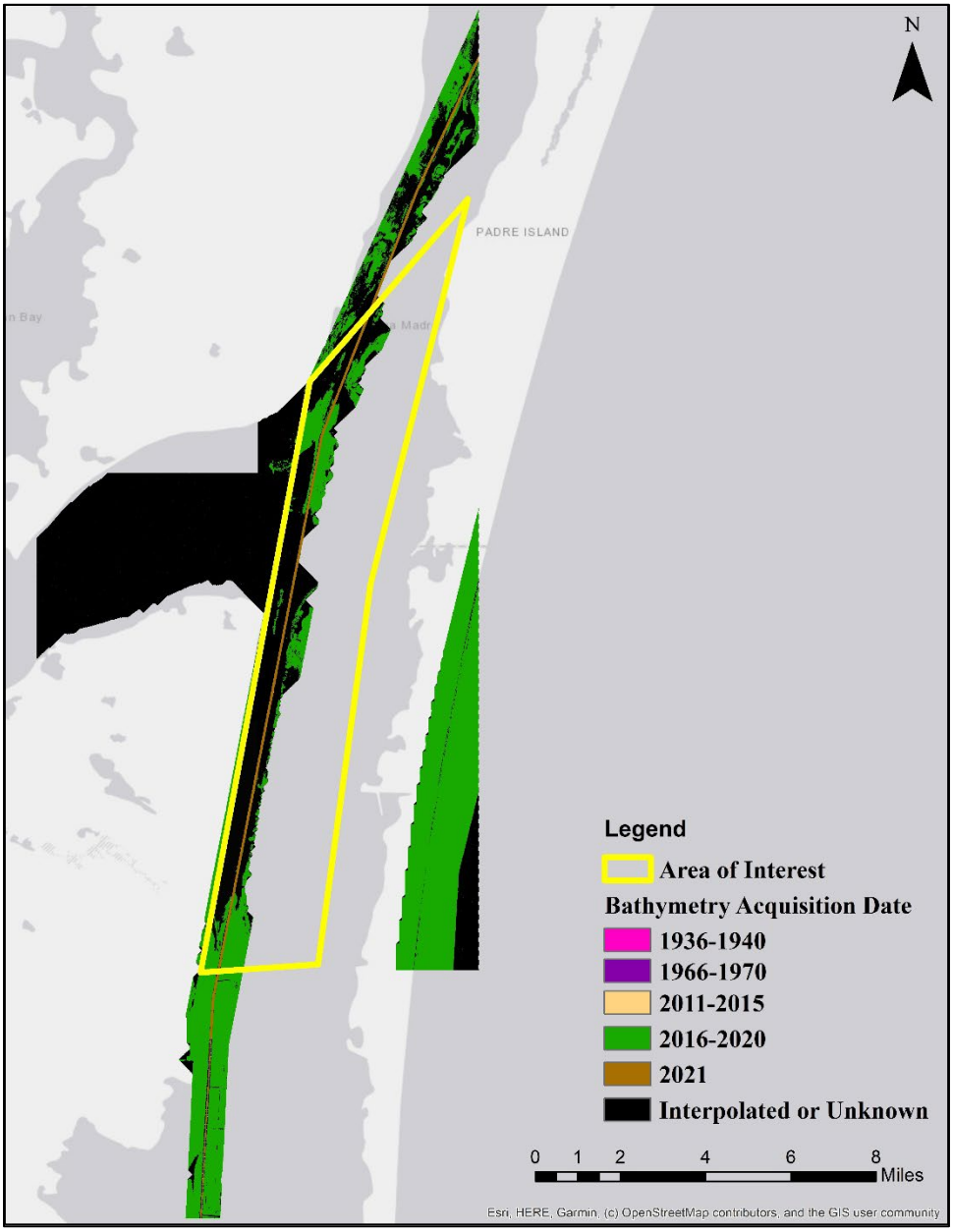

Figure 16. Latest bathymetry acquisition date for AOI 5 using the BlueTopo database.

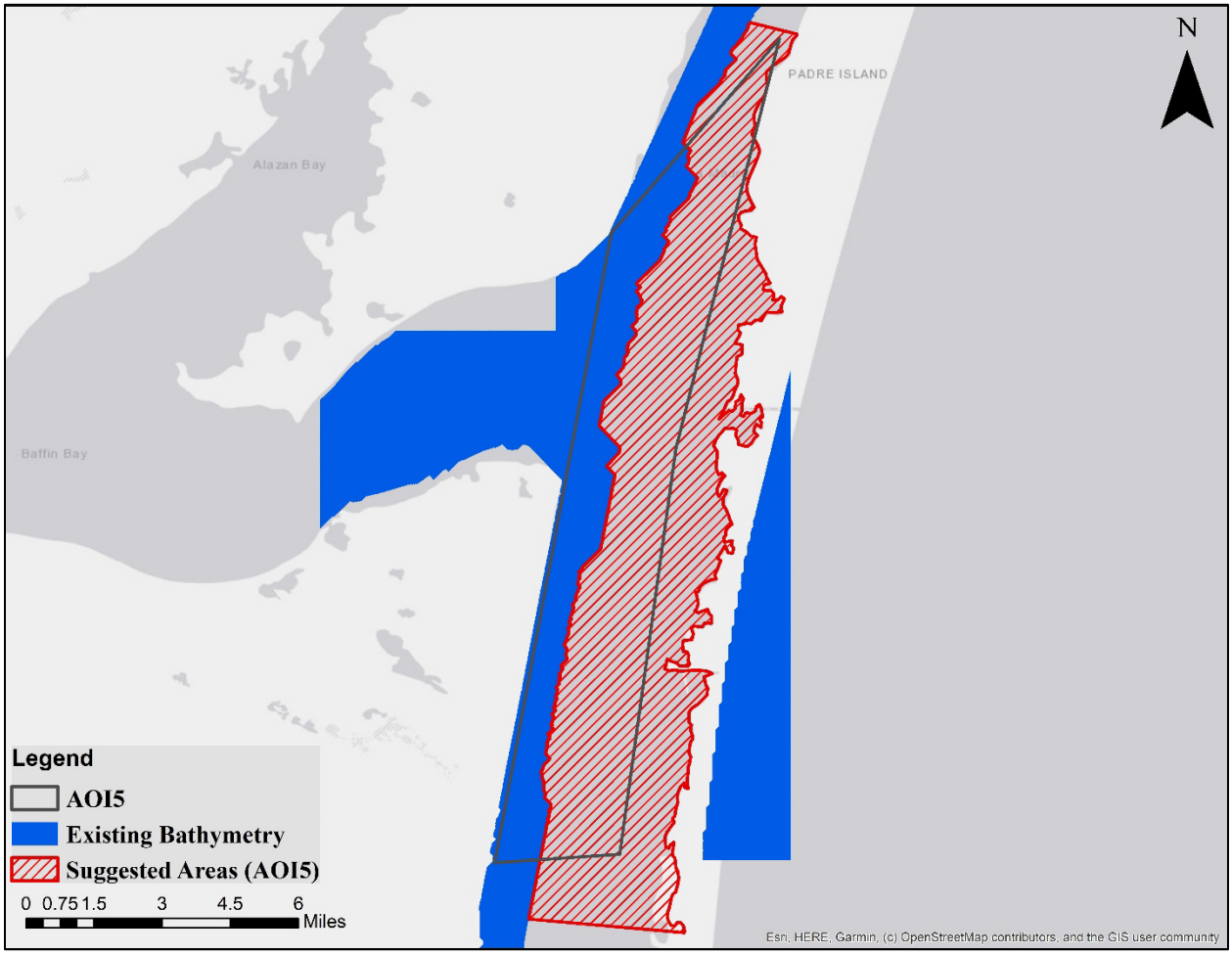

Figure 17. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 5.

AOI 6 Summary of suggestion

- Area Description: Laguna Madre
- Waterbody Type: Shallow Waters
- Reason for suggestion: No data is available (based on the analysis conducted in this effort)
- Suggested Area: 446.18 mi^2
- Estimated Cost: $2,677,000-$4,016,000
- Additional Information:
    - In addition to the tiles downloaded from the BlueTopo database, two recent DEMs (2017 LiDAR data funded by GLO for acquisition and TWDB for processing, and 2021 hydro survey data funded by TWDB) were also used during the data inventory. The DEMs are accessible through the "Bathy" GIS file for AOI6. Figures 17 and 18 show the available bathymetry data without and with the added datasets.
    - The suggested areas are very shallow, and the new LiDAR study funded by the TWDB) might cover some of the suggested areas.

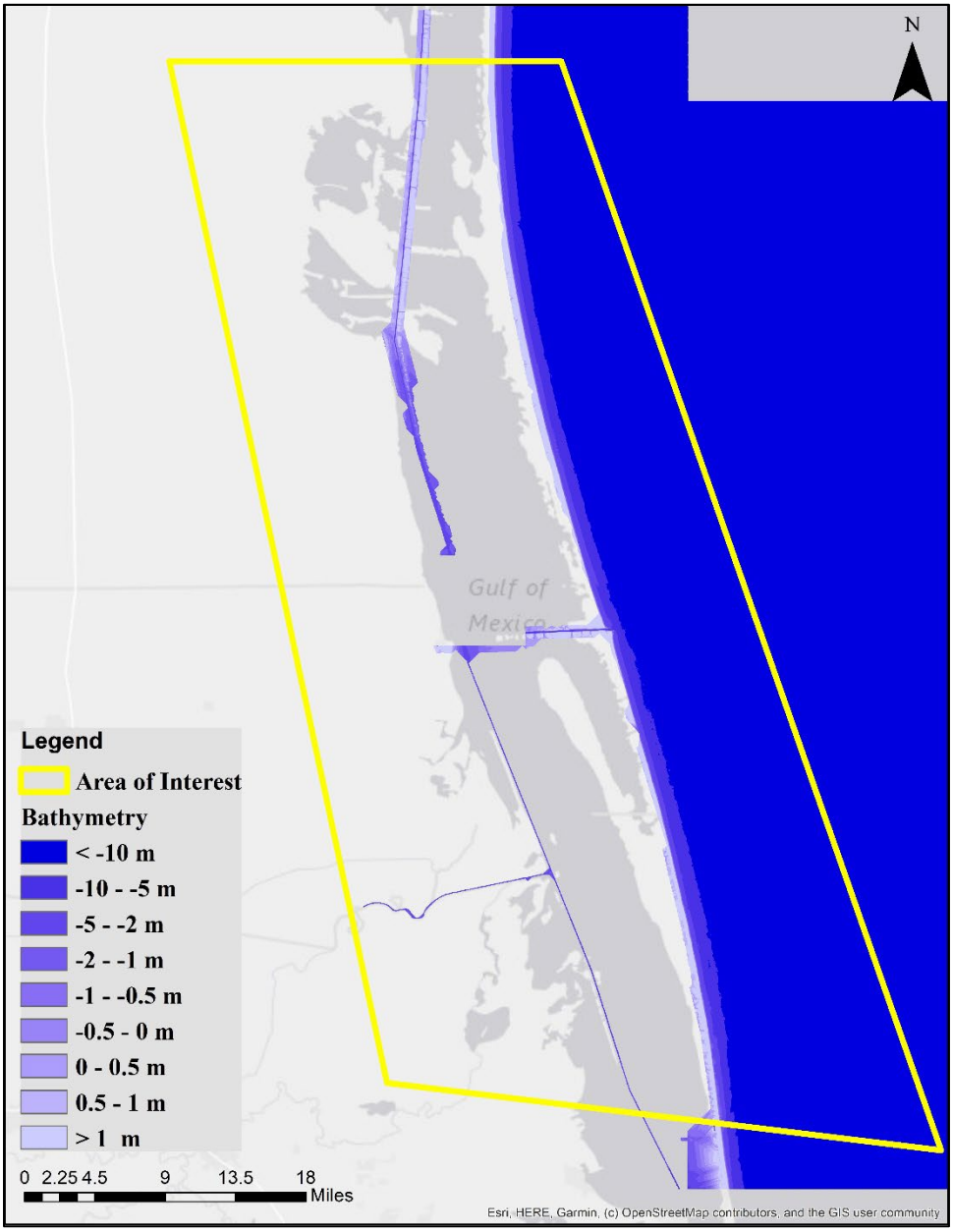

Figure 18. Bathymetry of AOI 6 using the BlueTopo database.

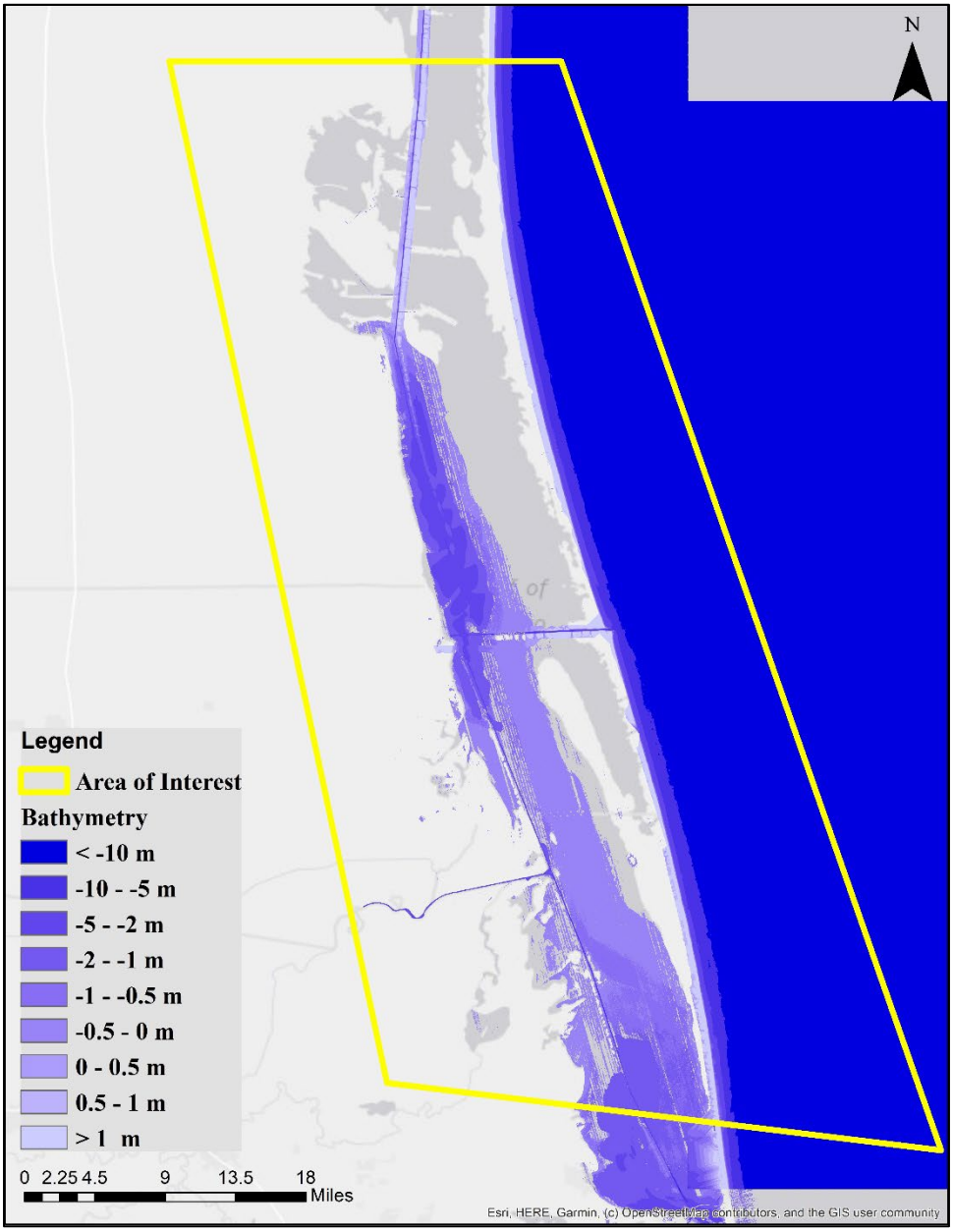

Figure 19. Bathymetry of AOI 6 using the BlueTopo and the 2 extra TWDB databases.

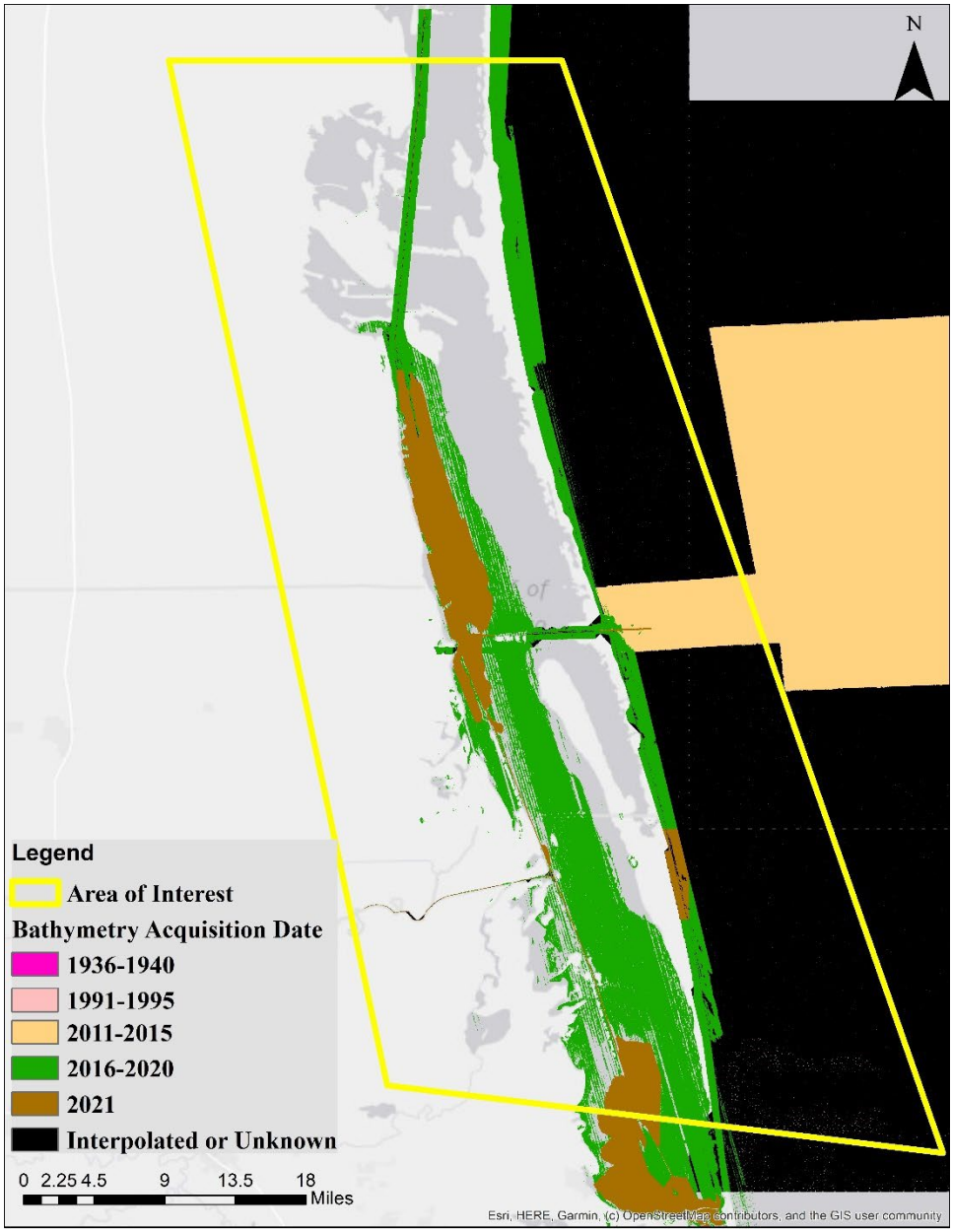

Figure 20. Latest bathymetry acquisition date for AOI 6 using the BlueTopo and the 2 extra TWDB databases.

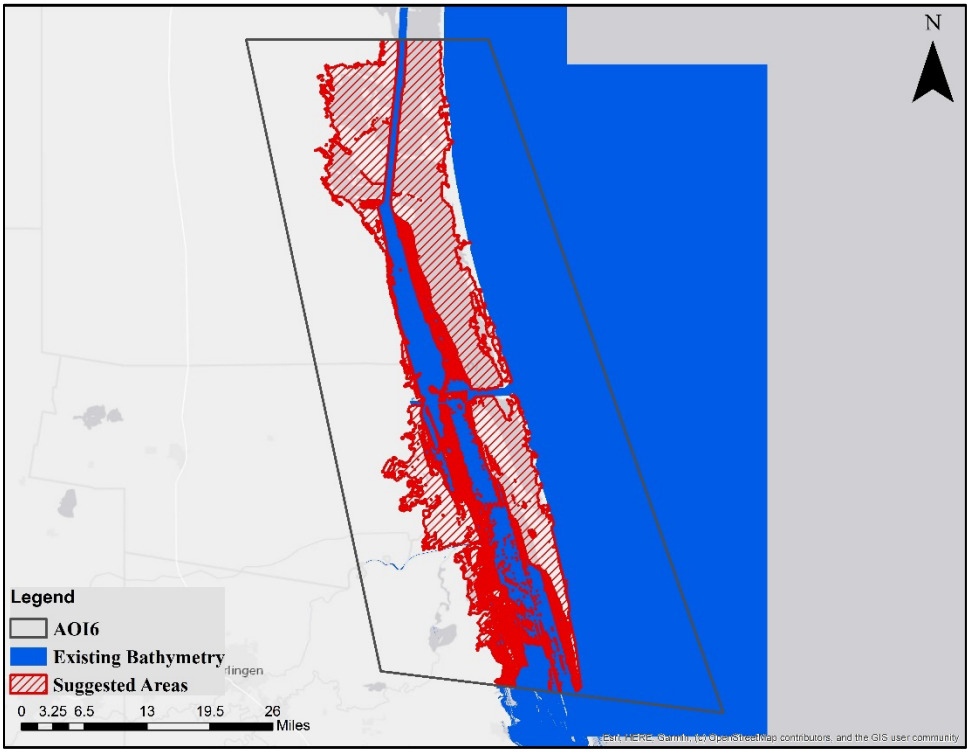

Figure 21. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 6.

AOI 7 Summary of suggestion

- Area Description: Houston Ship Channel (HSC) - Galveston Bay (GB) - San Jacinto River (SJR) - Trinity Bay (TB), East Bay (EB) system, and GOM entrance. We only provided suggestions for Upper and Lower GB and GOM entrance here. Suggestions for other areas could be found under AOI 4, 11, 13.
- Waterbody Type: Shallow (Upper and Lower GB) and Deep (GOM entrance) Waters
- Reason for suggestion: Old bathymetry data (Upper GB: 1995-1996, Lower GB: 1962 and 1995-1996, GOM: 1963, 1965, and 1995, based on the analysis conducted in this effort)
- Suggested Area:
    - Upper GB: 139.05 mi^2
    - Lower GB: 110.23 mi^2
    - Gulf of Mexico Entrance: 69.30 mi^2
- Estimated Cost:
    - Upper GB: $835,000-$1,252,000
    - Lower GB: $661,000-$992,000
    - Gulf of Mexico Entrance: $416,000-$624,000
- Additional Information:
    - In addition to the tiles downloaded from the BlueTopo database, a recent DEM provided by the Texas Parks & Wildlife Department (TPWD, https://tpwd.texas.gov/landwater/water/habitats/coastal-fisheries-habitat-assessment-team/) was also used during the data inventory. The DEM is accessible through the "Bathy" GIS file for AOI7.

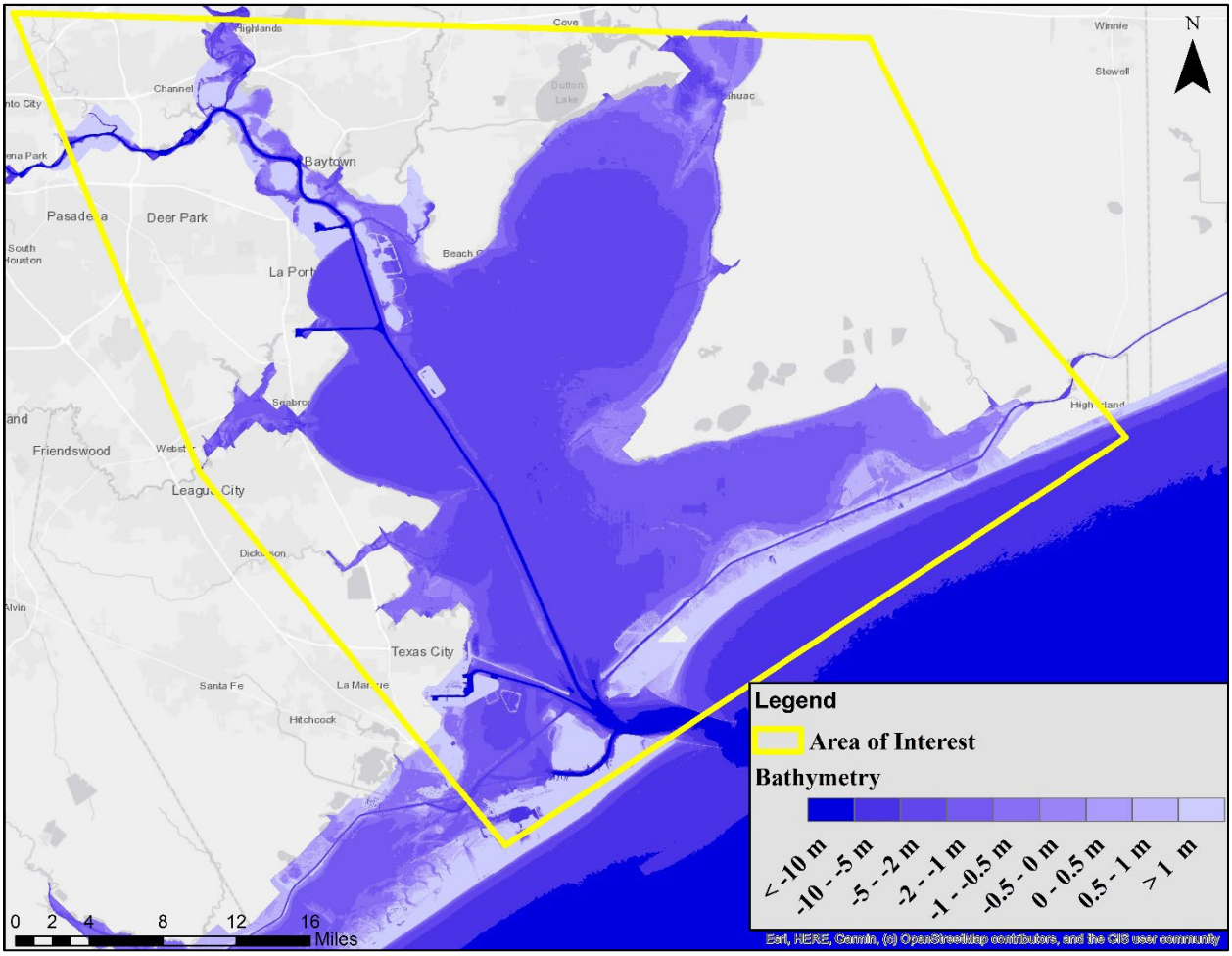

Figure 22. Bathymetry of AOI 7 using the BlueTopo and the TPWD databases.

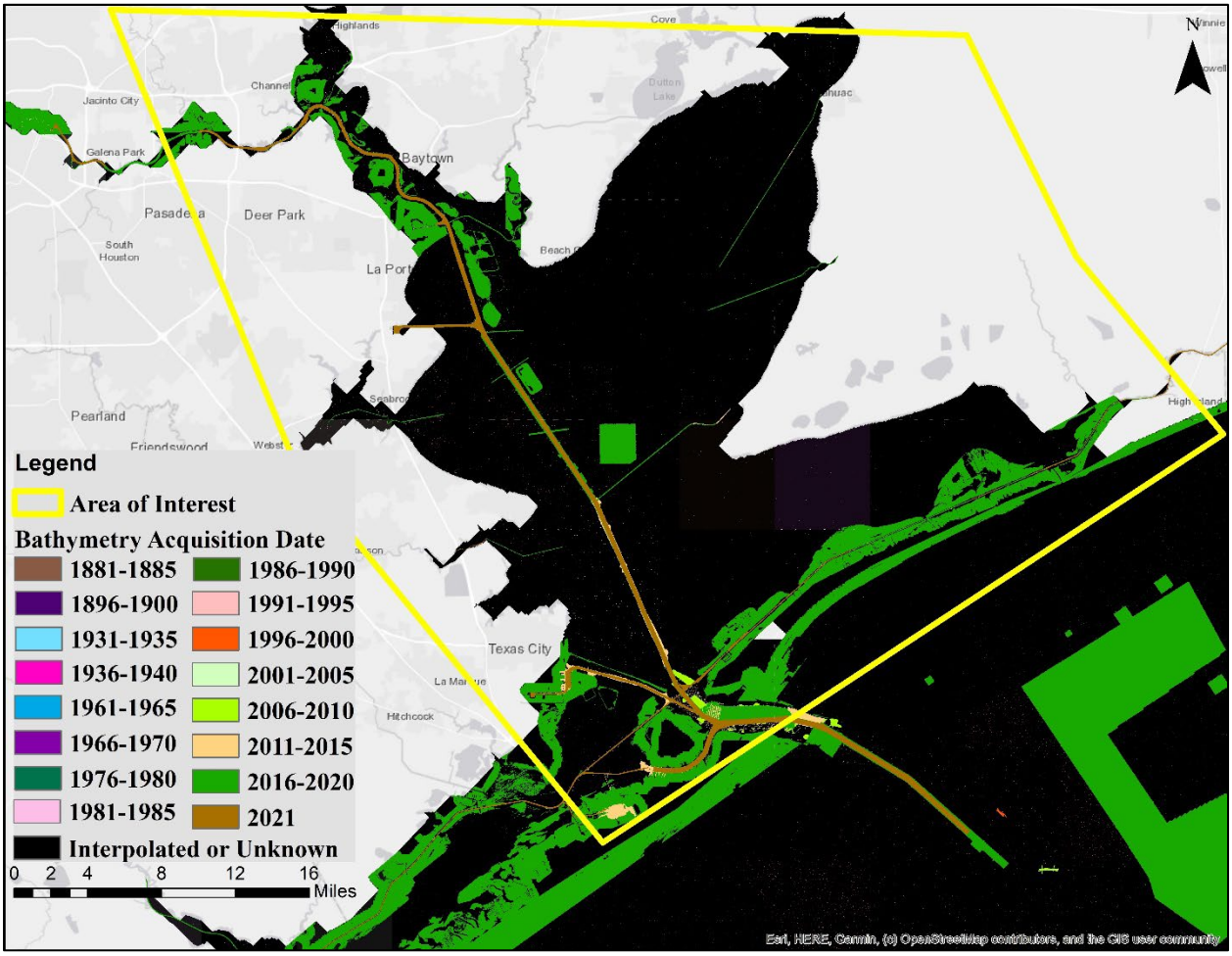

Figure 23. Latest bathymetry acquisition date for AOI 7 using the BlueTopo and the TPWD databases.

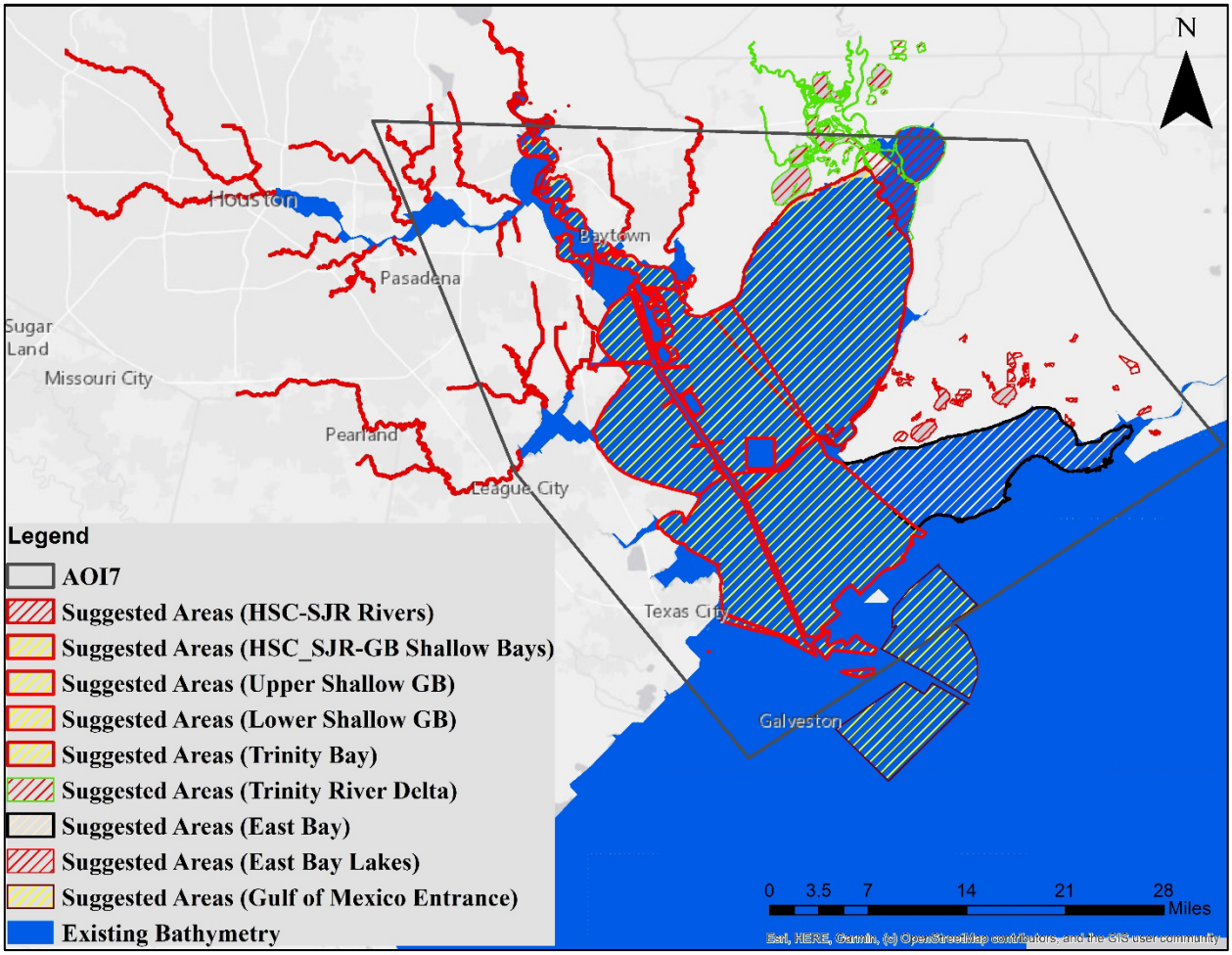

Figure 24. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 7. Please also refer to AOI 4, 11, and 13 for more information on some of the suggested areas shown here and not listed under AOI 7. Different hatched colors are not clearly distinguishable tin the figure to the number of active layers. All the GIS files can be found here.

AOI 8 and 9 Summary of suggestion

- Area Description: Sabine Lake system (AOI8) and Taylor and Hillebrandt Bayous (AOI9)
- Waterbody Type: Shallow Bay (AOI 8) and Rivers (AOI 9)
- Reason for suggestion: No bathymetry data on AOI9 and part of AOI 8 and old bathymetry data (shallower parts of Sabine Lake on the Texas side: 1885)
- Suggested Area:
    - Sabine Lake (AOI 8): 51.43 mi^2
    - Taylor and Hillebrandt Bayous (AOI 9): 10.19 mi^2
- Estimated Cost:
    - Sabine Lake (AOI 8): $309,000-$463,000
    - Taylor and Hillebrandt Bayous (AOI 9): $61,000-$92,000
- Additional Information:
    - In addition to the tiles downloaded from the BlueTopo database, we identified some other data sources for AOI8. In April of 2007, the Texas Water Development Board (TWDB) entered into agreement with the Texas Parks and Wildlife Department for the purpose of collecting bathymetric data within the Keith Lake-Salt Bayou system near Port Arthur, Texas. Data collection was performed using a Knudsen 200 kHz echosounder integrated with differentially corrected global positioning system (DGPS) navigation equipment. The data collected by the TWDB was augmented with data from surveys conducted during projects sponsored by the J.D Murphree Wildlife Management Area and the McFaddin National Wildlife Refuge in June 2002, and by Exxon-Mobil (as part of the Golden Pass Pipeline project) in July 2006. This dataset is included in the "Bathy" GIS file for AOI8_9. but is not activated on the map. More information could be found here: https://www.twdb.texas.gov/surfacewater/surveys/completed/list/index.asp
    - Bathymetry data for the portion of Sabine Lake that is located in Louisiana (already incorporated into BlueTopo) was also downloaded separately and included in the Bathy" GIS file for AOI8_9 due to some differences found in the datasets. This dataset was collected by the Louisiana Coastal Protection and Restoration Authority. To download more data from their web-portal go to https://cims.coastal.louisiana.gov/Viewer/Map.aspx?guid=f8ec2690-bbb1-4879-ac30-aa44f5878b7f and then click "Add Layers" and then select "LASARD (Sediment Resources)" and then click "Bathy/Topo Catalog"
    - Some limited bathymetry data in the format of xyz is also available through the U.S. Army Corps of Engineering (USACE)-Galveston District portal (https://www.swg.usace.army.mil/Missions/Navigation/Hydrographic-Surveys/). This dataset is also included but not activated in the Bathy" GIS file for AOI8_9.

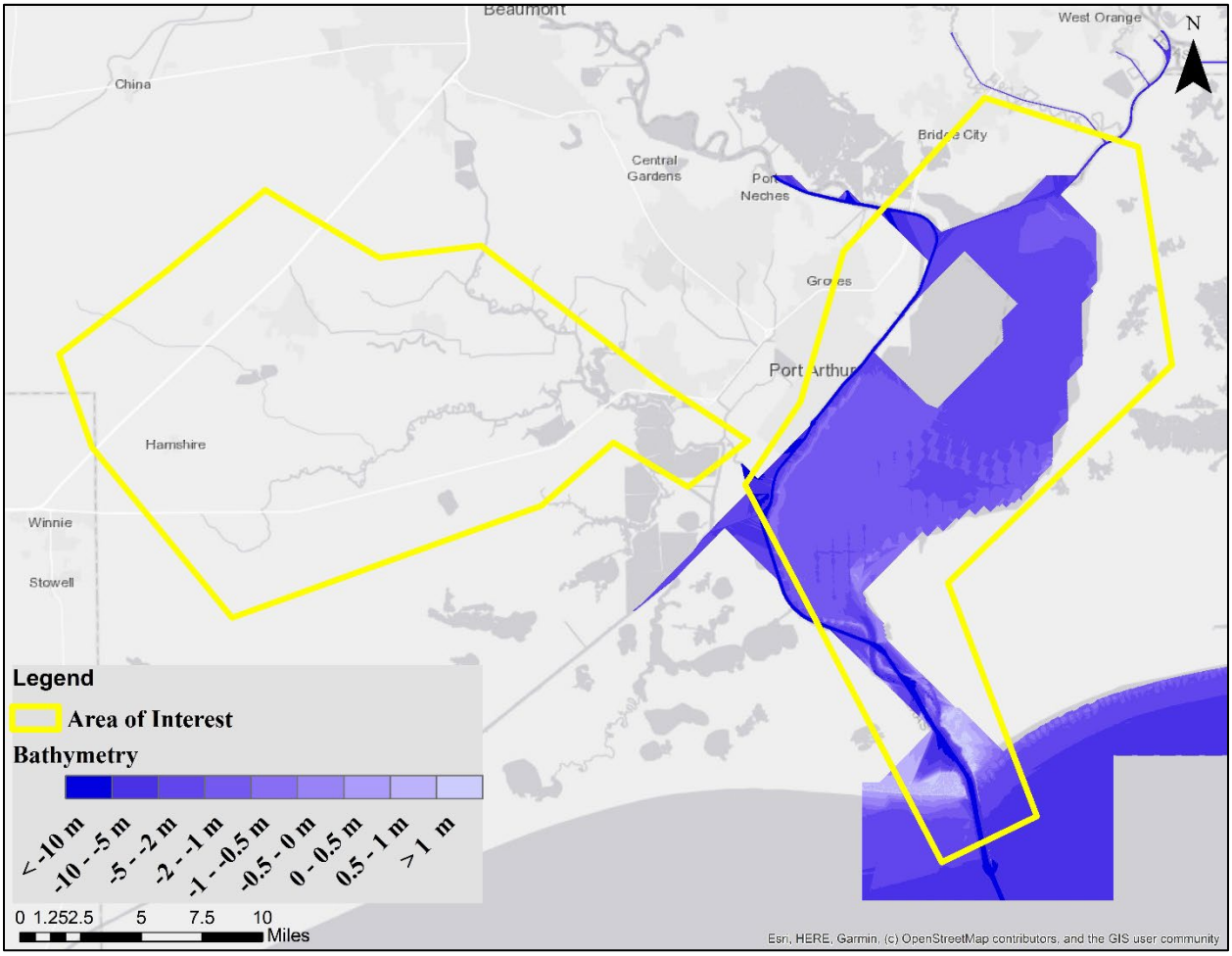

Figure 25. Bathymetry of AOI 8 and 9 using the BlueTopo database.

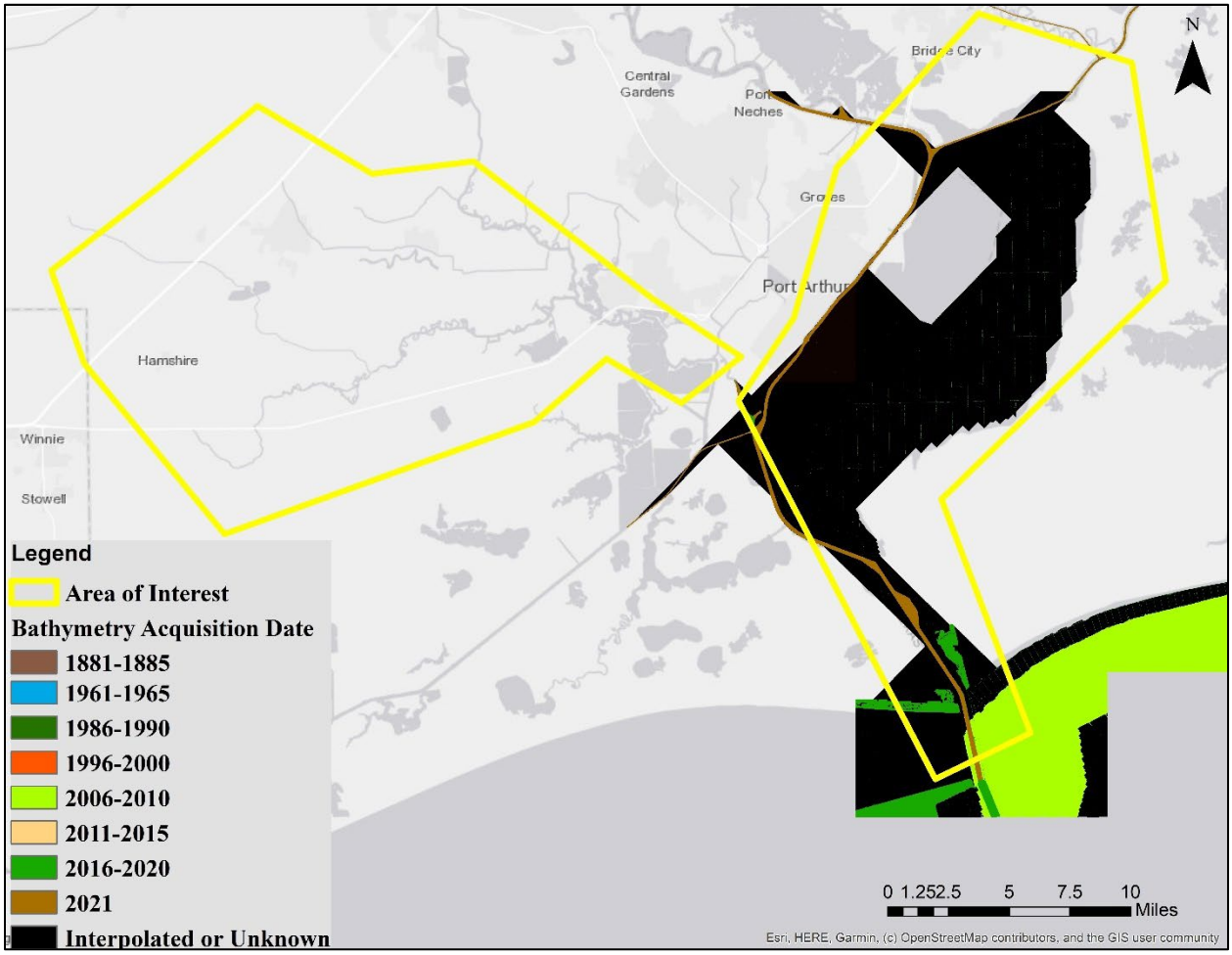

Figure 26. Latest bathymetry acquisition date for AOI 8 and 9 using the BlueTopo database.

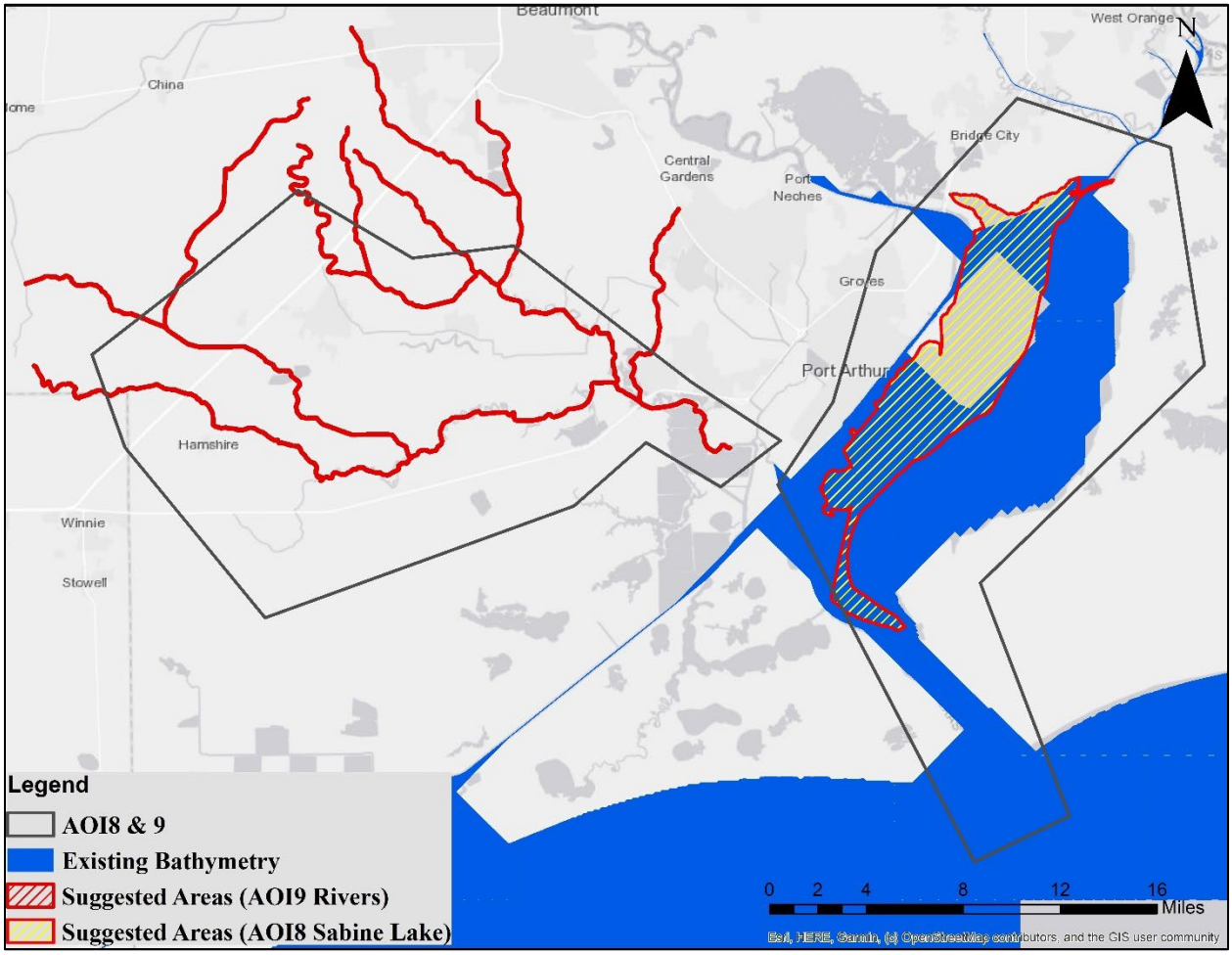

Figure 27. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 8 and 9.

AOI 10 Summary of suggestion

- Area Description: Lower Colorado River
- Waterbody Type: River
- Reason for suggestion: No data is available in one of the tributaries (based on the analysis conducted in this effort)
- Suggested Area: 2.17 mi^2
- Estimated Cost: $13,000-$20,000
- Additional Information:
    - In addition to the tiles downloaded from the BlueTopo database, we identified some other data sources for AOI10. In 2019, bathymetry data was collected from the mouth of the River near Matagorda, TX, up to the approximate area of the Ellinger area County Line. This dataset was collected using multi-beam sonar technique and the results are provided in point shapefiles rather than DEMs.

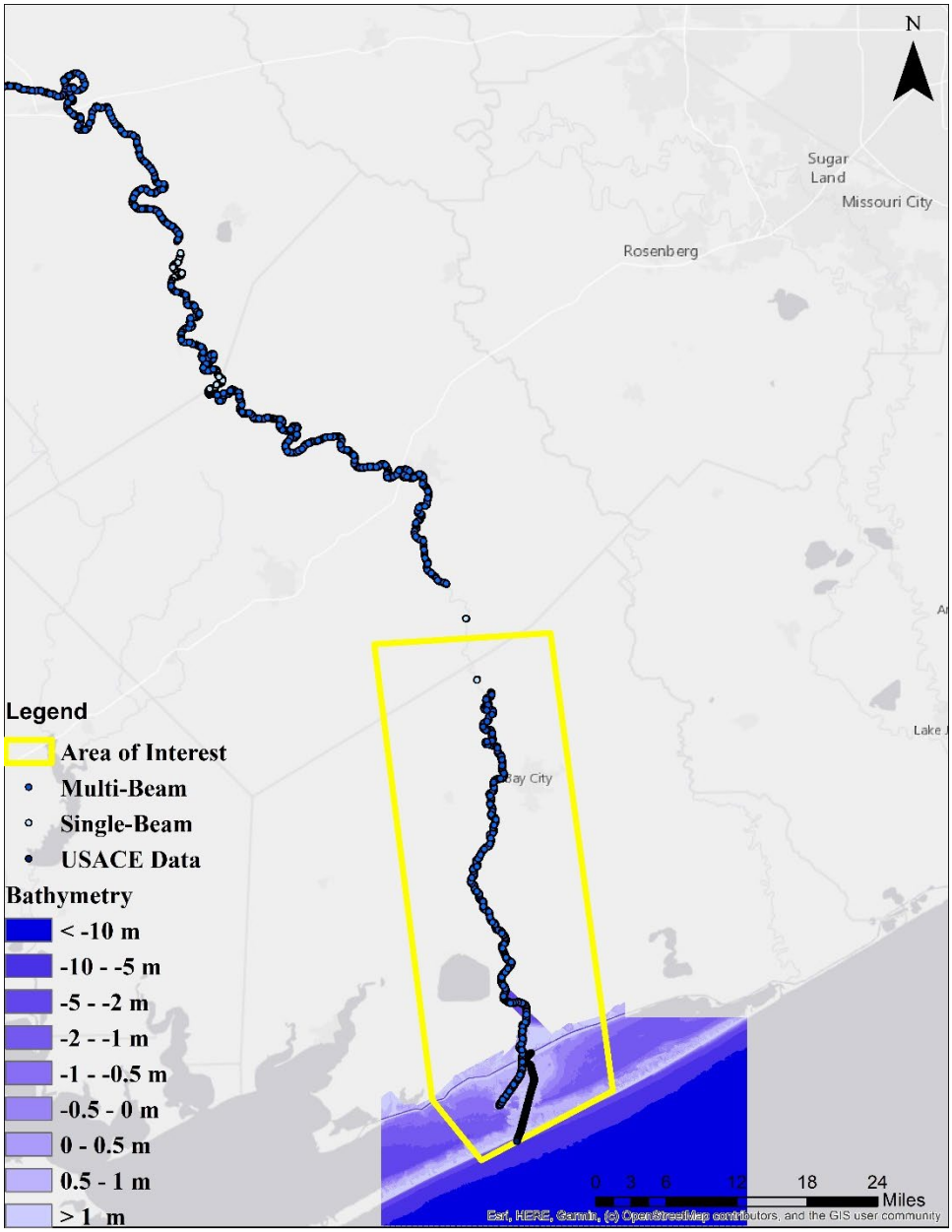

Figure 28. Bathymetry of AOI 10 using the BlueTopo and TWDB databases.

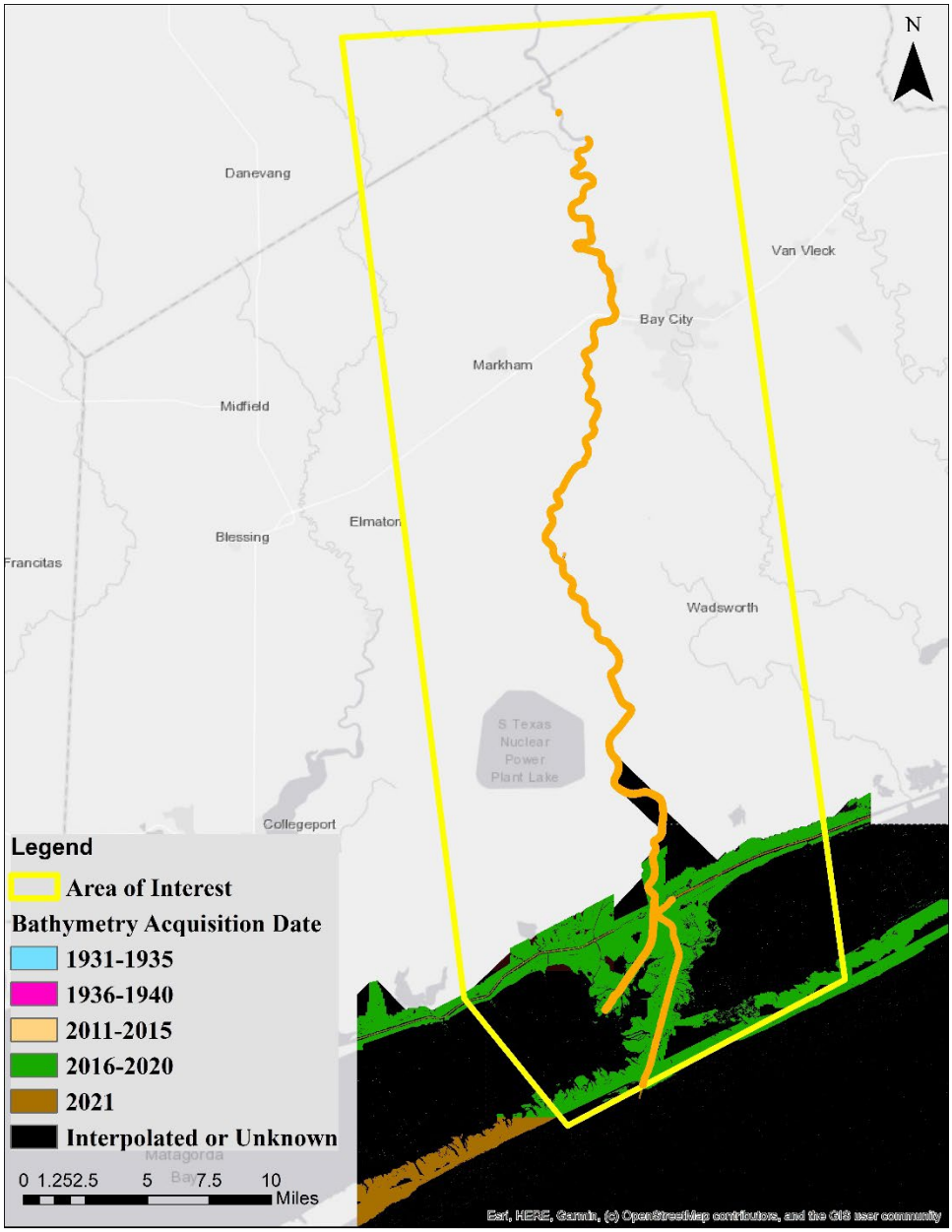

Figure 29. Latest bathymetry acquisition date for AOI 10 using the BlueTopo database.

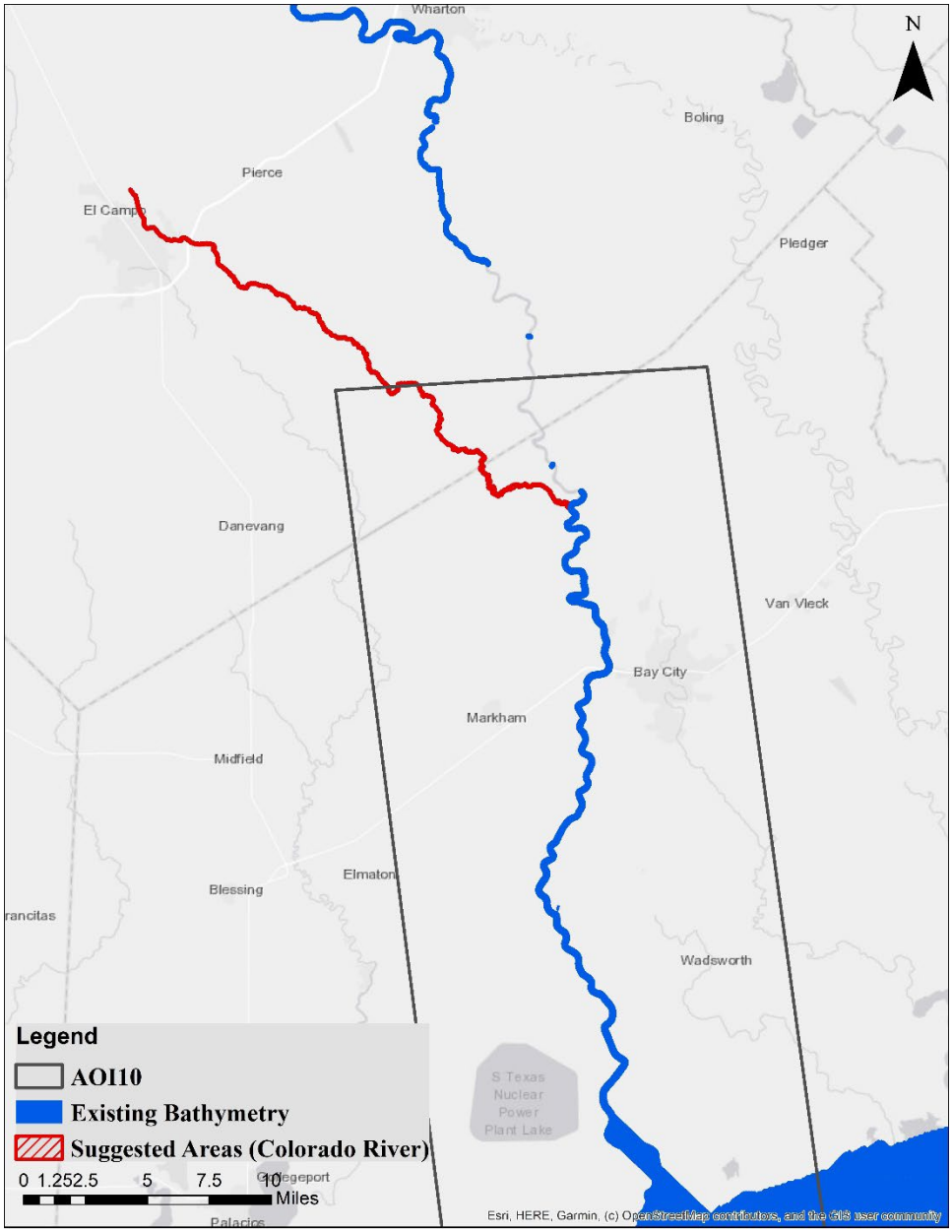

Figure 30. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 10.

AOI 11 Summary of suggestion

- Area Description: Houston Ship Channel (HSC) - Galveston Bay (GB) - San Jacinto River (SJR) - Trinity Bay (TB), East Bay (EB) system, and GOM entrance. We only provided suggestions for EB and system here. Suggestions for other areas could be found under AOI 4, 7, and 13.
- Waterbody Type: Shallow Waters and Small Lakes
- Reason for suggestion: Old bathymetry data for East Bay (1965) and no data for East Bay Lakes
- Suggested Area:
  - East Bay=76.16 mi^2
  - East Bay Lakes= 9.96 mi^2
- Estimated Cost:
  - East Bay: $457,000-$685,000
  - East Bay Lakes: $60,000-$90,000

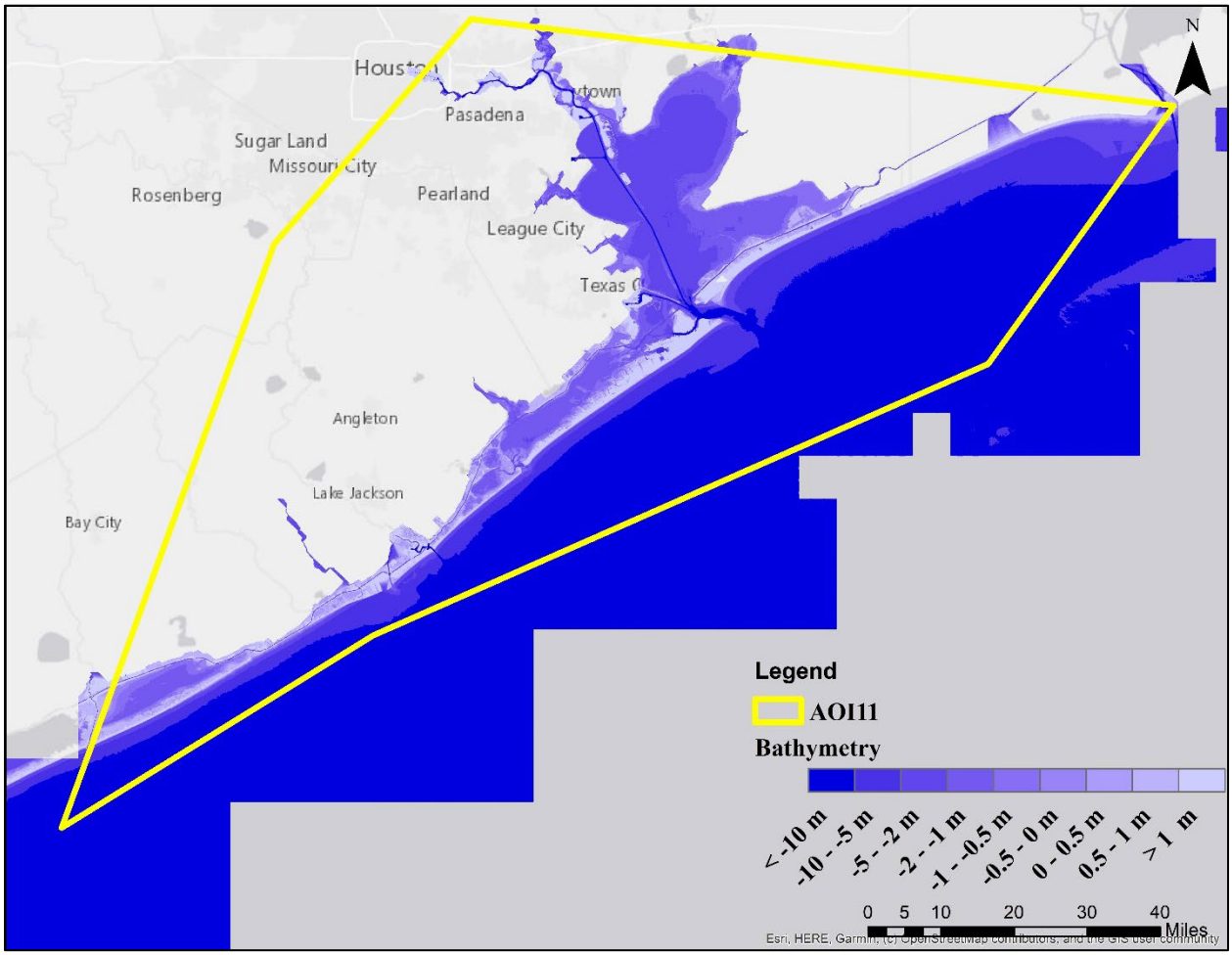

Figure 31. Bathymetry of AOI 11.

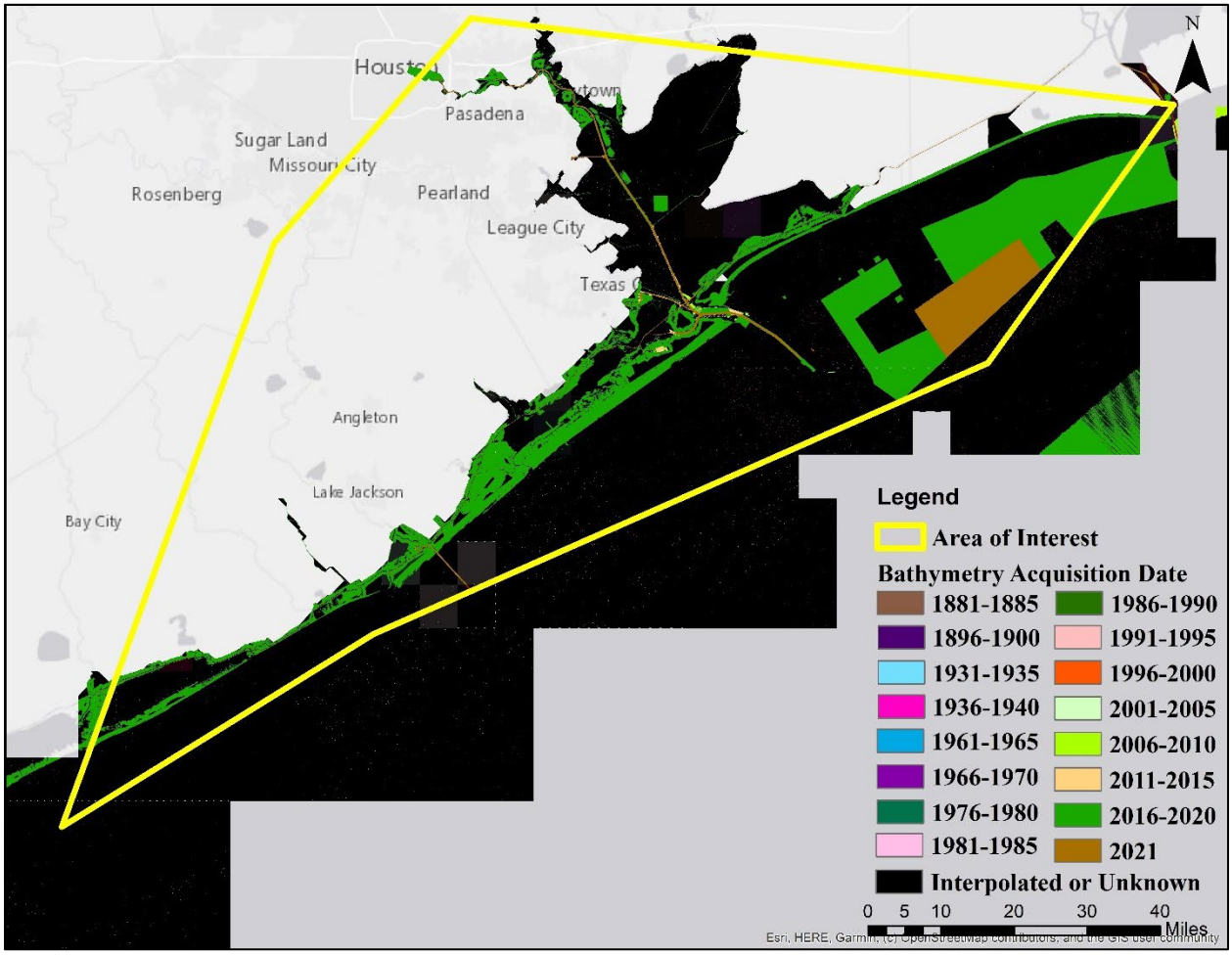

Figure 32. Latest bathymetry acquisition date for AOI 11.

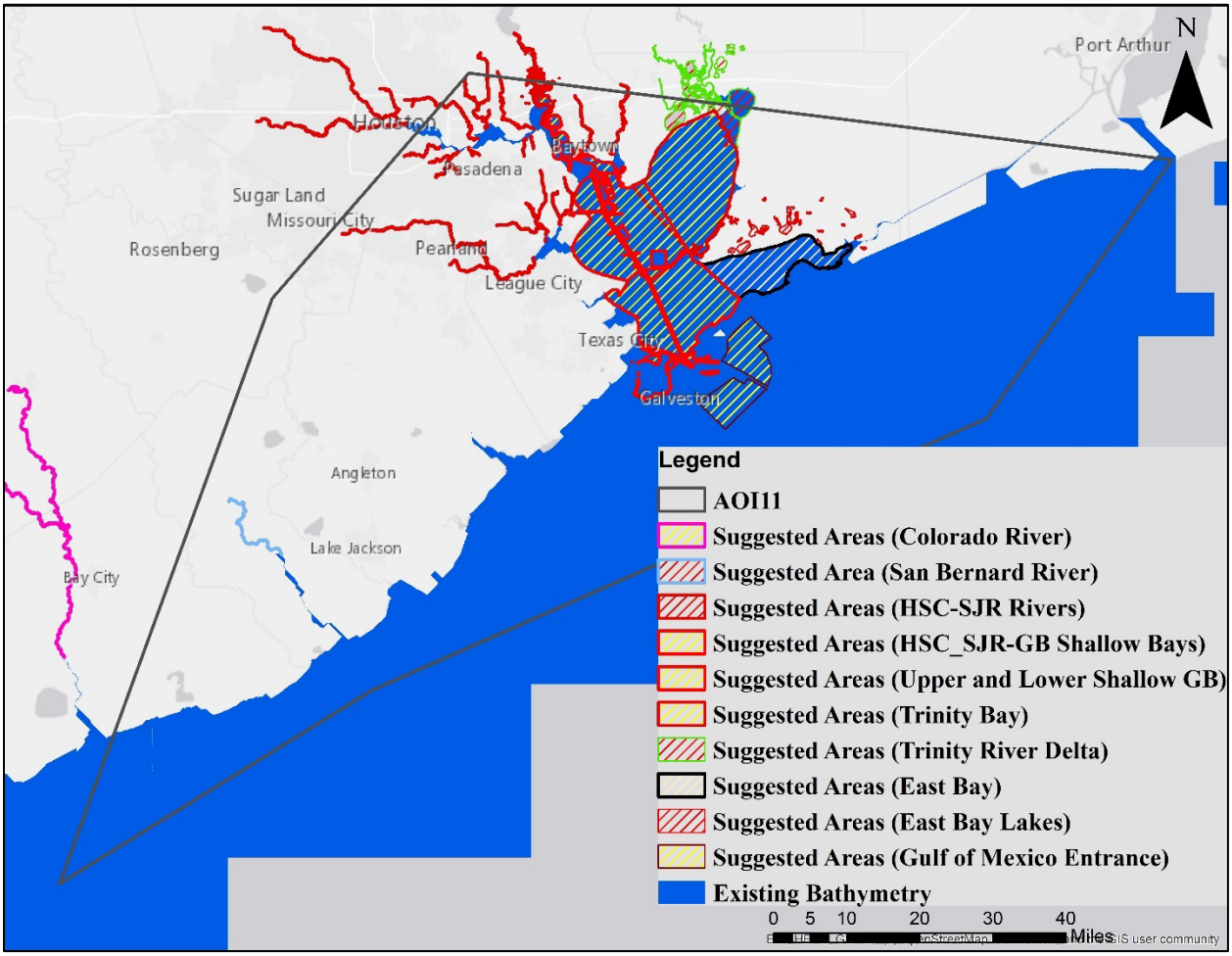

Figure 33. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 11. Please also refer to AOI 4, 7, and 13 for more information on some of the suggested areas shown here and not listed under AOI 11. Different hatched colors are not clearly distinguishable tin the figure to the number of active layers. All the GIS files can be found here.

AOI 13 Summary of suggestion

- Area Description: Trinity Bay (TB) and East Bay (EB) system. We only provided suggestions for TB system here. Suggestions for other areas could be found under AOI 4, 7, and 11.
- Waterbody Type: Shallow Waters, Lakes, and Rivers
- Reason for suggestion: Old bathymetry data for Lake Anahuac and Trinity River delta (1933 and no data for the most parts) and Trinity Bay (1965)
- Suggested Area:
    - Trinity Bay= 167.61 mi^2
    - Trinity River Delta and Lake Anahuac= 46.28 mi^2
- Estimated Cost:
    - East Bay: $1,006,000-$1,509,000
    - East Bay Lakes: $278,000-$417,000

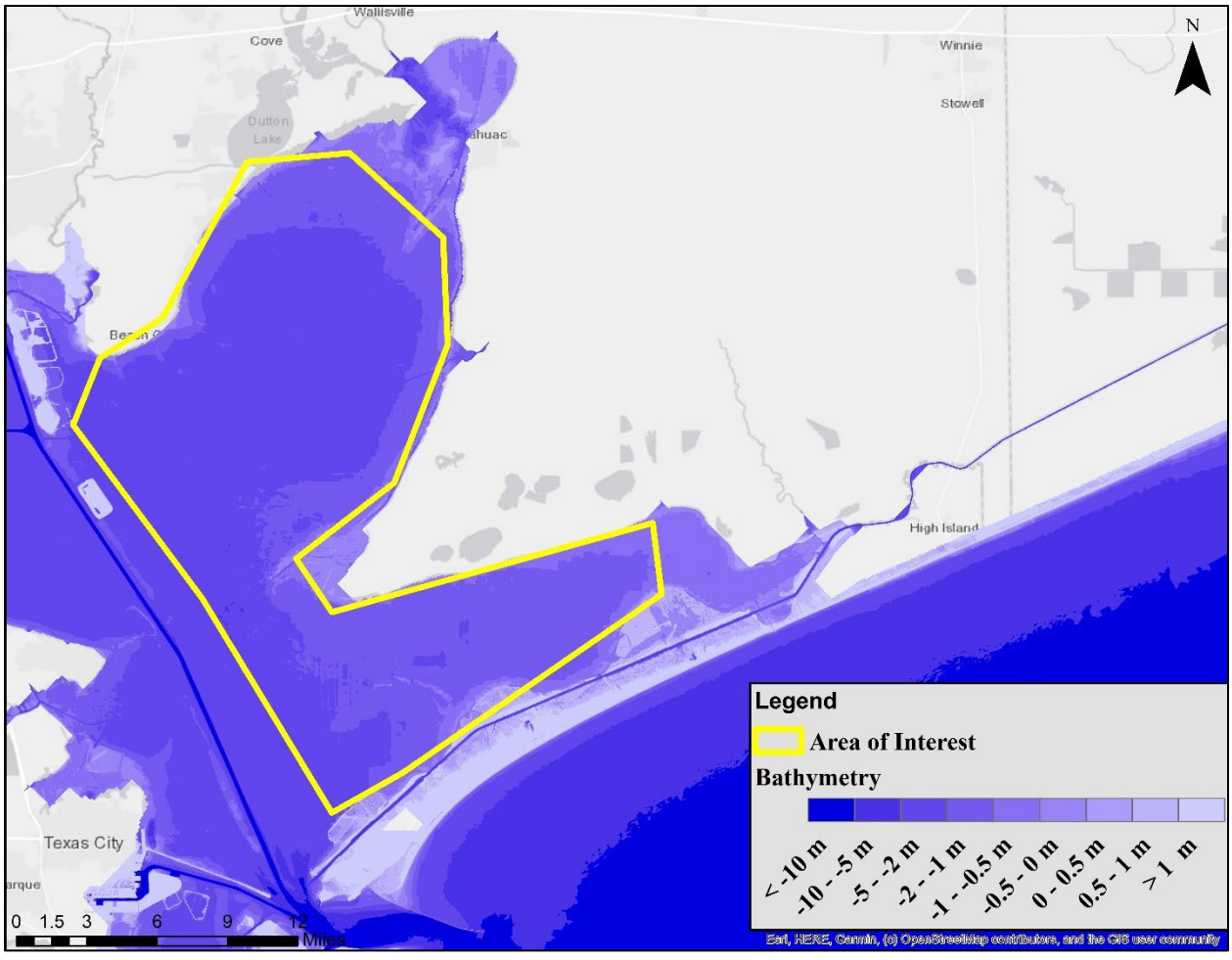

Figure 34. Bathymetry of AOI 13.

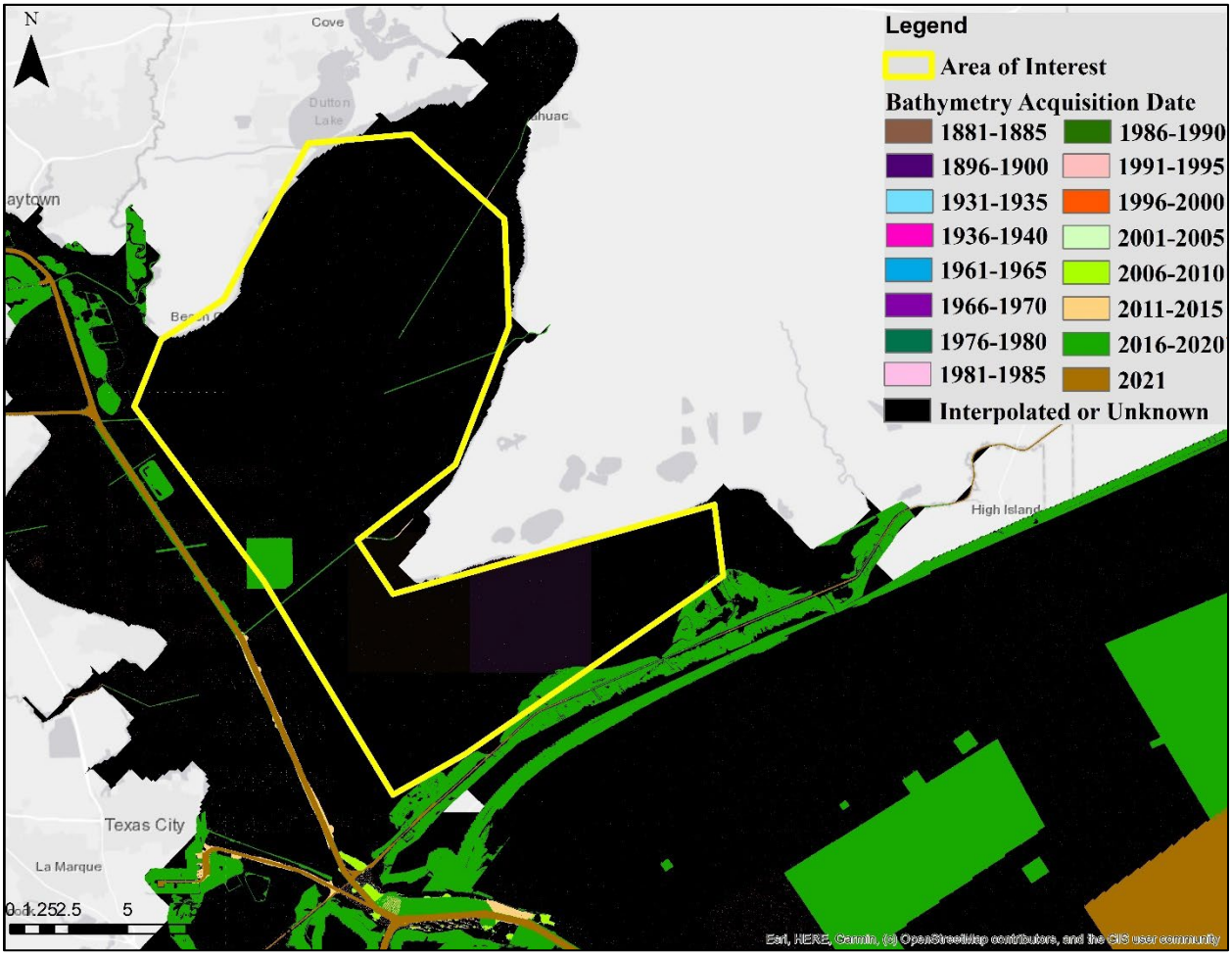

Figure 35. Latest bathymetry acquisition date for AOI 13.

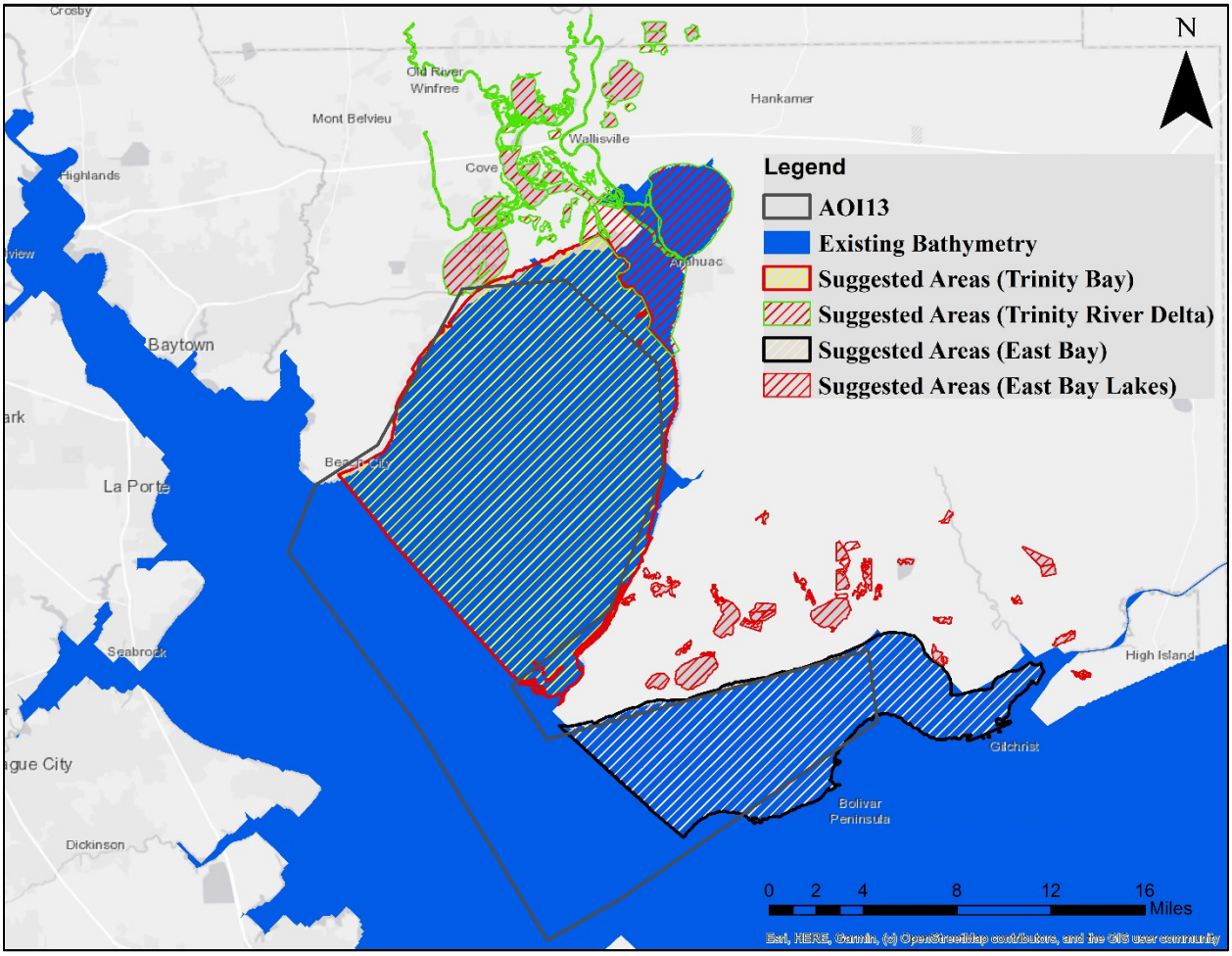

Figure 36. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 13. Please also refer to AOI 4, 7, and 11 for more information on some of the suggested areas shown here and not listed under AOI 13. Different hatched colors are not clearly distinguishable tin the figure to the number of active layers. All the GIS files can be found here.

AOI 14 Summary of suggestion

- Area Description: Nueces Bay
- Waterbody Type: Shallow Bay
- Reason for suggestion: No data is available (based on the analysis conducted in this effort).
- Suggested Area: 39.16 mi^2
- Estimated Cost: $235,000-$352,000

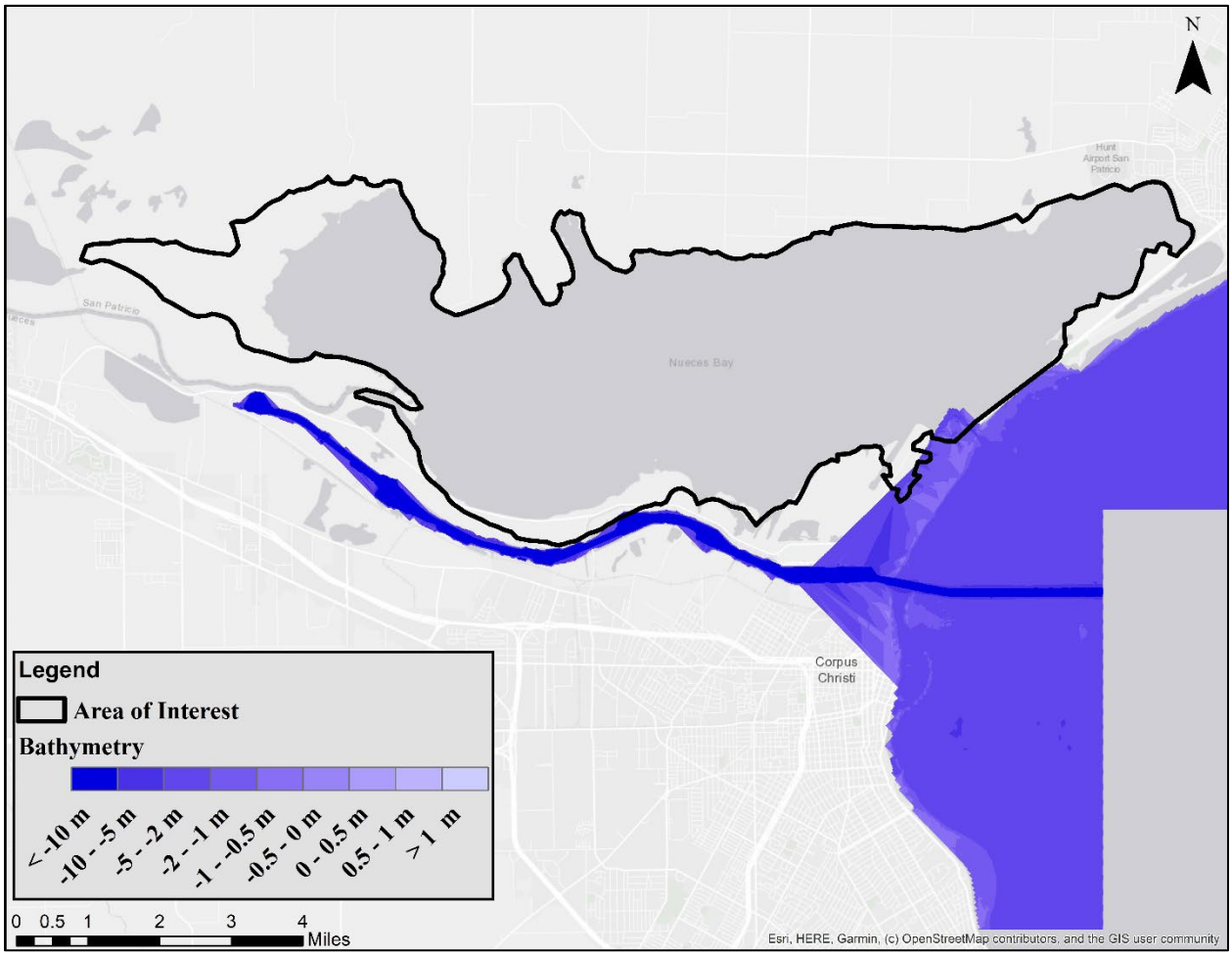

Figure 37. Bathymetry of AOI 14.

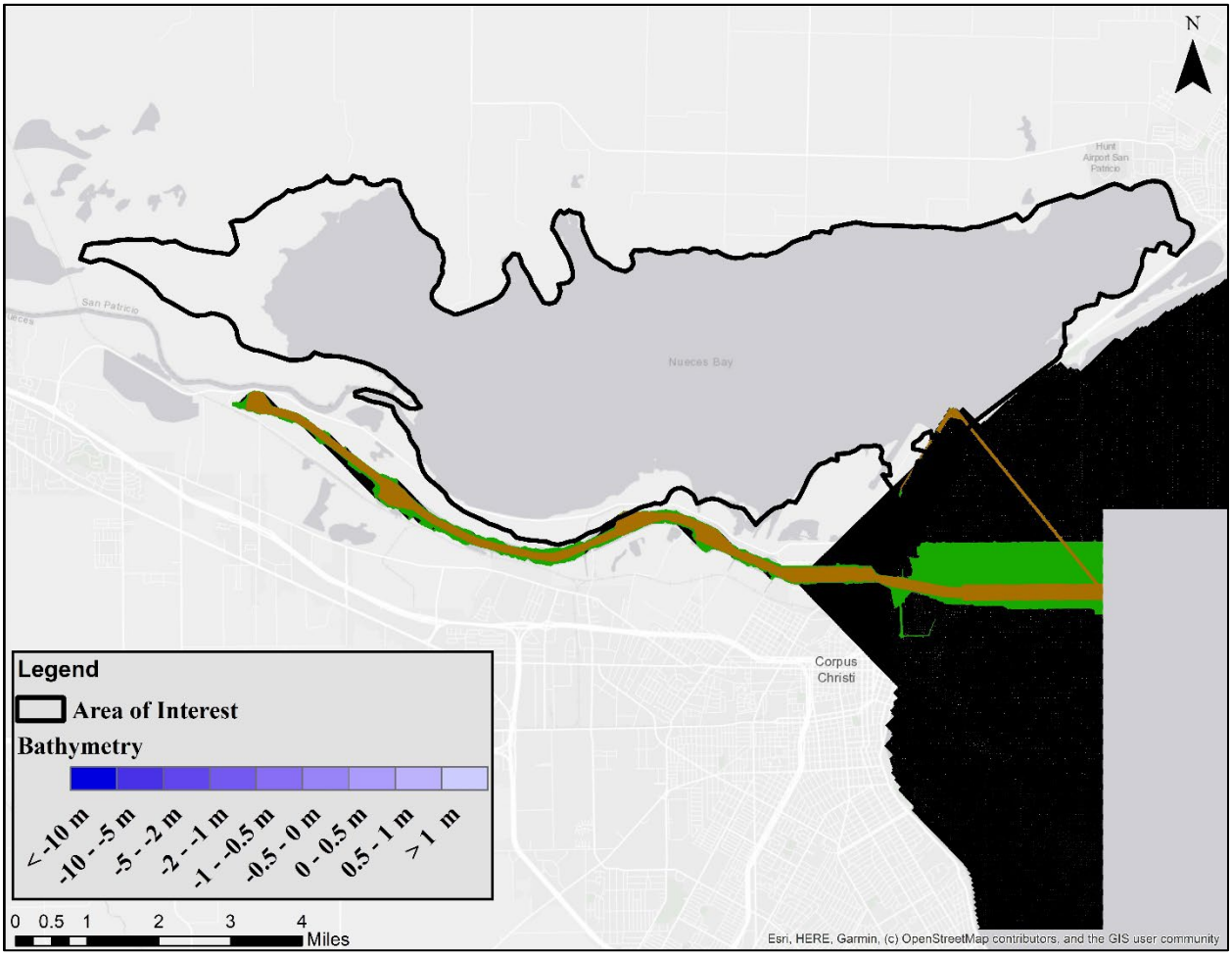

Figure 38. Latest bathymetry acquisition date for AOI 14.

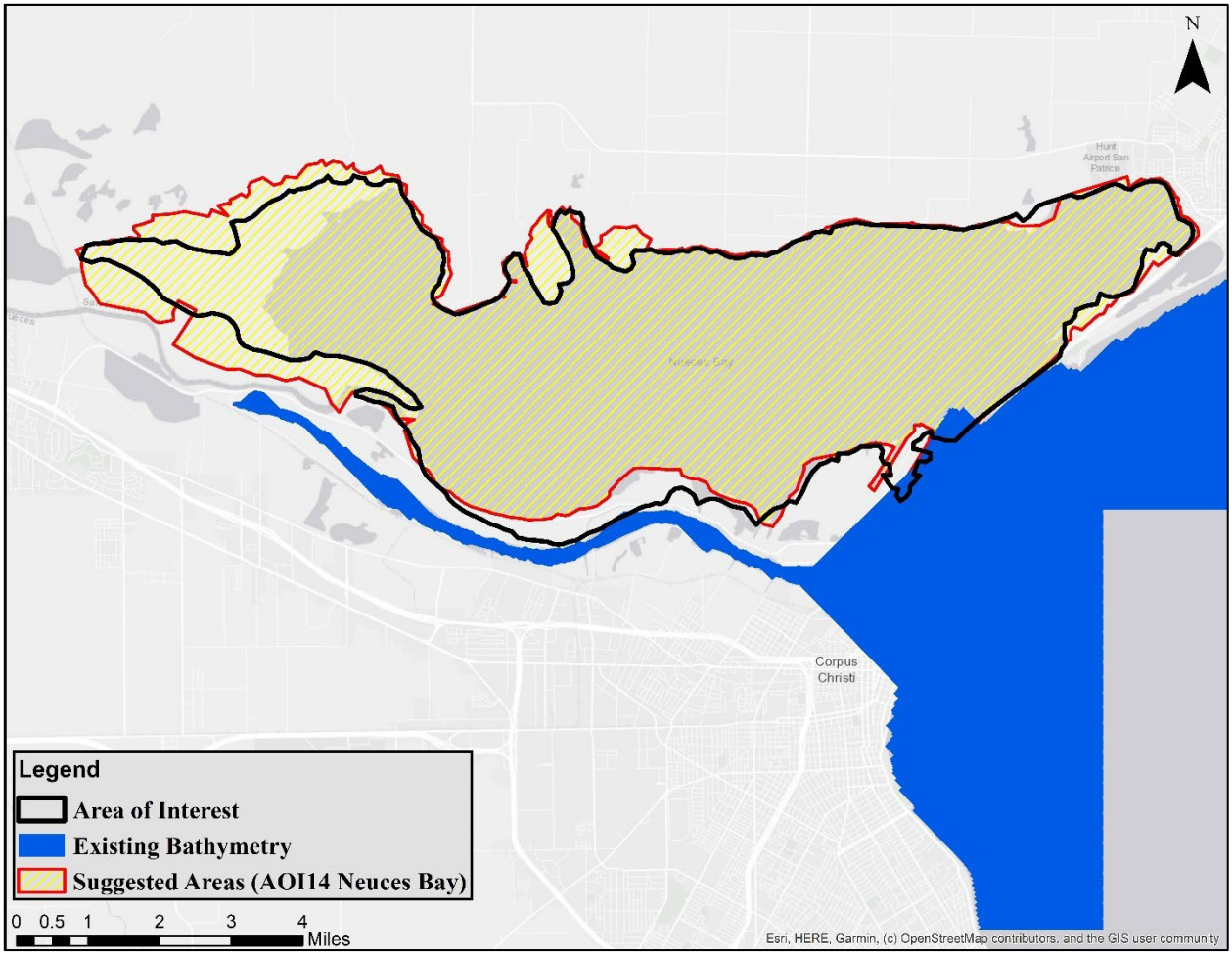

Figure 39. Existing bathymetry and the suggested area to acquire bathymetric data based on data availability of year of last acquisition for AOI 14.

Priority Analysis

The results of the post survey are shown in Table 3. Nueces Bay followed by Lower Galveston Bay, Sabine Lake, Laguna Madre, Gulf of Mexico Entrance, and the shallow bays in the Houston Ship Channel - San Jacinto River - Galveston Bay system had the highest TIFF importance scores with values greater than 50%. All six areas also had a high NOAA (above 67%) and combined (average of TIFF and NOAA scores, above 69%) importance scores. The estimated costs for bathymetric data collection for each of the suggested areas are presented in Table 4.

Table 3. Summary of the post-survey responses and the priority analysis for the suggested areas

Name	Priority					TIFF Weight	NOAA Weight	TIFF Importance	NOAA Importance	Combined Importance
	1	2	3	4	5					
1. Nueces Bay	2	0	4	1	0	24	8	100%	67%	83%
2. Lower Galveston Bay	0	3	0	3	0	18	12	75%	100%	88%
3. Sabine Lake	2	1	0	1	1	17	8	71%	67%	69%
4. Laguna Madre	2	0	1	1	0	15	10	63%	83%	73%
5. Gulf of Mexico Entrance	2	0	1	0	1	14	12	58%	100%	79%
6. Houston Ship Channel - San Jacinto Rivers - Galveston Bay Shallow Bays	1	1	1	0	1	13	12	54%	100%	77%
7. East Bay	0	1	2	0	1	11	12	46%	100%	73%
8. Houston Ship Channel - San Jacinto Rivers - Galveston Bay Rivers	1	1	0	1	0	11	8	46%	67%	56%
9. Matagorda Bay	2	0	0	0	0	10	10	42%	83%	63%
10. Trinity Bay	0	1	0	2	1	9	11	38%	92%	65%
11. Keller Bay	0	2	0	0	1	9	10	38%	83%	60%
12. Upper Galveston Bay	0	0	2	0	1	7	12	29%	100%	65%
13. Trinity Bay Delta	1	0	0	0	2	7	10	29%	83%	56%
14. Rio Grande River Floodplain Small Lakes and Shallow Waters	0	1	0	1	1	7	7	29%	58%	44%
15. Baffin Bay Entrance	0	1	0	1	0	6	10	25%	83%	54%
16. Taylor and Hillebrandt Bayous	0	0	1	0	1	4	3	17%	25%	21%
17. San Bernard River Tidal	0	1	0	0	0	4	3	17%	25%	21%
18. East Bay Lakes	0	0	0	0	0	0	10	0%	83%	42%
19. Rio Grande River Floodplain	0	0	0	0	0	0	6	0%	50%	25%
20. Lower Colorado River	0	0	0	0	0	0	3	0%	25%	13%

Table 4. The size and estimated cost for bathymetric data collection for each of the suggested areas.

Name	Area (sq mi)	Estimated Cost*
1. Nueces Bay	42.3	$234,975 - $352,462
2. Lower Galveston Bay	110.2	$873,773 - $1,310,660
3. Sabine Lake	51.4	$308,591 - $462,887
4. Laguna Madre	446.2	$2,677,062 - $4,015,593
5. Gulf of Mexico Entrance	69.3	$415,784 - $623,676
6. Houston Ship Channel - San Jacinto Rivers - Galveston Bay Shallow Bays	14.0	$110,666 - $165,999
7. East Bay	76.1	$456,512 - $684,768
8. Houston Ship Channel - San Jacinto Rivers - Galveston Bay Rivers	15.8	$145,564 - $218,345
9. Matagorda Bay	5.1	$30,679 - $46,019
10. Trinity Bay	167.6	$1,005,673 - $1,508,509
11. Keller Bay	10.1	$60,817 - $91,225
12. Upper Galveston Bay	139.1	$834,306 - $1,251,459
13. Trinity Bay Delta	45.8	$274,787 - $412,181
14. Rio Grande River Floodplain Small Lakes and Shallow Waters	56.9	$341,491 - $512,237
15. Baffin Bay Entrance	48.4	$290,663 - $435,995
16. Taylor and Hillebrandt Bayous	10.1	$60,881 - $91,321
17. San Bernard River Tidal	1.2	$6,960 - $10,440
18. East Bay Lakes	10.0	$59,773 - $89,660
19. Rio Grande River Floodplain	13.6	$81,720 - $122,580
20. Lower Colorado River	2.2	$13,020 - $19,530

* The actual cost of the project could be significantly different from the estimated cost provided here because bathymetry acquisition cost depends on the type of water body, size of project, and method of collection. we estimate, on average, it would cost $6,000-$9,000 (2021 US. dollars) to collect bathymetry data per square mile ($9-$14 per acre) using sonar techniques in shallow waterbodies. This estimate is based on some of the previous contracts managed by the TWDB in 2021.

Interested agencies and organizations can provide funding opportunities to complete the work recommended by TIFF. As the first agency to adopt this recommendation, TWDB will use available funds to work with vendors to collect bathymetry data, but this fund will not cover all data acquisition needs. Other agencies will play an important role in adopting this recommendation and making funds available to further bathymetry data collection for strategic areas of the state. When the bathymetry data acquisition is complete, potential locations that could host the data include the soon-to-be-released Texas Disaster Information System (TDIS) and other locations, such as TWDB's Water Data for Texas and the Texas Natural Resource Information System's Geospatial Data Hub, to improve access.

Appendix A

Attachments

- **Bathymetry Workshop Agenda:** https://txst-my.sharepoint.com/:b:/g/personal/alh4_txstate_edu/Eb_FoPceZiNMmO3UCJ_yeaEBpTBASGyl72jTvcvquoyV4Q?e=rfDpSB
- **Bathymetry Workshop Recording:** https://txst-my.sharepoint.com/:v:/g/personal/alh4_txstate_edu/EY8HK1oPwApGnDlSYEpsTvIBe-QIii57MLjiWEIVoKLJQw?e=ilxWKY
- **TIFF Bathymetry Mapping Survey:** https://survey123.arcgis.com/share/eeb1fed030f24c62ad4d1736ffba9cbf
- **Bathymetry Pre-Recorded Video Presentations & Summary Slides:**
  - **USACE Hydrographic Survey**
    Erin Diurba - Chief of the Hydrographic Survey Section at the Galveston District, U.S. Army Corps of Engineers
  - **Use of Multibeam Echo Sounder for Localized Bathymetric Surveys**
    Richard Huizinga – Hydrologist, U.S. Geological Survey, Lower Mississippi Water Science Center
  - **GLO Sponsored Airborne Lidar Bathymetry Products (2013-2019)**
    Daniel Gao – Geographic Information Specialist, Texas General Land Office
  - **Seamless Topobathy Data Integration for Southeast Texas**
    Jeff Danielson – Coastal National Elevation Database (CoNED) Applications Project Chief, U.S. Geological Survey
  - **Habitat Assessment Team Bathymetric Mapping**
    Emma Clarkson – Ecosystem Resources Program Director, Texas Parks & Wildlife Department Coastal Fisheries Division
  - **Strategic Mapping Program Bathymetry Initiatives**
    Joey Thomas – Elevation Data Specialist and Project Manager, Texas Natural Resources Information System/Texas Water Development Board
  - **The National Bathymetric Source**
    Katrina Wyllie – National Bathymetric Source Operations Lead, National Oceanic & Atmospheric Administration Office of Coast Survey
  - **Overview of Integrated Ocean and Coastal Mapping Resources**
    Meredith Westington, GISP – Chief Geographer, National Oceanic & Atmospheric Administration Office of Coast Survey
  - **USACE National Coastal Mapping Program in Texas**
    Jennifer Wozencraft– National Coastal Mapping Program Manager, U.S. Army Corps of Engineers

- Combined Speaker Summary Slides

Workshop Participants

NAME	ORGANIZATION
Alan Zundel	Aquaveo LLC
Alex Stum	US Department of Agriculture - Natural Resources Conservation Service
Amin Kiaghadi (TIFF Steering Committee)	Texas Water Development Board
Andy Ernest	The University of Texas Rio Grande Valley
Anna Huff (Facilitator)	Meadows Center for Water and the Environment - Texas State University
Ben Hodges	University of Texas at Austin
Brach Lupher	Harte Research Inistute
Brian Barr	January Advisors
Briana Hillstrom	National Oceanic and Atmospheric Administration
Caimee Schoenbaechler (TIFF Steering Committee)	Texas Water Development Board
Carla Guthrie	Texas Water Development Board
Carrie Thompson (Facilitator)	Meadows Center for Water and the Environment - Texas State University
Chelsea Sidenblad	Texas Natural Resources Information System - University of Texas at Austin
Chris Massey	US Army Corps of Engineers
Christopher Fuller	Research, Applied Technology, Education, Services, Inc.
Clinton Dawson	University of Texas at Austin
Collin Mccormick	US Department of Agriculture
Craig Glennie	University of Houston
Dane McCollum	Texas Water Development Board
Daniel Gao	Texas General Land Office
Davey Edwards	Texas A&M University - Corpus Christi
David Maidment	University of Texas at Austin
Dawn Pilcher	LJA Engineering, Inc.
Dena Green	Harris Country Flood Control District
Derek Giardino	National Weather Service
Donald Karr	Texas Water Development Board

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Douglas Manning	Orange County Drainage District
Edra Brashear	Texas Department of Transportation
Emma Clarkson	Texas Parks & Wildlife
Erin Diurba	US Army Corps of Engineers – Galveston District
Evan Turner	Texas Water Development Board
Gayla Mullins	Texas Water Development Board
Gordon Wells	Center for Space Research - UT Austin
Hanadi Rifai	University of Houston
Himangshu Das	US Army Corps of Engineers
Jack Meaut	Orange County Drainage District
Jacob Garrett	US Army Corps of Engineers
Josh Duty	Texas Water Development Board
Jeffrey Danielson	US Geological Survey
Jennifer Wozencraft	US Army Corps of Engineers
Jerry Cotter USACE	US Geological Survey
Jessica Magolan	Harte Research Inistute
Joey Thomas	Texas Water Development Board
John Beard Jr	Port Arthur Community Action Network
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Julia Wallace	National Oceanic and Atmospheric Administration - Office of Coast Survey
Katrina Wyllie	National Oceanic and Atmospheric Administration
Kelsey Williams	Texas General Land Office
Kevin De Santiago	Texas Water Development Board
Khan Iqbal	Texas Water Development Board
Kris Lander	National Weather Service
Lee von Gynz-Guethle	West Consultants
Linda Navarro	Research, Applied Technology, Education and Service, Inc.
Lisa Marshall	Texas Commission on Environmental Quality
Lonnie Anderson	Pape-Dawson Engineers, Inc.
Luci Cook-Hildreth	Texas Water Development Board
Manny Cruz	Power Engineers
Mark Lopez	Texas Water Development Board

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Mark Wentzel	Texas Water Development Board
Matt Bilskie	University of Georgia
Matt Nelson	Texas Water Development Board
Meredith Westington	National Oceanic and Atmospheric Administration
Mike Lee	US Geological Survey
Mukesh Subedee	Harte Research Inistute
Nathan Brock	Texas Water Development Board
Nathan Leber	Texas Water Development Board
Norberto Carlos Nadal	US Army Corps of Engineers
Paul Turner	National Oceanic and Atmospheric Administration
Pu Huang	Harte Research Inistute
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