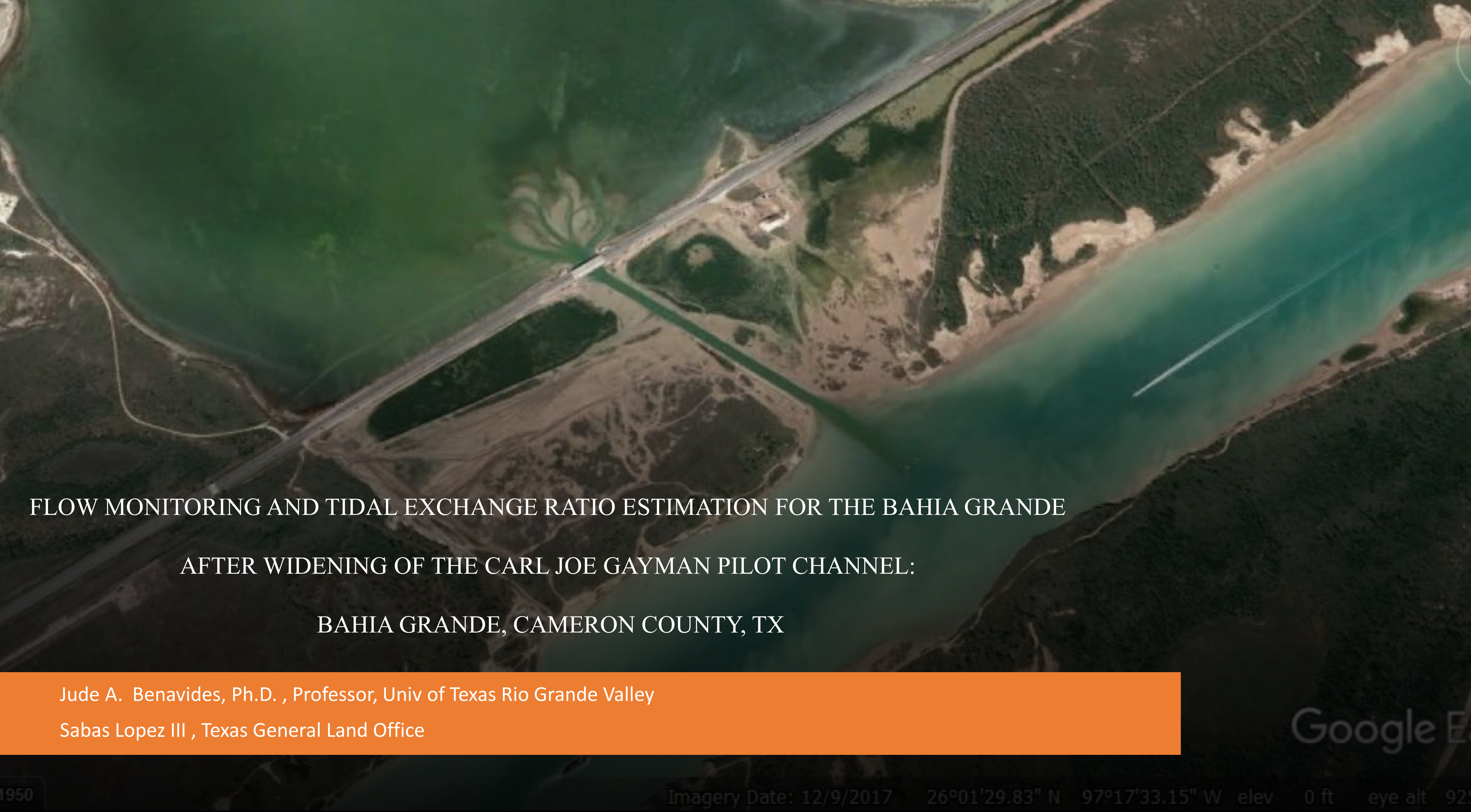

FLOW MONITORING AND TIDAL EXCHANGE RATIO ESTIMATION FOR THE BAHIA GRANDE AFTER WIDENING OF THE CARL JOE GAYMAN PILOT CHANNEL:

BAHIA GRANDE, CAMERON COUNTY, TX

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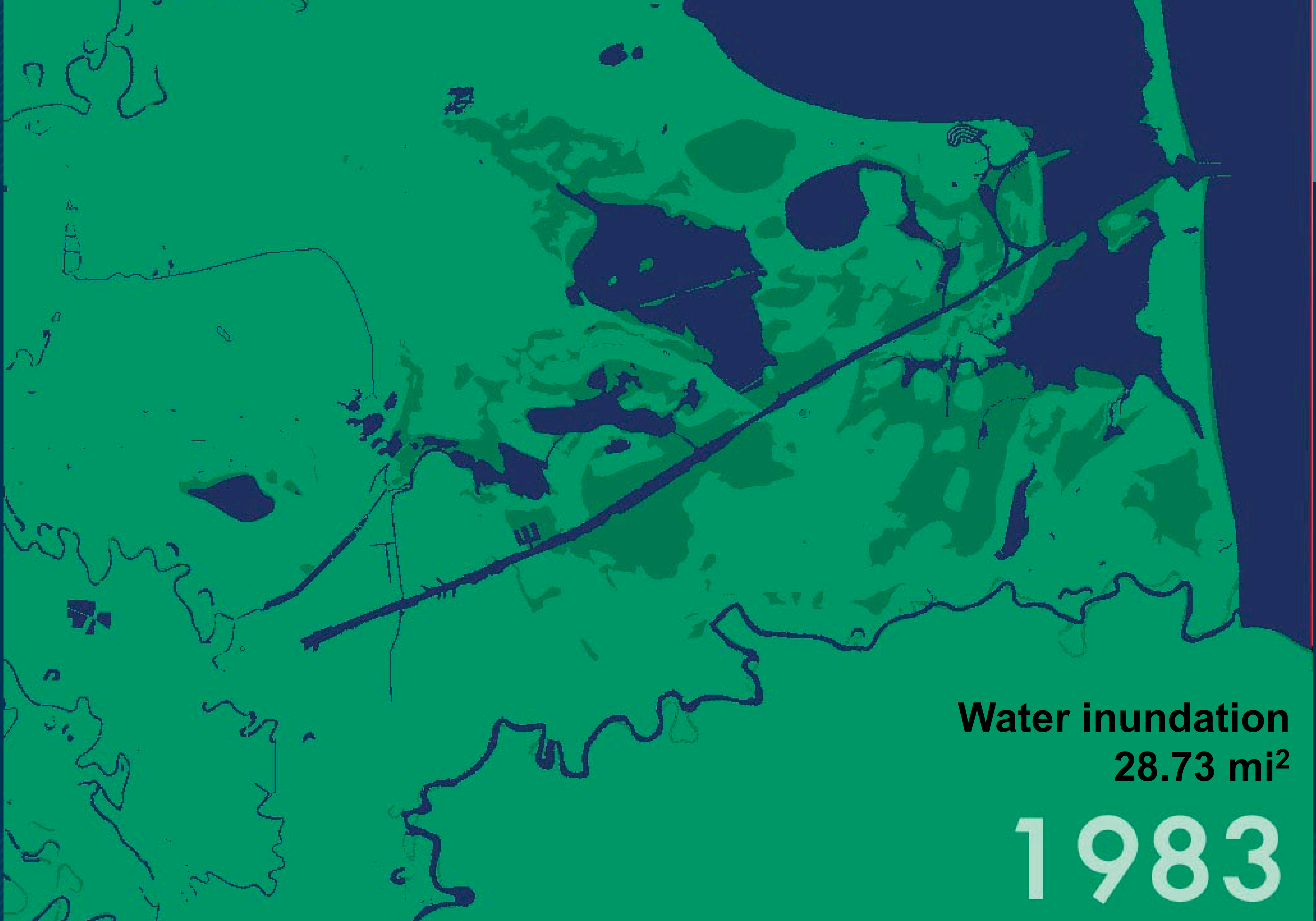
Sabas Lopez III , Texas General Land Office

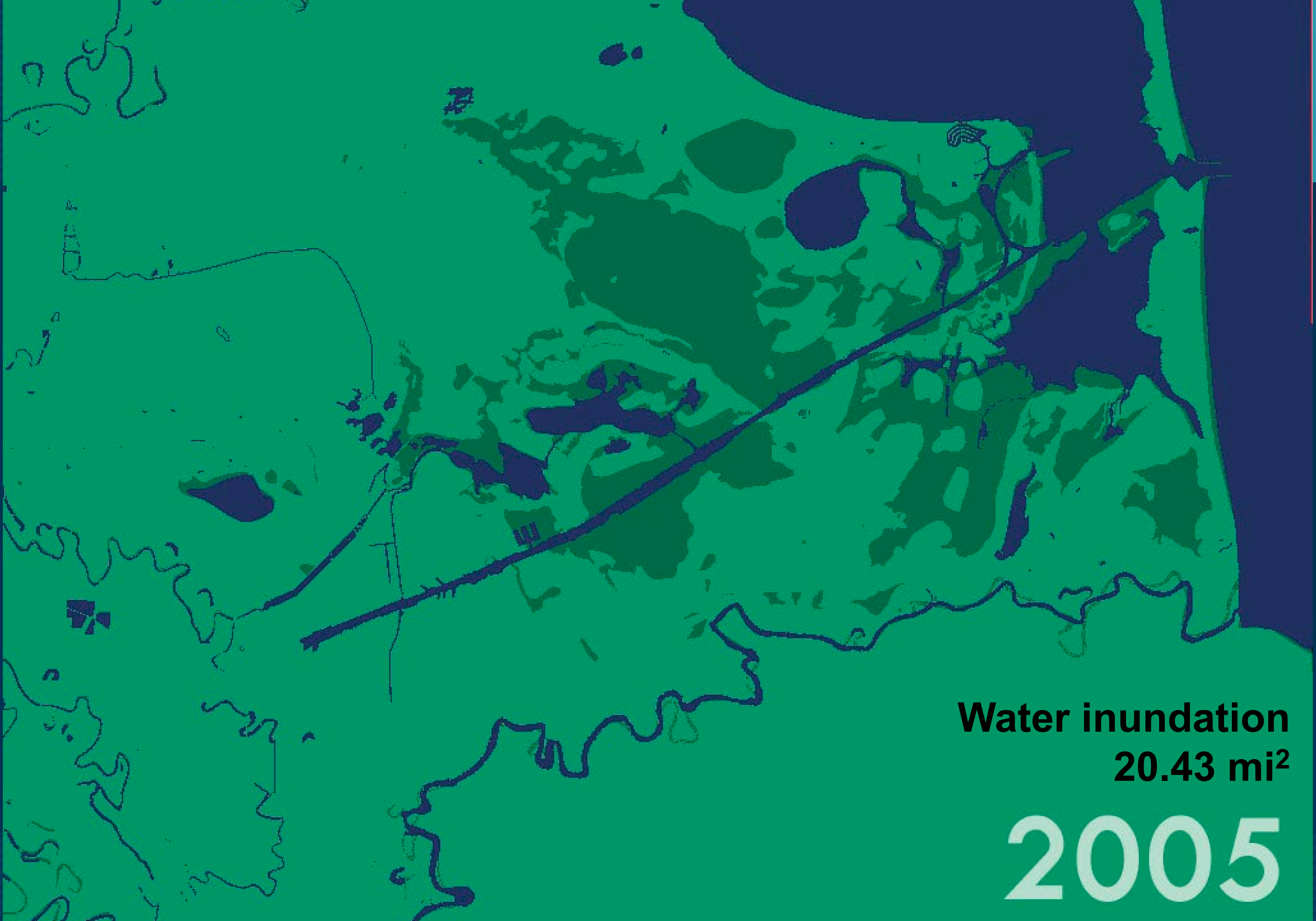
Introduction - What is the Bahia Grande?

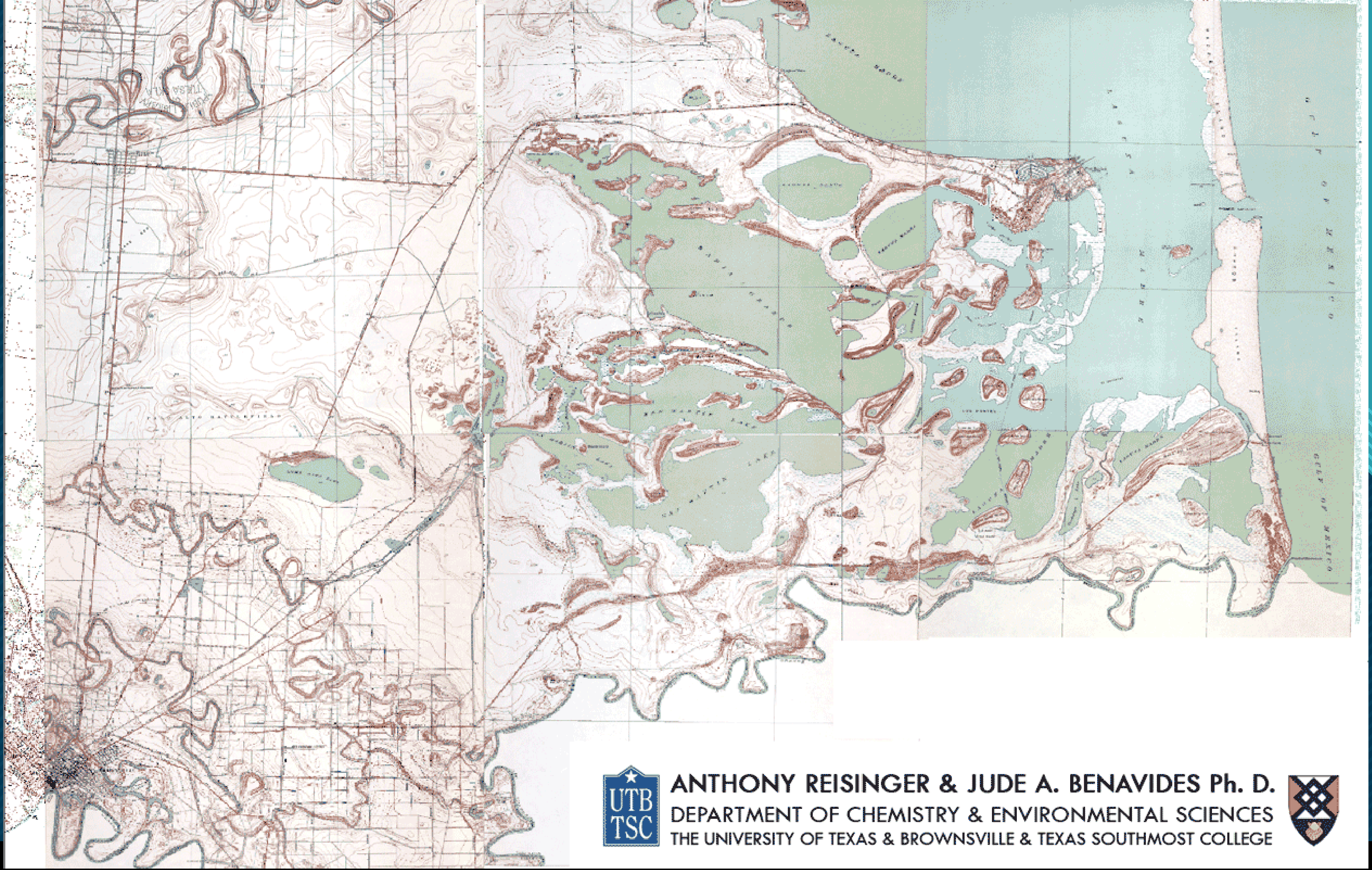
- (BG): 8,500-acre set of Coastal Wetlands and Tidal Flats formed as part of the delta of the Rio Grande River.
- Historically isolated from tidal circulation due to both anthropogenic and natural influences.
- Construction of the Brownsville Ship Channel (1934 – 1936) and Texas Highway 48 (1953)
- Eolian (wind-driven), depositional, and hydrologic processes

Aerial view of lower Laguna Madre, Bahia Grande unit, along with San Martin Lake (far left) and South Bay (far right, bottom), displaying differences of the landscape before the Brownsville Ship channel was constructed (1929) and after (1983). Maps courtesy of Jude Benavides and Anthony Reisinger, III.


Water inundation
53.32 mi²
1929


Water inundation
28.73 mi²
1983


Water inundation
20.43 mi²
2005


UTB TSC
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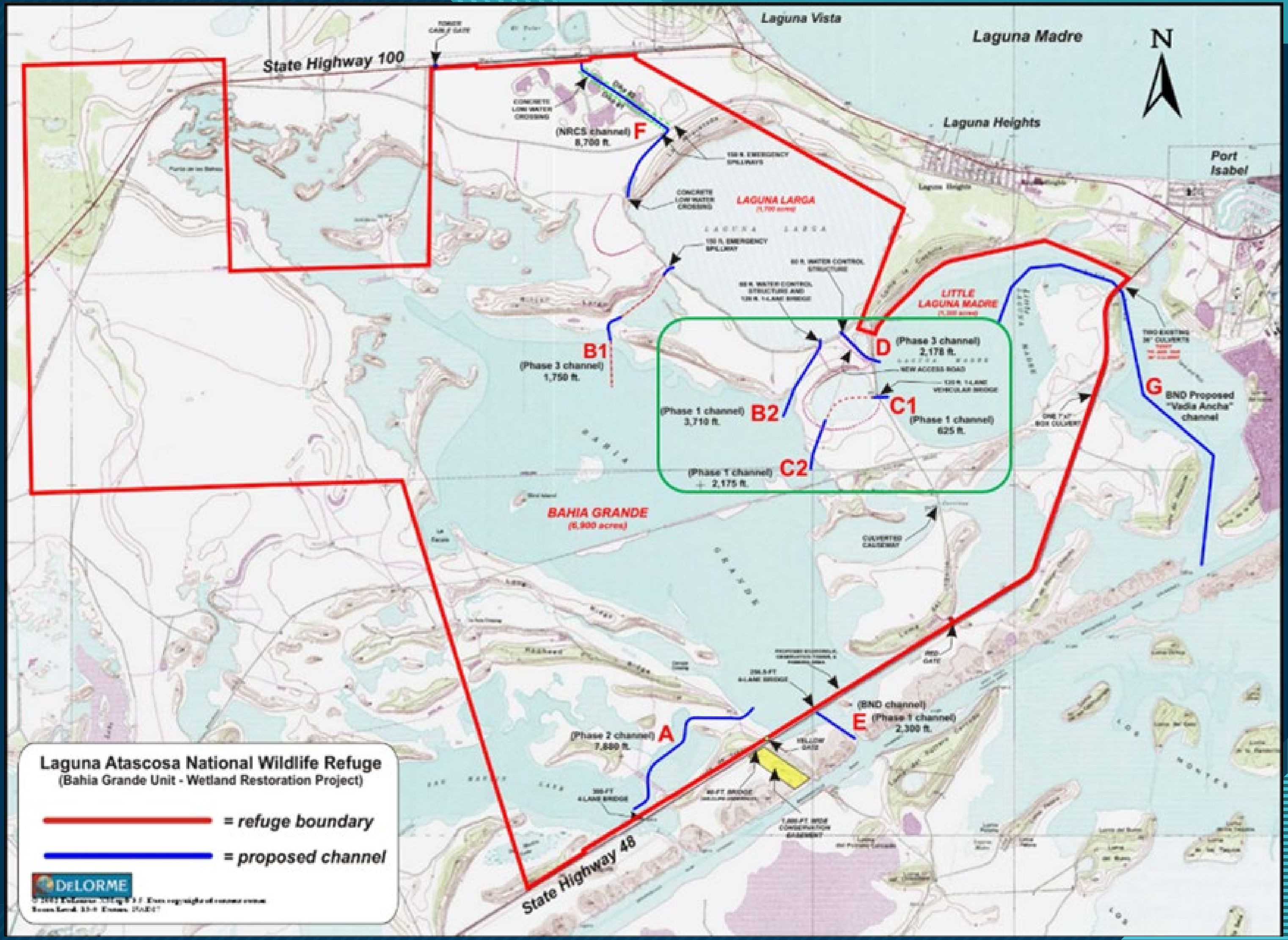
Isolation from tidal influence has caused hypersalinity issues in the Bahia Grande

- The Bahia Grande suffers from periods of hypersalinity
  - Shallow system driven by
    - Tides
    - Wind
  - High evaporation to precipitation ratio (~2:1)
  - Limited tidal exchange ratio
    - Major goal of this work is to increase the tidal circulation ratio and confirm it with measurements
- Reduced salinity may be achieved by increased tidal circulation ratios

Study Area: Re-establishing Tidal Connection

Digital view (USGS) of the Bahia Grande, Laguna Larga, and Little Laguna Madre.

- Over the last 30 years, the BG has been reconnected to tidal influence via man-made channels.
  - Began in the 1980's; quickly re-filled due to concerns over mineral rights
  - "Pilot Channel" (Channel E) Completed earlier in 2005
  - Channels B2, D, C1, and C2 were completed in 2007 to enhance tidal circulation within the BG complex
  - The "Pilot Channel" was recently widened/finalized in May of last year (2022)



Pilot Channel with culverts (2005): Exchange Ratio of 0-5%

- Pilot Channel was constructed in 2005, prior to TX48 bridge (photo to right)
  - Concrete culverts severely restricted flow
- Tidal Exchange Ratio ranged from near zero to a maximum of 5%.
- Tidal Exchange Ratio = $((Q_{in}+Q_{out})/2)$ / Vol_{BG}

(SW) Brownsville

(NE)Port Isabel

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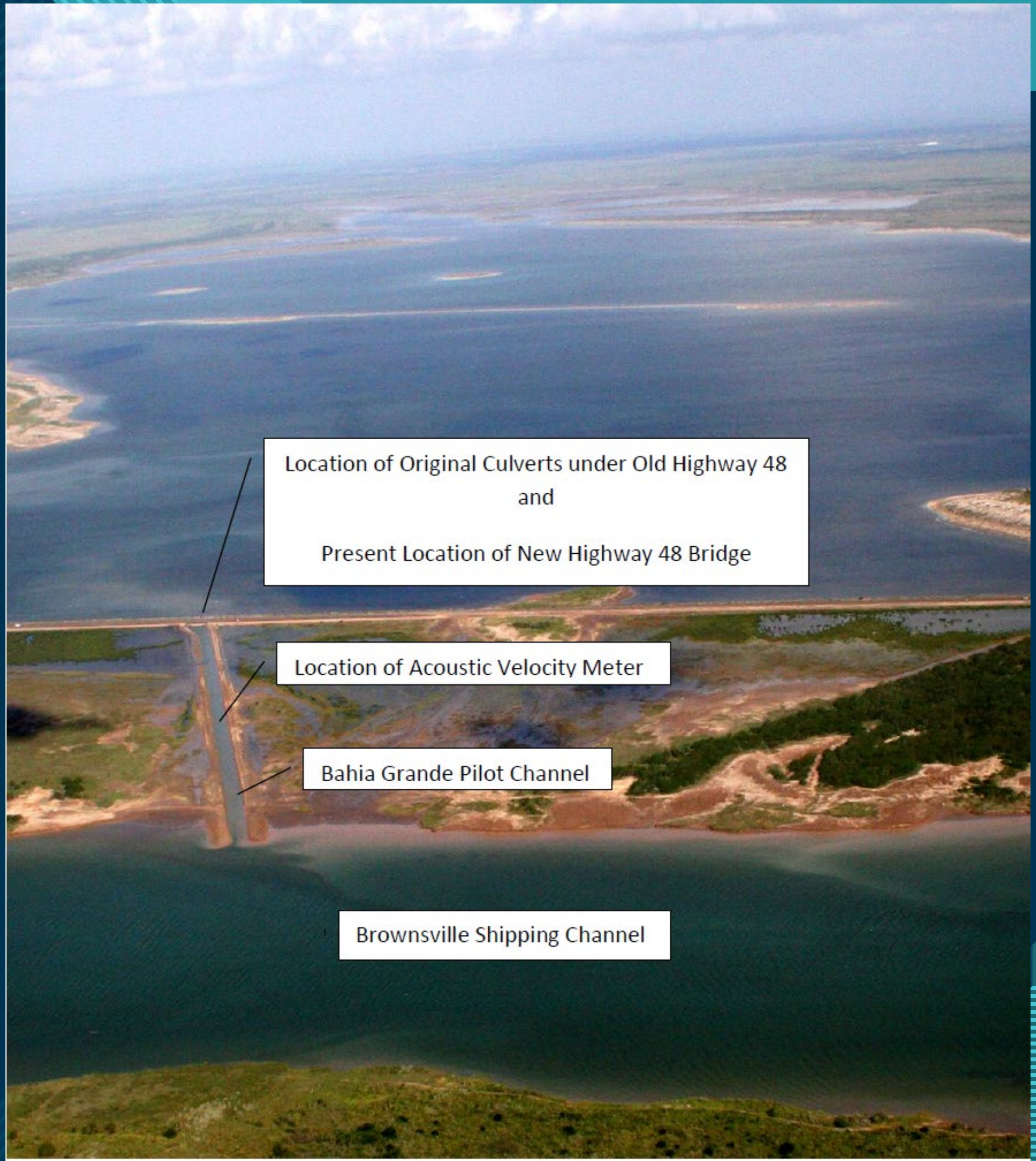
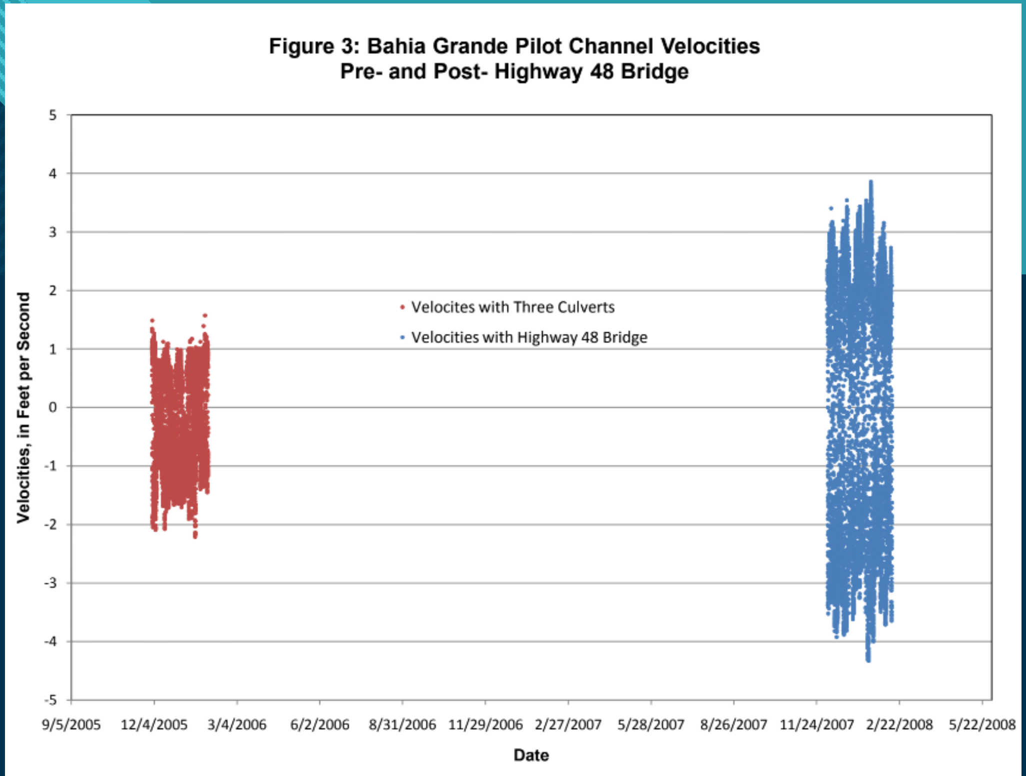


Figure 1: Aerial view of Bahia Grande, Highway 48, Pilot Channel and Brownsville Shipping Channel.

Culverts Replaced by Bridge (2007-2021): Exchange Ratio of 5-10%

- Texas Highway 48 bridge across channel was built in 2007
- Velocities increased, shown by ADCP data collected by Broska and Benavides (2005 and 2007)
- Estimated Tidal Exchange Ratios increased
- Because of channel deepening due to fast water velocity erosion, the exchange ratio increased to an estimated 5-10% over the next 15 years.
  - 7.9% (2019) - Flo-Mate Measurements
- No further changes until channel widening in May of last year (2022)



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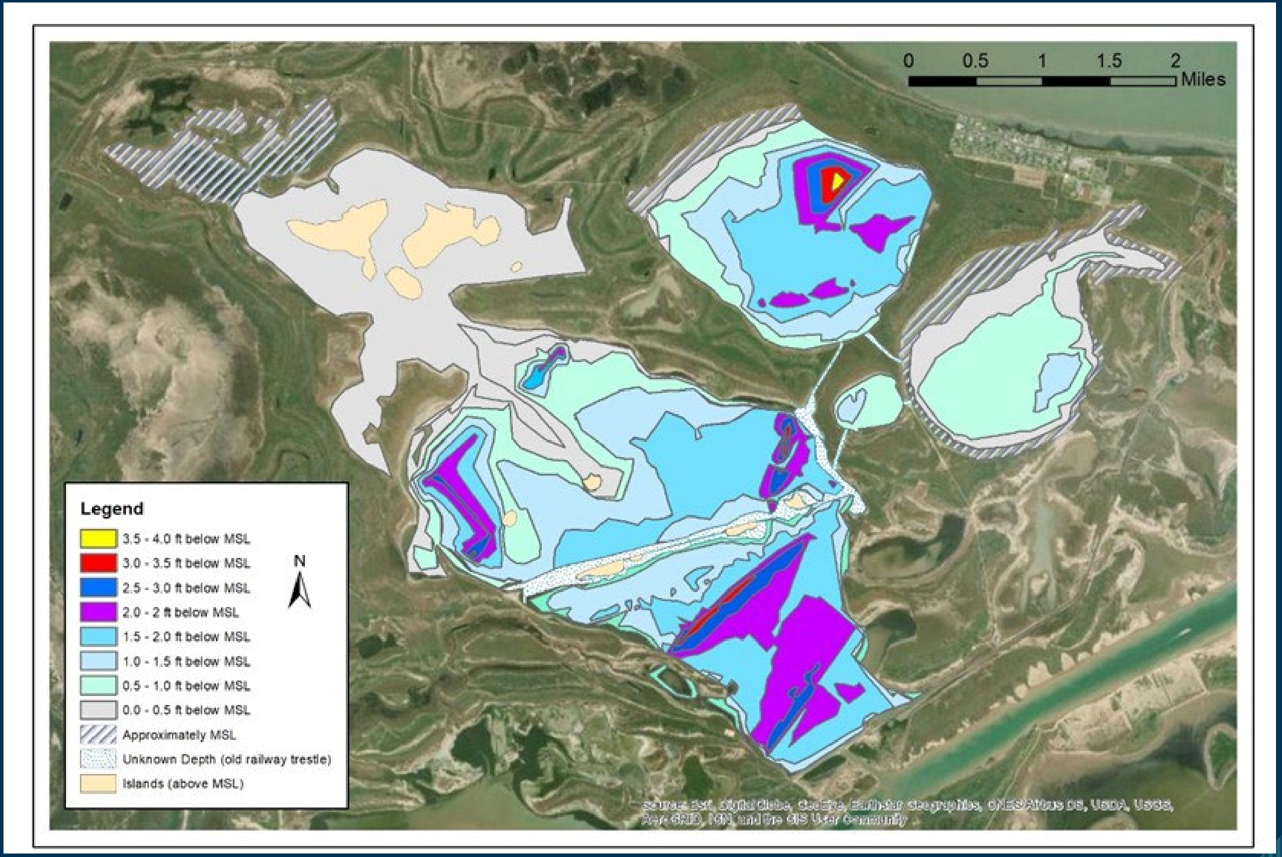
Estimating the volume of the Bahia Grande using GIS-based water level and bathymetry data

- Precisely georeferenced the NRCS bathymetry map
  - Shows up in a precise and correct location in GIS
- Digitized (traced) new shapefiles for each polygon
- Now possible to determine volume in each polygon region
  - Volume = Depth * Area of polygon
- This results in a depth-to-volume relationship
  - Allows us to estimate the volume of the BG Complex at any depth

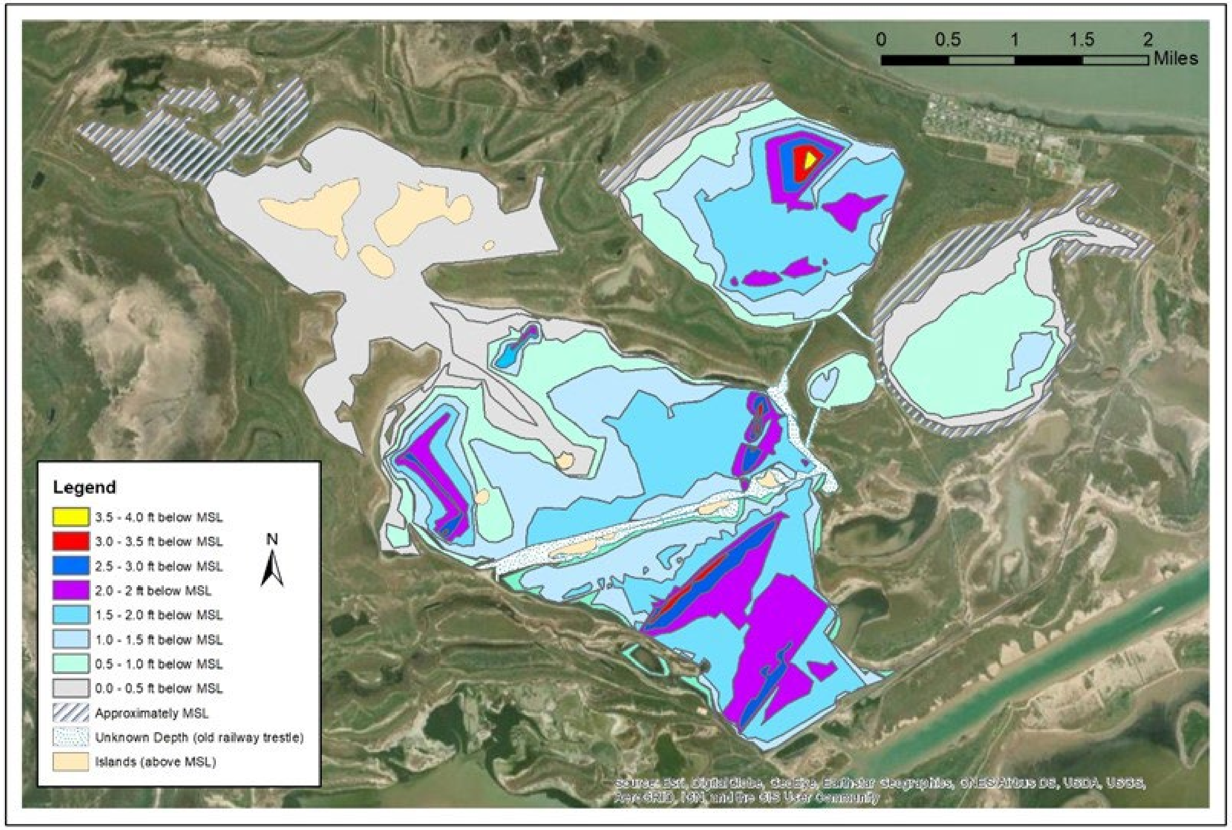


Bathymetric contour GIS map constructed by Lopez and Benavides (2023).

Results: Deliverable 1

BG Volume Calculations

- MHHW: 597,047,735 ft³
- MSL: 400,457,940 ft³
- MLLW: 161,853,714 ft³



Developed a spreadsheet that can be easily modified and update with newer data if and when available

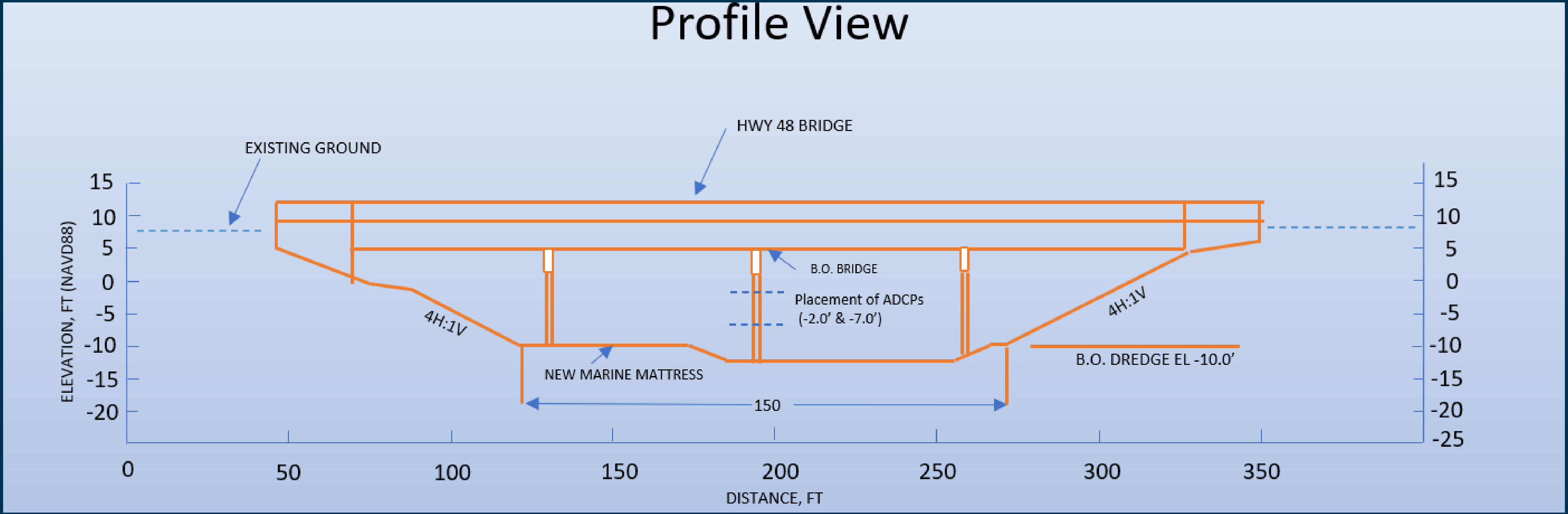
Bahia Grande Complex (Volumes in ft^3)	Volume at MSL	% of System	Volume at MHHW	% of System	Volume at MLLW	% of System
BG Upper	145,239,930	36.3	238,782,416	40.0	49,111,722	30.3
BG Lower	127,010,070	31.7	164,271,294	27.5	66,642,444	41.2
Laguna Larga	99,436,590	24.8	136,552,324	22.9	44,792,748	27.7
Little Laguna Madre	25,003,440	6.2	51,363,338	8.6	958,320	0.6
Connecting Basin	3,767,940	0.9	6,078,362	1.0	348,480	0.2
Total	400,457,970	100	597,047,735	100	161,853,714	100

Deploying two side-looking ADCPs (SL-1500s) to collect post-widening water velocity measurements (index velocity) beneath TX48

- Side-looking ADCP's were deployed on center row of pilings, looking toward right and left banks (next slide).
- New 14-foot maximum depths required deployments at two different depths
- Deployment Depths: ~ 2 ft and 7 ft below the water surface (MSL).
- Deployment periods of at least 2-3 weeks in order to collect data across neap and spring tides.

(Left): system configuration process via Sontek's SL Program
(Right): shows the installed canal mount with the submerged ADCP; photos taken by advisor Dr. Jude A. Benavides and student volunteer Bridgett Collis (2022).

Side-looking ADCP deployment and beam pattern (profile view)



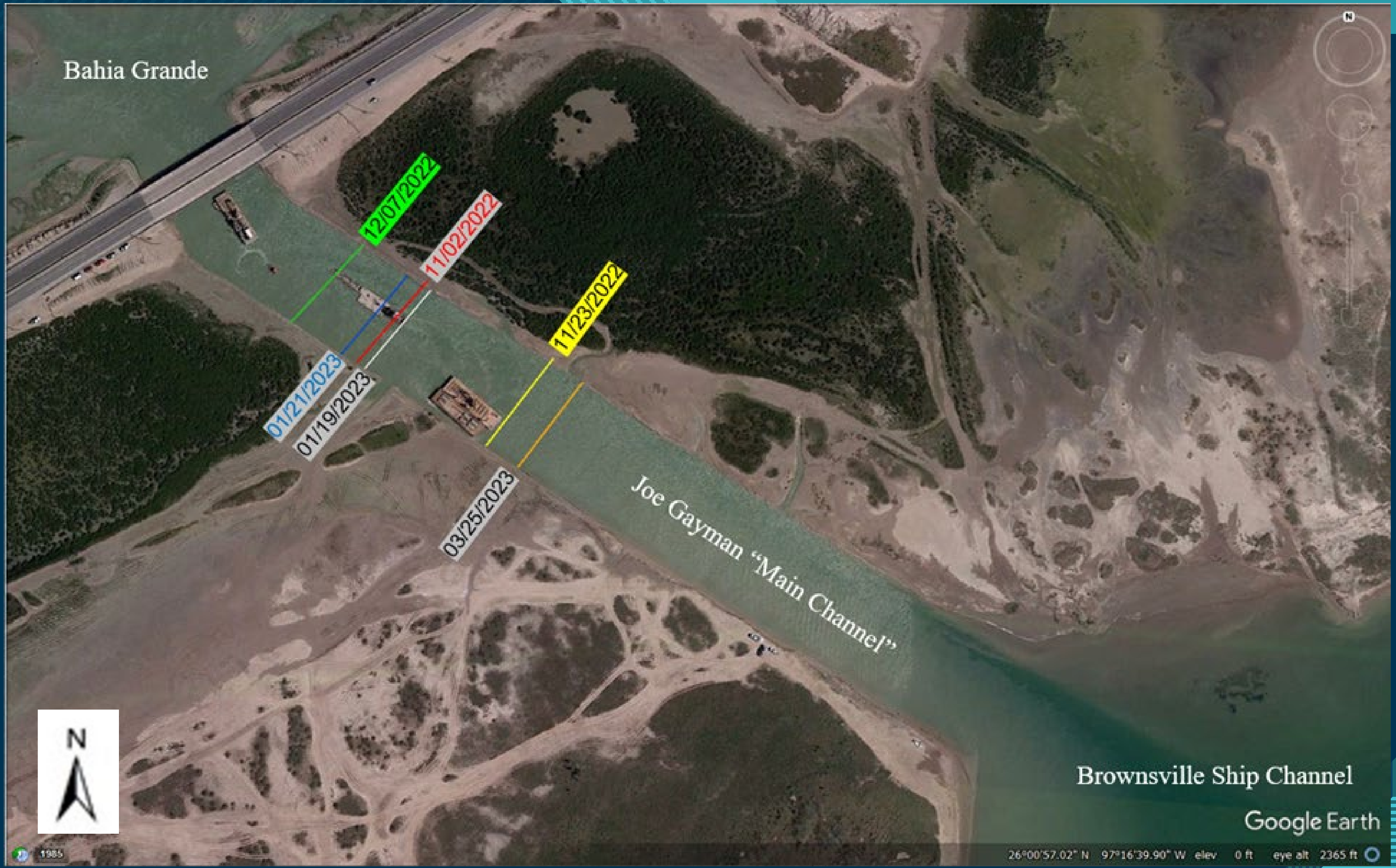
- SL-1500s generate an index (average) velocity across the beam pattern.
- The primary benefit of this instrument is to observe how velocities change with time

Point in Time Channel Flow Measurements – Deploying the Sontek River Surveyor (RS-S5)

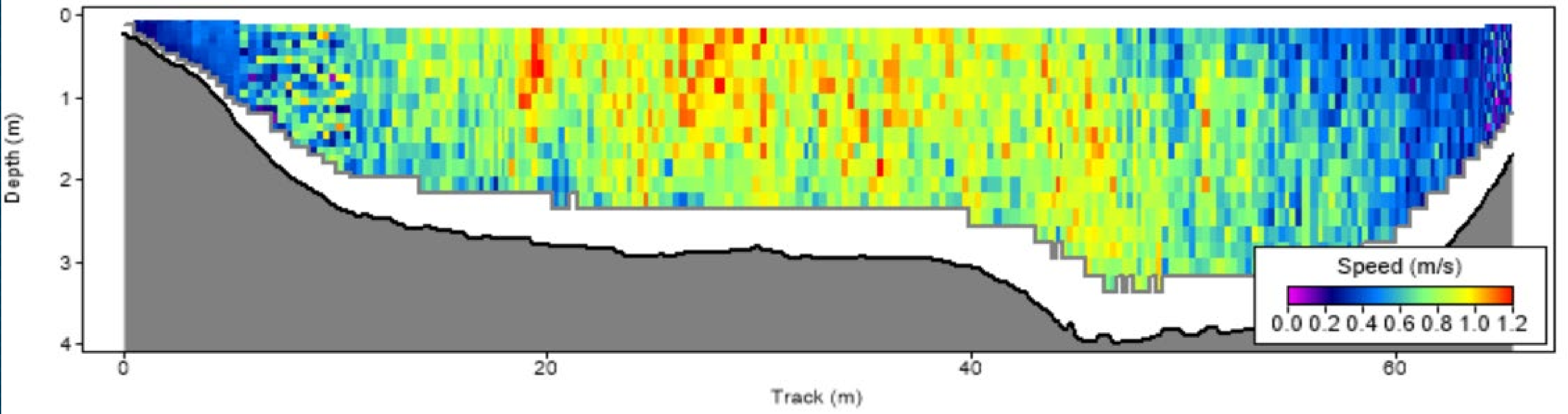
- River Surveyor was deployed 6 times
  - Initial Plan: twice during a flood tide and twice during an ebb tide.
- Deployed at discrete locations in space and time.
- Data provides velocity measurements and checks for any variation with depth across the channel.
- Data provides an independent data check to compare with the index velocities measured by SL-1500s
- Measures and displays how velocity varies with:
  - Depth
  - Distance across the channel
  - Away from the Tx48 Hwy Bridge

River surveyor deployment locations along the channel

Paths/runs of cross-channel velocity and flow measurements



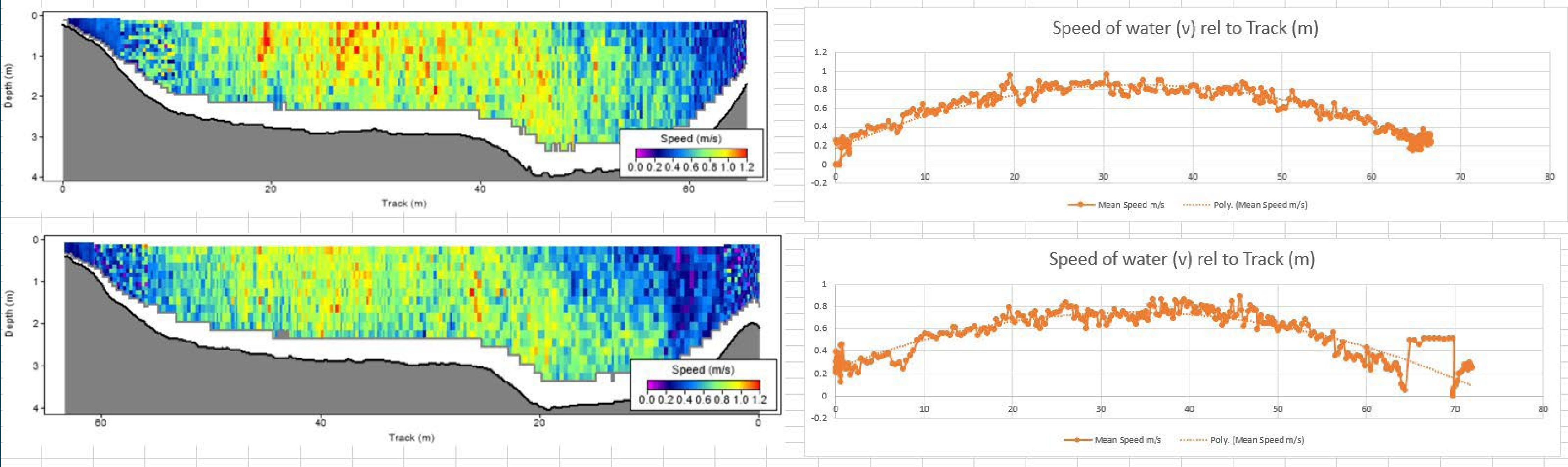
Sontek River Surveyor RS-S5 "Main Channel" Profile View



River Surveyor Flow Measurement Results

Date of Deployment	Calculated Velocity (m/s)	Calculated Flow (m^3/s)
11/2/2022 (EBB)	0.52	-106.59
11/23/2022	0.50	111.98
12/7/2022	0.56	110.07
1/19/2023	0.18	25.82
1/21/2023	0.70	145.66
3/25/2023 (EBB)	0.28	-55.07

11/2 data (EBB)



Background – Improved Channel Dimensions

- Original "Pilot Channel" dimensions limited tidal exchange ratio
    - 15 ft bottom width
    - ~50 ft top width
    - Depth started at 2-3 ft and incised to 5-9 ft over 15 years
- New "Main Channel" dimensions
    - 150 ft bottom width
    - 250 ft top width
    - Depth now 10-14 ft middle of channel

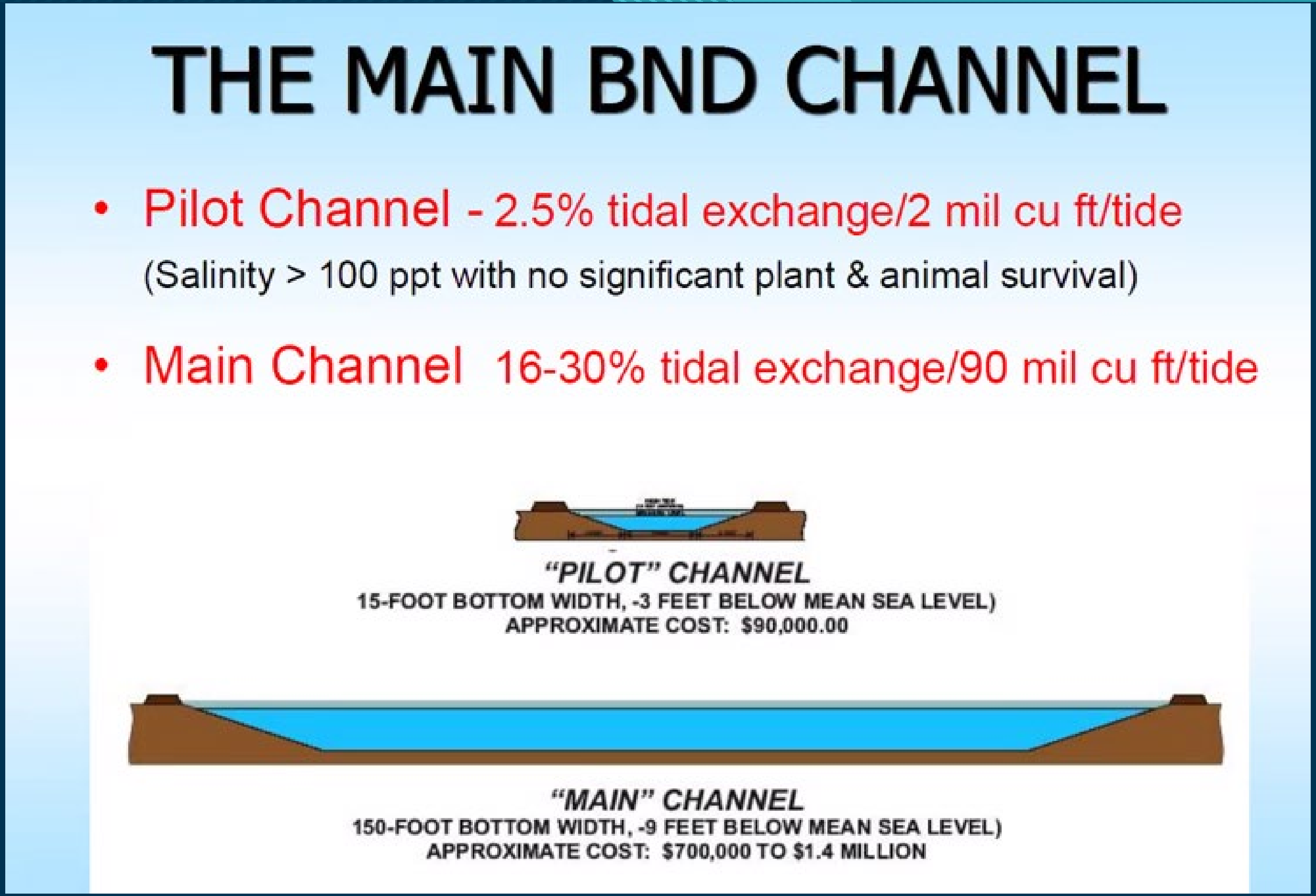


Image provided by the Texas General Land Office, 2021.

Exchange Ratio Results - Various Dates and Water Levels

Date	Tide (Spring/Neap)	Total Volume Exchanged Through Channel (ft³/tide)	Tidal Exchange Ratio MHHW (597,047,735 ft³)	Tidal Exchange Ratio MSL (400,457,970 ft³)	Tidal Exchange Ratio MLLW (161,853,714 ft³)
8/04 – 8/17/2022	SPRING	119,716,000.00	20.1%	29.9%	74.1%
8/18 – 8/31/2022	NEAP	93,297,000.00	15.7%	23.3%	57.6%
8/31 – 9/02/2022	NEAP	95,542,000.00	16.0%	23.8%	58.9%
9/02 – 9/20/2022	SPRING	141,447,000.00	23.7%	35.3%	87.4%
9/20 – 10/07/2022	NEAP/SPRING	113,924,000.00	19.1%	28.4%	70.3%
10/07 – 11/03/2022	SPRING/NEAP	75,563,000.00	12.7%	18.9%	46.7%
11/03 – 11/16/2022	SPRING	84,396,000.00	14.2%	21.0%	52.0%
11/16 – 12/07/2022	NEAP/SPRING	97,589,000.00	16.4%	24.4%	60.3%
12/20 – 12/25/2022	NEAP	86,218,000.00	14.5%	21.6%	53.4%
1/13 – 1/19/2023	SPRING/NEAP	124,019,000.00	20.8%	31.0%	76.7%
		Average Tidal Exchange Ratio	17.3%	25.8%	63.7%

Final Results Summary

- Our best estimate of tidal exchange ratios range from the MHHW to MSL tidal datum conditions
  - 14.7% – 29.6%
  - Resulting in average condition tidal exchange ratio of 22.2%

- Our over-arching conclusion
  - 2.81-fold increase from pre- to post-widening
  - 7.9% (2019) → **22.2%** (2023)

Questions

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