DRAFT 9/30/2025

CITY OF TITUSVILLE

VULNERABILITY ASSESSMENT

SECTION 3: EXPOSURE ANALYSIS

Prepared for:

City of Titusville, Florida
555 South Washington Avenue
Titusville, FL 32796

Prepared by:

Geosyntec Consultants, Inc.
6770 S. Washington Ave., Suite 3
Titusville, FL 32780

Geosyntec Project# FW11249
City Project #GF-2402
FDEP Grant Agreement #24PLN13

September 26, 2025

Geosyntec consultants

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The engineering material and data contained within the enclosed report was prepared by Geosyntec Consultants, Inc. for sole use by the City of Titusville, Florida. This report was prepared under the supervision and direction of the respective undersigned, whose seal as a registered professional engineer is affixed below.

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September 26, 2025

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3. EXPOSURE ANALYSIS

An exposure analysis to identify the impacts of storm surge, tidal, and rainfall-induced flooding within the City of Titusville (City) was performed. The scenarios and standards used for the analyses are pursuant to §380.093, FS. For this exposure analysis, flooding under baseline (existing), 2050, and 2080 planning horizons were evaluated. A previous report, entitled **Section 2: Background Data Collection**, outlined the data, and their sources, used in the analyses including measured water levels (NOAA and USGS), topography, soils, rainfall, groundwater levels, and Federal Emergency Management Agency (FEMA) flood information.

The City is located on the western side of the Indian River Lagoon (IRL) (**Figure 3.1**). The City limits, along with the extent of the project study area for the vulnerability assessment, are outlined in **Figure 3.1**. The project study area includes the City limits as well as areas outside of the City that contain City-maintained infrastructure. Topography within the study area ranges from near sea level along the coastlines on the east, up to approximately 75 feet-NAVD88. The highest elevations are located along former north-south running dune ridges located throughout the City. Drainage during rainfall events flows to the IRL along the eastern side, toward the St. Johns River on the western side, and in some instances, to closed basin areas, i.e., areas with no outflow.

This report presents the results of the exposure analysis in three sections. **Section 3.1** outlines the general methodologies utilized to address each flooding type. **Section 3.2** provides details on the development of models utilized to address rainfall-driven flooding. **Section 3.3** presents the results including flood inundation maps that show the extent and depth of flooding for the various flooding types and scenarios.

3.1 Methodology

Pursuant to §380.093, FS, the exposure analysis should address flooding due to high tides, storm surge, rainfall, and their compounding effects. Additionally, the exposure analysis must address the 2050 and 2080 future conditions. This includes accounting for sea level rise (SLR) under the intermediate-low and intermediate projections based on nearby NOAA tidal stations. **Section 2: Background Data Collection**, submitted under separate cover, identified that the Florida Flood Hub's 2025 sea level rise projections for the Trident Pier station will be referenced. **Figure 3.2** presents the location of the NOAA Trident Pier station, which is located near Port Canaveral on the Atlantic.

The following sections provide the methodologies utilized to develop the existing, 2050, and 2080 inundation extents and depths within the project areas outlined in **Figure 3.1** for each of the flooding types. Prior to presentation of the methodologies, **Section 3.1.1** presents the SLR scenarios utilized in the exposure analyses. **Section 3.1.2** provides an overview of water level conditions within the IRL. The water levels within the IRL near Titusville have unique characteristics relative to those measured at Trident Pier. The differences impact the flooding analyses.

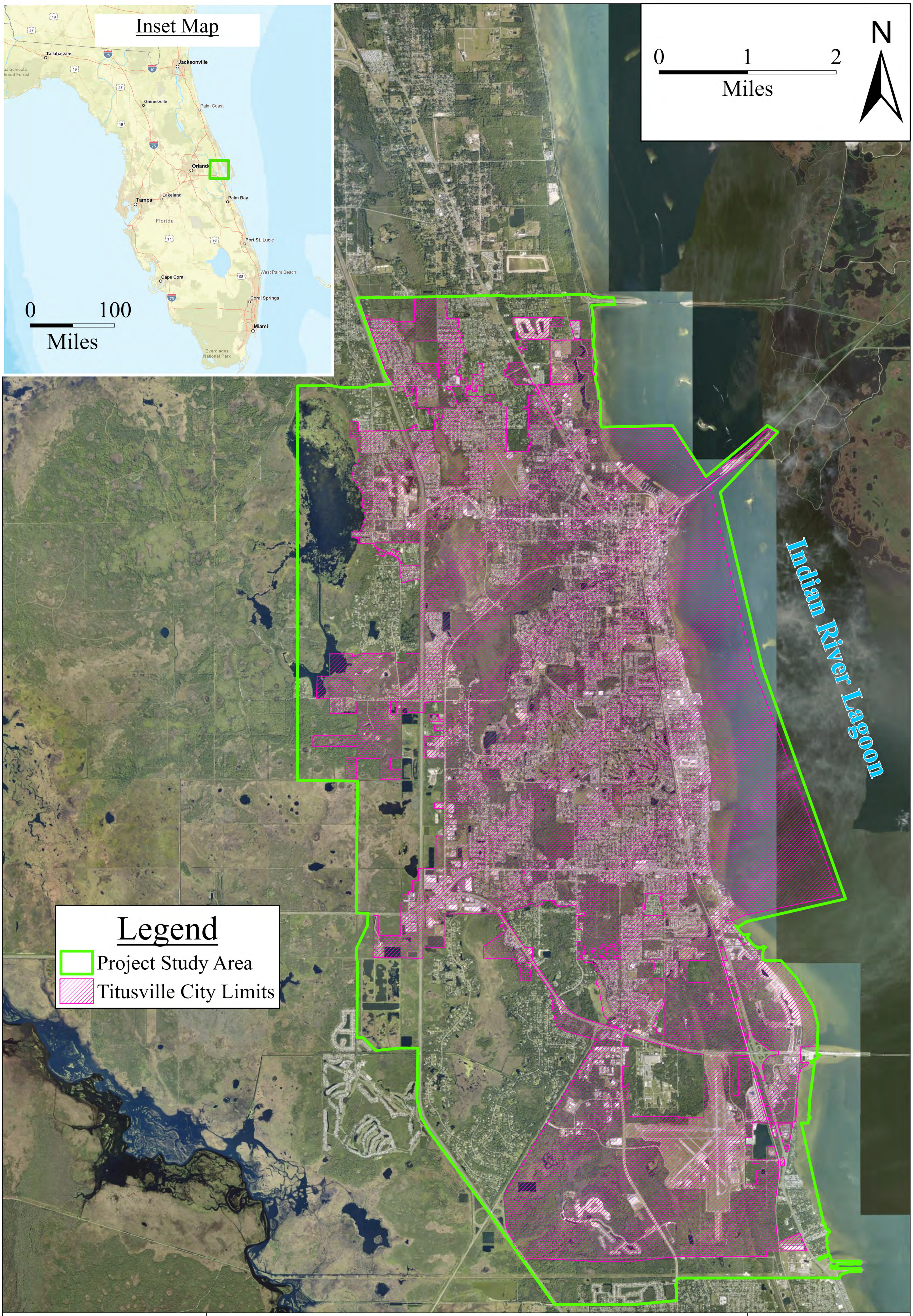

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Figure 3.1 - Project Area

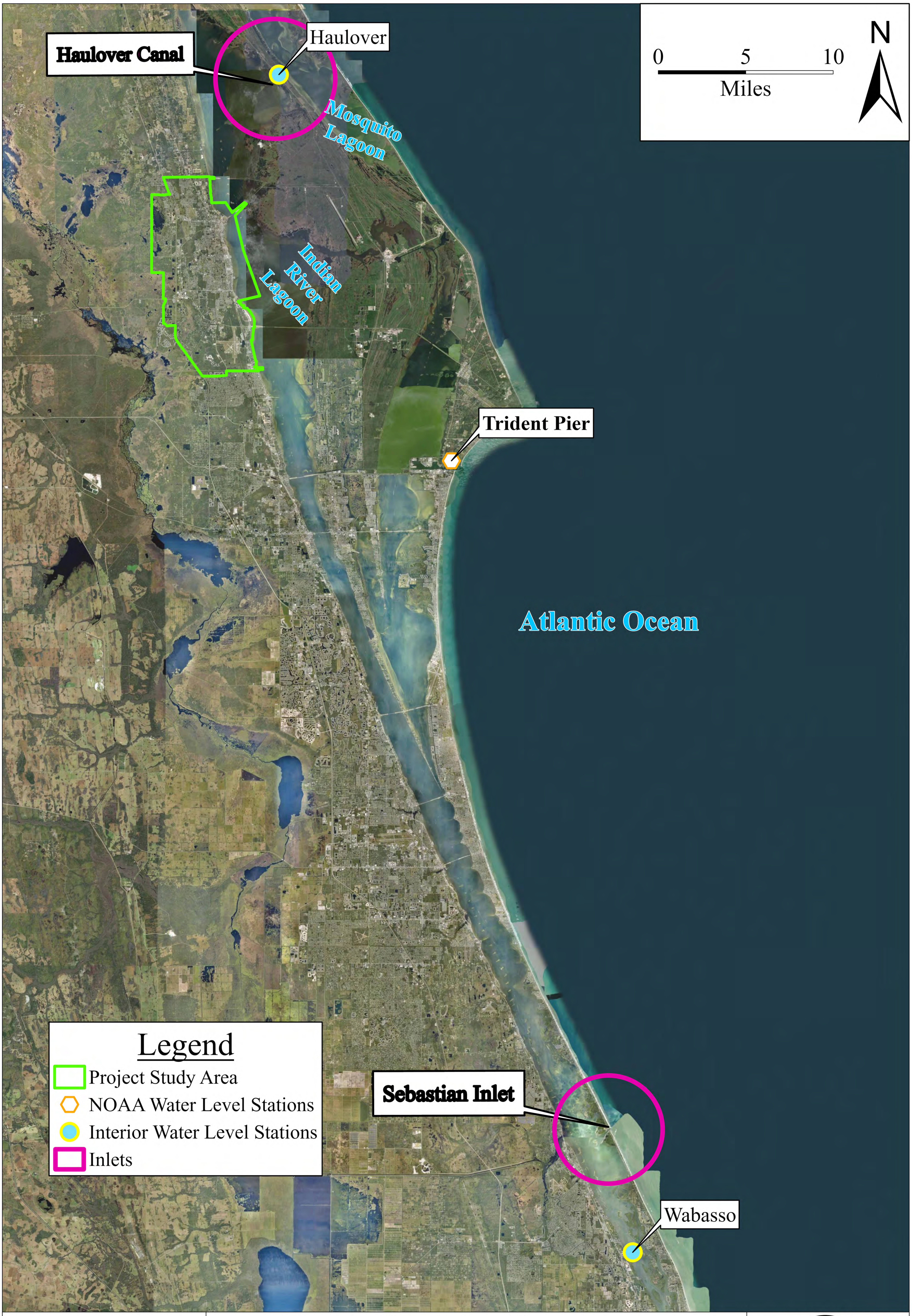

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Figure 3.2 - Water Level Stations

3.1.1 Sea Level Rise

The Florida Flood Hub recently published table with Sea Level Elevations under present and projected future SLR was utilized to determine existing and future water levels in the IRL based on the Trident Pier gage at Port Canaveral. **Figure 3.2** shows the location of the Trident Pier gage associated with the Atlantic Ocean. It was assumed that the SLR within the IRL mirrored the future conditions at Trident Pier. **Table 3.1** presents the published elevations for Mean Higher High Water (MHHW), Mean Sea Level (MSL), and Mean Lower Low Water (MLLW) at the various NOAA stations throughout Florida including Trident Pier relative to NAVD88. The Trident Pier MSL values within the table were utilized to define the baseline (existing) water elevations in 2025 as well as the 2050 and 2080 future planning horizons under the intermediate-low and intermediate future planning scenarios within the IRL.

3.1.2 Indian River Lagoon Water Levels

For those portions of the City that ultimately discharge to the east, water levels within the IRL act as tailwater conditions that directly impact flooding extents and depths during extreme rainfall events. As such, the determination of appropriate tailwater conditions for the rainfall-driven flood modeling requires an understanding and analyses of water levels within the IRL.

The IRL is a shallow coastal lagoon with limited direct connection to the Atlantic. Titusville is located along the western shoreline near the northern end of the IRL. The nearest inlets are Sebastian Inlet, approximately 56 miles south, and Ponce de Leon Inlet, 36 miles to the north through Haulover Canal and Mosquito Lagoon (**Figure 3.2**). Detailed analyses were performed on measured water levels at two stations within the IRL along with data from the NOAA Trident Pier station. The interior stations included continuous water level gages maintained by the United States Geologic Survey (USGS) at Haulover Canal and Wabasso (**Figure 3.2**). The proximity of the USGS Haulover Canal station to Titusville makes it ideal for use in defining the historical water levels. All data were available referenced to NAVD88. The period of record for the combined datasets spanned from 2010 through 2024.

The analyses showed that due to the limited connection to the offshore, daily tidal fluctuations, measured at the Trident Pier station, are almost completely damped out by the time they reach the northern IRL. **Figure 3.3** presents the measured data for each of the stations for a 1-month period in 2014. Additional plots of the data are provided in **Appendix A**. The water level fluctuations within the northern IRL are the result of longer-term mean water level fluctuations offshore and locally driven wind set-up and set-down. Using continuous data from the Haulover gage, an equivalent, non-tidal, MHHW was developed for the northern IRL along with differences in MSL between the IRL and offshore. The equivalent MHHW condition was developed to support the tidal flooding analysis, which per §380.093 FS must utilize MHHW plus 2.0 feet.

TABLE 3.1: FLORIDA FLOOD HUB SLR PROJECTIONS

NOAA TIDE GAUGE STATION	DATUM	SEA LEVEL ELEVATIONS, 1983-2001 EPOCH (*in FEET relative to NAVD88*)															
		1992	2000	*2020*		*2030*		*2040**		*2050^*		*2060*		*2070***		*2080^^*	
				Int-Low	*Int*	*Int-Low*	*Int*	*Int-Low*	*Int*	*Int-Low*	*Int*	*Int-Low*	*Int*	*Int-Low*	*Int*	*Int-Low*	*Int*
8720030 Fernandina Beach, FL	MHHW	2.74	2.83	3.16	3.17	3.36	3.39	3.57	3.64	3.79	3.93	4.01	4.26	4.23	4.66	4.46	5.13
	MSL	-0.53	-0.44	-0.11	-0.10	0.09	0.12	0.30	0.37	0.52	0.66	0.74	0.99	0.96	1.39	1.19	1.86
	MLLW	-3.82	-3.73	-3.40	-3.39	-3.20	-3.17	-2.99	-2.92	-2.77	-2.63	-2.55	-2.30	-2.33	-1.90	-2.10	-1.43
8720218 Mayport (Bar Pilots Dock), FL	MHHW	1.96	2.05	2.38	2.39	2.58	2.61	2.79	2.86	3.01	3.15	3.23	3.48	3.45	3.88	3.68	4.35
	MSL	-0.52	-0.43	-0.10	-0.09	0.10	0.13	0.31	0.38	0.53	0.67	0.75	1.00	0.97	1.40	1.20	1.87
	MLLW	-2.99	-2.90	-2.57	-2.56	-2.37	-2.34	-2.16	-2.09	-1.94	-1.80	-1.72	-1.47	-1.50	-1.07	-1.27	-0.60
8720219 Dames Point, FL	MHHW	1.42	1.51	1.84	1.85	2.04	2.07	2.25	2.32	2.47	2.61	2.69	2.94	2.91	3.34	3.14	3.81
	MSL	-0.38	-0.29	0.04	0.05	0.24	0.27	0.45	0.52	0.67	0.81	0.89	1.14	1.11	1.54	1.34	2.01
	MLLW	-2.24	-2.15	-1.82	-1.81	-1.62	-1.59	-1.41	-1.34	-1.19	-1.05	-0.97	-0.72	-0.75	-0.32	-0.52	0.15
8720226 Southbank Riverwalk, St Johns River, FL	MHHW	0.65	0.74	1.07	1.08	1.27	1.30	1.48	1.55	1.70	1.84	1.92	2.17	2.14	2.57	2.37	3.04
	MSL	-0.24	-0.15	0.18	0.19	0.38	0.41	0.59	0.66	0.81	0.95	1.03	1.28	1.25	1.68	1.48	2.15
	MLLW	-1.30	-1.21	-0.88	-0.87	-0.68	-0.65	-0.47	-0.40	-0.25	-0.11	-0.03	0.22	0.19	0.62	0.42	1.09
8720357 I-295 Buckman Bridge, FL	MHHW	0.39	0.48	0.81	0.82	1.01	1.04	1.22	1.29	1.44	1.58	1.66	1.91	1.88	2.31	2.11	2.78
	MSL	-0.11	-0.02	0.31	0.32	0.51	0.54	0.72	0.79	0.94	1.08	1.16	1.41	1.38	1.81	1.61	2.28
	MLLW	-0.62	-0.53	-0.20	-0.19	0.00	0.03	0.21	0.28	0.43	0.57	0.65	0.90	0.87	1.30	1.10	1.77
8721604 Trident Pier, Port Canaveral, FL	MHHW	1.10	1.19	1.52	1.53	1.72	1.75	1.93	2.00	2.15	2.29	2.37	2.62	2.59	3.02	2.82	3.49
	MSL	-0.95	-0.86	-0.53	-0.52	-0.33	-0.30	-0.12	-0.05	0.10	0.24	0.32	0.57	0.54	0.97	0.77	1.44
	MLLW	-2.83	-2.74	-2.41	-2.40	-2.21	-2.18	-2.00	-1.93	-1.78	-1.64	-1.56	-1.31	-1.34	-0.91	-1.11	-0.44
8722670 Lake Worth Pier, Atlantic Ocean, FL	MHHW	0.55	0.64	0.97	0.98	1.17	1.20	1.38	1.45	1.60	1.74	1.82	2.07	2.04	2.47	2.27	2.94
	MSL	-0.97	-0.88	-0.55	-0.54	-0.35	-0.32	-0.14	-0.07	0.08	0.22	0.30	0.55	0.52	0.95	0.75	1.42
	MLLW	-2.51	-2.42	-2.09	-2.08	-1.89	-1.86	-1.68	-1.61	-1.46	-1.32	-1.24	-0.99	-1.02	-0.59	-0.79	-0.12
8722956 South Port Everglades, FL	MHHW	0.57	0.66	0.99	1.00	1.19	1.22	1.40	1.47	1.62	1.76	1.84	2.09	2.06	2.49	2.29	2.96
	MSL	-0.80	-0.71	-0.38	-0.37	-0.18	-0.15	0.03	0.10	0.25	0.39	0.47	0.72	0.69	1.12	0.92	1.59
	MLLW	-2.21	-2.12	-1.79	-1.78	-1.59	-1.56	-1.38	-1.31	-1.16	-1.02	-0.94	-0.69	-0.72	-0.29	-0.49	0.18
8723214 Virginia Key, FL	MHHW	0.23	0.32	0.65	0.66	0.85	0.88	1.06	1.13	1.28	1.42	1.50	1.75	1.72	2.15	1.95	2.62
	MSL	-0.89	-0.80	-0.47	-0.46	-0.27	-0.24	-0.06	0.01	0.16	0.30	0.38	0.63	0.60	1.03	0.83	1.50
	MLLW	-2.02	-1.93	-1.60	-1.59	-1.40	-1.37	-1.19	-1.12	-0.97	-0.83	-0.75	-0.50	-0.53	-0.10	-0.30	0.37
8723970 Vaca Key, Florida Bay, FL	MHHW	-0.36	-0.27	0.06	0.07	0.26	0.29	0.47	0.54	0.69	0.83	0.91	1.16	1.13	1.56	1.36	2.03
	MSL	-0.83	-0.74	-0.41	-0.40	-0.21	-0.18	0.00	0.07	0.22	0.36	0.44	0.69	0.66	1.09	0.89	1.56
	MLLW	-1.34	-1.25	-0.92	-0.91	-0.72	-0.69	-0.51	-0.44	-0.29	-0.15	-0.07	0.18	0.15	0.58	0.38	1.05
8724580 Key West, FL	MHHW	0.05	0.14	0.47	0.48	0.67	0.70	0.88	0.95	1.10	1.24	1.32	1.57	1.54	1.97	1.77	2.44
	MSL	-0.87	-0.78	-0.45	-0.44	-0.25	-0.22	-0.04	0.03	0.18	0.32	0.40	0.65	0.62	1.05	0.85	1.52
	MLLW	-1.76	-1.67	-1.34	-1.33	-1.14	-1.11	-0.93	-0.86	-0.71	-0.57	-0.49	-0.24	-0.27	0.16	-0.04	0.63
8725114 Naples Bay, North, FL	MHHW	0.69	0.78	1.11	1.12	1.31	1.34	1.52	1.59	1.74	1.88	1.96	2.21	2.18	2.61	2.41	3.08
	MSL	-0.50	-0.41	-0.08	-0.07	0.12	0.15	0.33	0.40	0.55	0.69	0.77	1.02	0.99	1.42	1.22	1.89
	MLLW	-2.07	-1.98	-1.65	-1.64	-1.45	-1.42	-1.24	-1.17	-1.02	-0.88	-0.80	-0.55	-0.58	-0.15	-0.35	0.32
8725520 Fort Myers, FL	MHHW	0.28	0.37	0.70	0.71	0.90	0.93	1.11	1.18	1.33	1.47	1.55	1.80	1.77	2.20	2.00	2.67
	MSL	-0.41	-0.32	0.01	0.02	0.21	0.24	0.42	0.49	0.64	0.78	0.86	1.11	1.08	1.51	1.31	1.98
	MLLW	-1.04	-0.95	-0.62	-0.61	-0.42	-0.39	-0.21	-0.14	0.01	0.15	0.23	0.48	0.45	0.88	0.68	1.35
8726384 Port Manatee, FL	MHHW	0.58	0.67	1.00	1.01	1.20	1.23	1.41	1.48	1.63	1.77	1.85	2.10	2.07	2.50	2.30	2.97
	MSL	-0.43	-0.34	-0.01	0.00	0.19	0.22	0.40	0.47	0.62	0.76	0.84	1.09	1.06	1.49	1.29	1.96
	MLLW	-1.59	-1.50	-1.17	-1.16	-0.97	-0.94	-0.76	-0.69	-0.54	-0.40	-0.32	-0.07	-0.10	0.33	0.13	0.80
8726520 St. Petersburg, FL	MHHW	0.78	0.87	1.20	1.21	1.40	1.43	1.61	1.68	1.83	1.97	2.05	2.30	2.27	2.70	2.50	3.17
	MSL	-0.28	-0.19	0.14	0.15	0.34	0.37	0.55	0.62	0.77	0.91	0.99	1.24	1.21	1.64	1.44	2.11
	MLLW	-1.48	-1.39	-1.06	-1.05	-0.86	-0.83	-0.65	-0.58	-0.43	-0.29	-0.21	0.04	0.01	0.44	0.24	0.91
8726607 Old Port Tampa, FL	MHHW	0.79	0.88	1.21	1.22	1.41	1.44	1.62	1.69	1.84	1.98	2.06	2.31	2.28	2.71	2.51	3.18
	MSL	-0.39	-0.30	0.03	0.04	0.23	0.26	0.44	0.51	0.66	0.80	0.88	1.13	1.10	1.53	1.33	2.00
	MLLW	-1.69	-1.60	-1.27	-1.26	-1.07	-1.04	-0.86	-0.79	-0.64	-0.50	-0.42	-0.17	-0.20	0.23	0.03	0.70
8726674 East Bay, FL	MHHW	0.86	0.95	1.28	1.29	1.48	1.51	1.69	1.76	1.91	2.05	2.13	2.38	2.35	2.78	2.58	3.25
	MSL	-0.36	-0.27	0.06	0.07	0.26	0.29	0.47	0.54	0.69	0.83	0.91	1.16	1.13	1.56	1.36	2.03
	MLLW	-1.82	-1.73	-1.40	-1.39	-1.20	-1.17	-0.99	-0.92	-0.77	-0.63	-0.55	-0.30	-0.33	0.10	-0.10	0.57
8726724 Clearwater Beach, FL	MHHW	0.95	1.04	1.37	1.38	1.57	1.60	1.78	1.85	2.00	2.14	2.22	2.47	2.44	2.87	2.67	3.34
	MSL	-0.32	-0.23	0.10	0.11	0.30	0.33	0.51	0.58	0.73	0.87	0.95	1.20	1.17	1.60	1.40	2.07
	MLLW	-1.79	-1.70	-1.37	-1.36	-1.17	-1.14	-0.96	-0.89	-0.74	-0.60	-0.52	-0.27	-0.30	0.13	-0.07	0.60
8727520 Cedar Key, FL	MHHW	1.54	1.63	1.96	1.97	2.16	2.19	2.37	2.44	2.59	2.73	2.81	3.06	3.03	3.46	3.26	3.93
	MSL	-0.22	-0.13	0.20	0.21	0.40	0.43	0.61	0.68	0.83	0.97	1.05	1.30	1.27	1.70	1.50	2.17
	MLLW	-2.26	-2.17	-1.84	-1.83	-1.64	-1.61	-1.43	-1.36	-1.21	-1.07	-0.99	-0.74	-0.77	-0.34	-0.54	0.13
8728690 Apalachicola, FL	MHHW	0.85	0.94	1.27	1.28	1.47	1.50	1.68	1.75	1.90	2.04	2.12	2.37	2.34	2.77	2.57	3.24
	MSL	0.15	0.24	0.57	0.58	0.77	0.80	0.98	1.05	1.20	1.34	1.42	1.67	1.64	2.07	1.87	2.54
	MLLW	-0.76	-0.67	-0.34	-0.33	-0.14	-0.11	0.07	0.14	0.29	0.43	0.51	0.76	0.73	1.16	0.96	1.63
8729108 Panama City, FL	MHHW	0.78	0.87	1.20	1.21	1.40	1.43	1.61	1.68	1.83	1.97	2.05	2.30	2.27	2.70	2.50	3.17
	MSL	0.11	0.20	0.53	0.54	0.73	0.76	0.94	1.01	1.16	1.30	1.38	1.63	1.60	2.03	1.83	2.50
	MLLW	-0.56	-0.47	-0.14	-0.13	0.06	0.09	0.27	0.34	0.49	0.63	0.71	0.96	0.93	1.36	1.16	1.83
8729210 Panama City Beach, FL	MHHW	0.86	0.95	1.28	1.29	1.48	1.51	1.69	1.76	1.91	2.05	2.13	2.38	2.35	2.78	2.58	3.25
	MSL	0.13	0.22	0.55	0.56	0.75	0.78	0.96	1.03	1.18	1.32	1.40	1.65	1.62	2.05	1.85	2.52
	MLLW	-0.54	-0.45	-0.12	-0.11	0.08	0.11	0.29	0.36	0.51	0.65	0.73	0.98	0.95	1.38	1.18	1.85
8729840 Pensacola, FL	MHHW	0.94	1.03	1.36	1.37	1.56	1.59	1.77	1.84	1.99	2.13	2.21	2.46	2.43	2.86	2.66	3.33
	MSL	0.30	0.39	0.72	0.73	0.92	0.95	1.13	1.20	1.35	1.49	1.57	1.82	1.79	2.22	2.02	2.69
	MLLW	-0.32	-0.23	0.10	0.11	0.30	0.33	0.51	0.58	0.73	0.87	0.95	1.20	1.17	1.60	1.40	2.07

Source: Florida Flood Hub. 2025. Florida Department of Environmental Protection, Statewide Office of Resiliency.

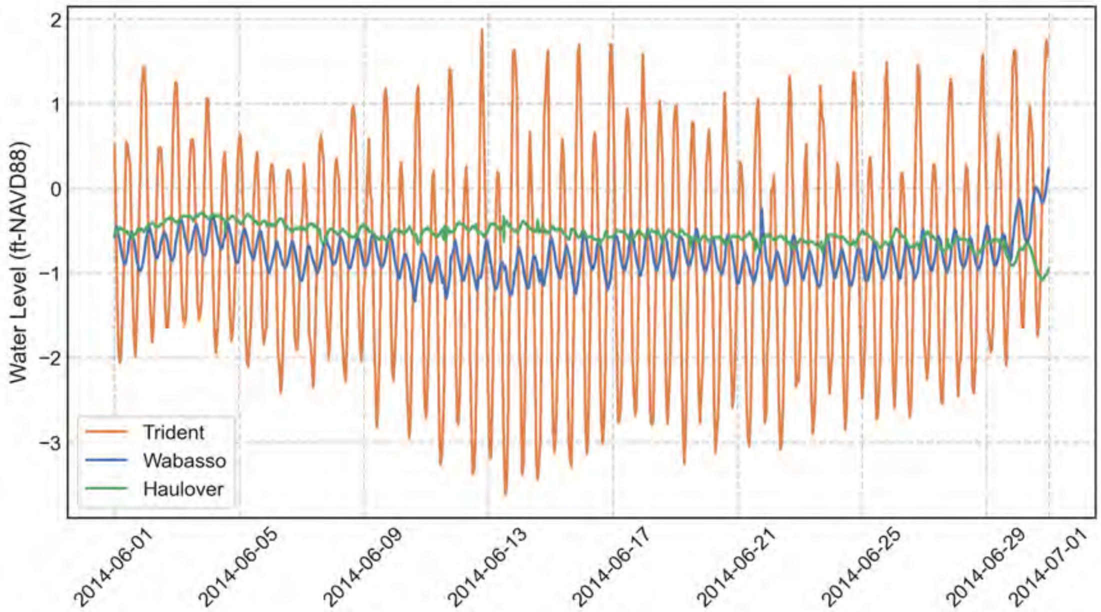

FIGURE 3.3: MEASURED WATER LEVELS AT INTERIOR STATIONS AND TRIDENT PIER (JUNE 2014)

The data analysis resulted in the following determinations.

- MSL within the northern IRL near Titusville is 0.25 feet higher than the offshore conditions at Trident Pier.
- In the northern IRL an equivalent MHHW plus 2.0 feet is 1.94 feet-NAVD88.
- The MHHW plus 2.0 feet of 1.94 feet-NAVD88 in the northern IRL represents a technically defensible and conservative tailwater condition.

The results of the analysis were presented to FDEP staff at a meeting on June 4, 2025, and then within a letter dated June 24, 2025. The letter is included as **Appendix A**. While FDEP staff determined that the analyses were accurate and the determinations reasonable, it was identified that per §380.093 FS, for mean water levels and tidal flooding, the conditions at the NOAA gage (Trident Pier) must be utilized for the flooding assessments based on water levels within the northern IRL.

3.1.3 Tidal Flooding

As outlined in **Section 3.1.2**, the tidal flooding analysis utilized the NOAA Trident gage MHHW plus 2.0 feet to define inundation extents and depths of flooding from the northern IRL. Based on interpolation of the published data between 2020 and 2030 (**Table 3.1**), the MHHW condition at the Trident station is 1.62-1.64 feet-NAVD88 for the intermediate-low and intermediate projections. Therefore, for the existing condition tidal flooding analysis, which requires the use of the MHHW plus 2.0 feet, the water levels were set at 3.64 feet-NAVD88 for the northern IRL near Titusville (**Table 3.2**).

TABLE 3.2: EXISTING AND FUTURE CONDITION WATER LEVELS FOR TIDAL AND RAINFALL-INDUCED FLOODING TAILWATER

Flooding Type	2025	2050 Intermediate-Low	2050 Intermediate	2080 Intermediate-Low	2080 Intermediate
	Northern IRL (feet)	Northern IRL (feet)	Northern IRL (feet)	Northern IRL (feet)	Northern IRL (feet)
Tidal Flooding	3.64	4.15	4.29	4.82	5.49
Tailwater	1.94	2.47	2.59	3.14	3.79

n/a – not applicable

Existing condition tidal flooding extents and depths were then determined through overlay of this water level elevation upon the Digital Elevation Model (DEM) within the project area (**Figure 3.4**). Any areas with potential connectivity to the northern IRL at elevations below 3.64 feet-NAVD88 were determined to be inundated. For future condition tidal flooding extents and depths, the elevations presented in **Table 3.2** were utilized for the 2050 and 2080 planning horizons at the intermediate-low and intermediate scenarios and flooding extents and depths mapped following the approach outlined above.

As identified in **Section 3.1.2**, daily tidal fluctuations within the northern IRL are almost completely damped out, and short-term water level variations are driven almost solely by local wind and rainfall runoff. As prescribed by statute, and as determined through coordination with FDEP, the MHHW condition at the Trident gage was utilized for tidal flooding from the northern IRL. It is noted that this method results in tidal flooding extents and depths that may likely be unrealistic and overly conservative. Based on this, the extents and depths of tidal flooding should be considered as informational only and may not be appropriate for future planning.

3.1.4 Storm Surge

Titusville is located along the northern portion of the IRL and as such, experiences potential storm surge impacts through wind-driven set up or other mechanisms that raise water levels within the northern IRL. Based on this, the assessment of storm surge flooding (from the northern IRL) extents and depths under existing and future conditions was accomplished via spatial analyses. ArcGIS (GIS) was used to outline areas of existing flooding from storm surge within specified coastal zones based on the FEMA 1% chance exceedance probability, commonly referred to as a "100-year flood." The baseline (existing condition) information came from the effective 2021 FEMA Flood Insurance Study (FIS) for Brevard County as well as from the 2022 SLR Technical Report.

Figure 3.5 displays the FEMA flood zones and Special Flood Hazard Areas (SFHAs) within the project area. A SFHA is an area FEMA identifies as vulnerable to flooding during a 100-year storm event. Existing (i.e., "present-day") SFHAs are based on the GIS layers from FEMA's FIS for Brevard County. FEMA designates base flood elevations (BFEs) for each SFHA by analyzing existing flooding and wave impacts. For Titusville, the existing condition BFE associated with the A/E zone bordering the City within the northern IRL was between 3 and 4 feet (NAVD88). This was the basis for the storm surge flood inundation areas and depths.

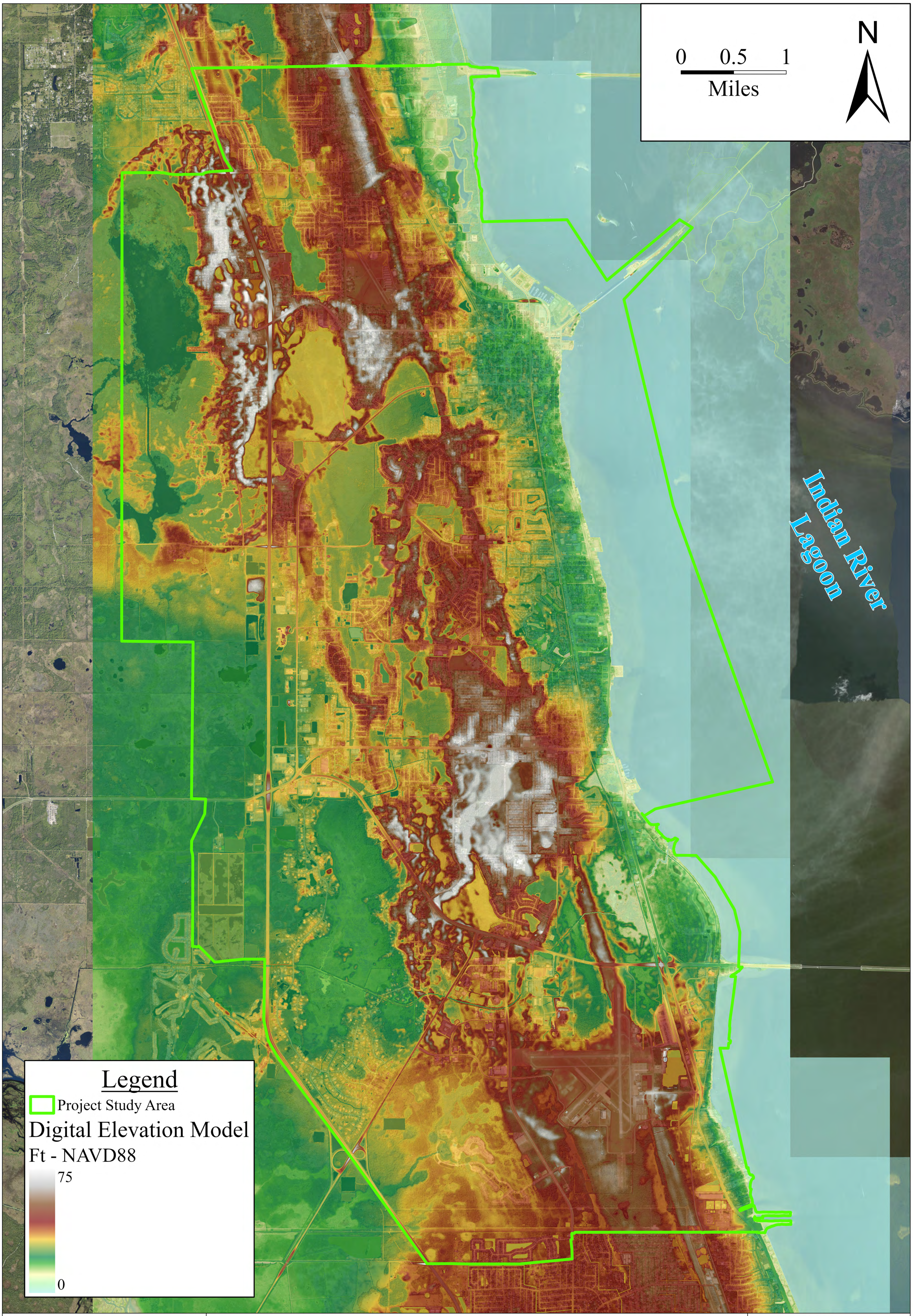

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Figure 3.4 - Project DEM

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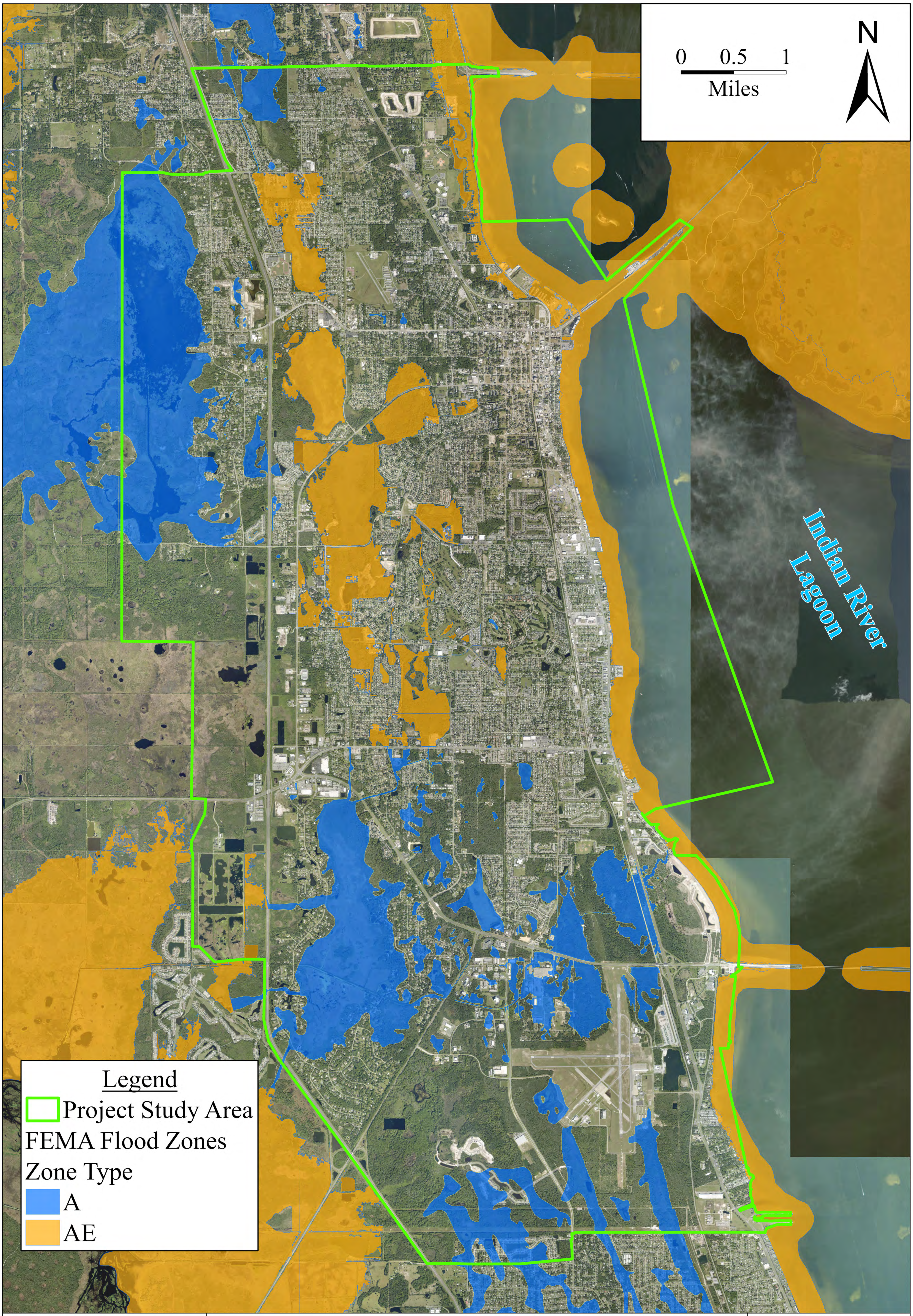

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Figure 3.5 - FEMA Flood Zones

A stillwater elevation (SWEL) can informally be thought of as a 100-year storm surge elevation that does not include wave height. In coastal environments, such as the northern IRL, wave effects atop the SWEL combine to create the BFE. A 2017 study published in the Journal of Regional Environmental Change demonstrated that SLR within coastal hazard areas is a non-linear relationship with the projected value of SLR calculated without consideration of wave impacts to BFEs (Biondi and Guannel, 2017). This means that a 1-foot projected rise in sea level could translate to more than just a 1-ft rise in BFE along inland coastal areas once wave impacts are factored in. Based on their analyses, calculated BFEs ranged from approximately 1.5 to 1.8 times higher than the nominal SLR. Using these findings as guidance, a coefficient of 1.5 was factored into BFEs within AE zones (FEMA's designation of base floodplain), which includes the study area within the northern IRL that borders the City.

The SLR values as outlined in **Section 3.1.1** were computed into the DEM and subsequently analyzed against the present-day SWEL to determine the new extents of flooding. SFHA zones (i.e., BFEs and zone types: AE) were overlaid onto the modified SWEL extents to determine updated flood depths utilizing the BFE factors for the respective AE zones as described above. Post-processing consisted of removing isolated areas of flooding to ensure the analysis only accounted for the expansion of existing SWEL extents due to surge flooding from the northern IRL in SLR scenarios. Waterbodies and canals were removed from the analysis as to not identify false bathymetry/depths in those areas.

3.1.5 Rainfall-Induced Flooding

Rainfall-induced flooding utilized a Stormwise (formerly ICPR) model of the City, and surrounding areas that the City drains to, in order to project inundation extents and depths under existing and future conditions. The Stormwise model for the City was developed specifically to address rainfall-induced flooding for this vulnerability assessment. **Section 3.2** provides a more detailed discussion of the existing and future condition model development and application.

As outlined in **Section 3.1.2** drainage from portions of the City on the east side flows into the northern IRL. Based on this, to support the Stormwise model application, tailwater conditions within the northern IRL must be defined for the existing and future conditions. **Section 3.1.2** described analyses performed on water level data within the northern IRL to support development of an appropriate existing condition tailwater. **Appendix A** provides the complete analyses. The defined tailwater condition for the 2025 existing condition runs is presented in **Table 3.2**. For the future condition modeling, the differences between 2025 (existing), 2050 and 2080 water levels in **Table 3.1** were added to the existing condition tailwater. **Table 3.2** presents the 2050 and 2080 tailwater conditions under the intermediate-low and intermediate scenarios. Simulation of the areas that did not directly drain to the northern IRL did not rely on tailwater conditions but rather utilized overland weirs in the model based upon the DEM to support the flooding response under extreme rainfall events.

For the purposes of this VA, the design storms used to identify flood inundation areas for both the existing and future conditions were the 100-year/24-hour and 500-year/24-hour. **Section 3.2** presents and discusses the rainfall depths and future condition rainfall change factors based on these storm event probabilities.

3.1.6 Compound Flooding

Per §380.093 FS, the vulnerability assessment must, to the extent practical, address compound flooding, i.e., the combination of tidal, storm surge, and rainfall-induced flooding. For the City, where the eastern areas drain to the northern IRL, compound flooding was addressed through inclusion of potential storm-driven tailwater conditions in the northern IRL that occur in combination with extreme rainfall events. In the water level analysis discussed in **Section 3.1.2** and presented in **Appendix A**, review of historical measured water levels since 2010 identified the highest measured storm-driven water levels including multiple recent hurricanes that passed through the area. Based on analyses of water levels and rainfall during these events, it was determined that the tailwater conditions discussed in **Section 3.1.5** and presented in **Table 3.2**, adequately account for the effects of compound flooding, and no additional analysis for compound flooding effects was conducted.

3.2 Existing and Future Condition Rainfall-Induced Flooding Models

The following provides details on the data and assumptions utilized in the development of the Stormwise model to project existing and future rainfall-driven flooding. As outlined in **Section 3.1.5**, existing and future condition Stormwise models were developed for the City to address the rainfall-driven flooding. The extents of the model are shown in **Figure 3.1** (project study area). While detailed subsurface stormwater infrastructure was not utilized for the model development, sufficient model detail was provided for a reasonable hydrologic focused simulation of overland flow and inundation during storm events (e.g., subbasin boundaries and overland flow weirs).

3.2.1 Existing Condition Stormwise Model

The Stormwise model representation within the City limits uses an overland flow representation to simulate storm events without subsurface drainage structural detail. **Figure 3.6** presents the Stormwise model network and basins. Drainage within the individual basin areas is directed based upon the project DEM, which was presented earlier in **Figure 3.4**.

The NRCS Curve Number (CN) method was used to generate direct runoff volumes. The NRCS CN method uses a combination of soil conditions and land use (ground cover) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CN), indicate the runoff potential of an area. The higher the CN, the higher the runoff potential. Land uses in the project boundary were converted to land cover types relative to their degree of infiltration or imperviousness. **Figure 3.7** presents the land cover conditions utilized in the model throughout the project area along with a table showing percents of each type. The land cover conditions were preprocessed into a simplified representation of pervious versus impervious cover and water. The dominant land cover through the study area is pervious with 77% of the study area. Impervious area was at 18% with the remaining 5% water.

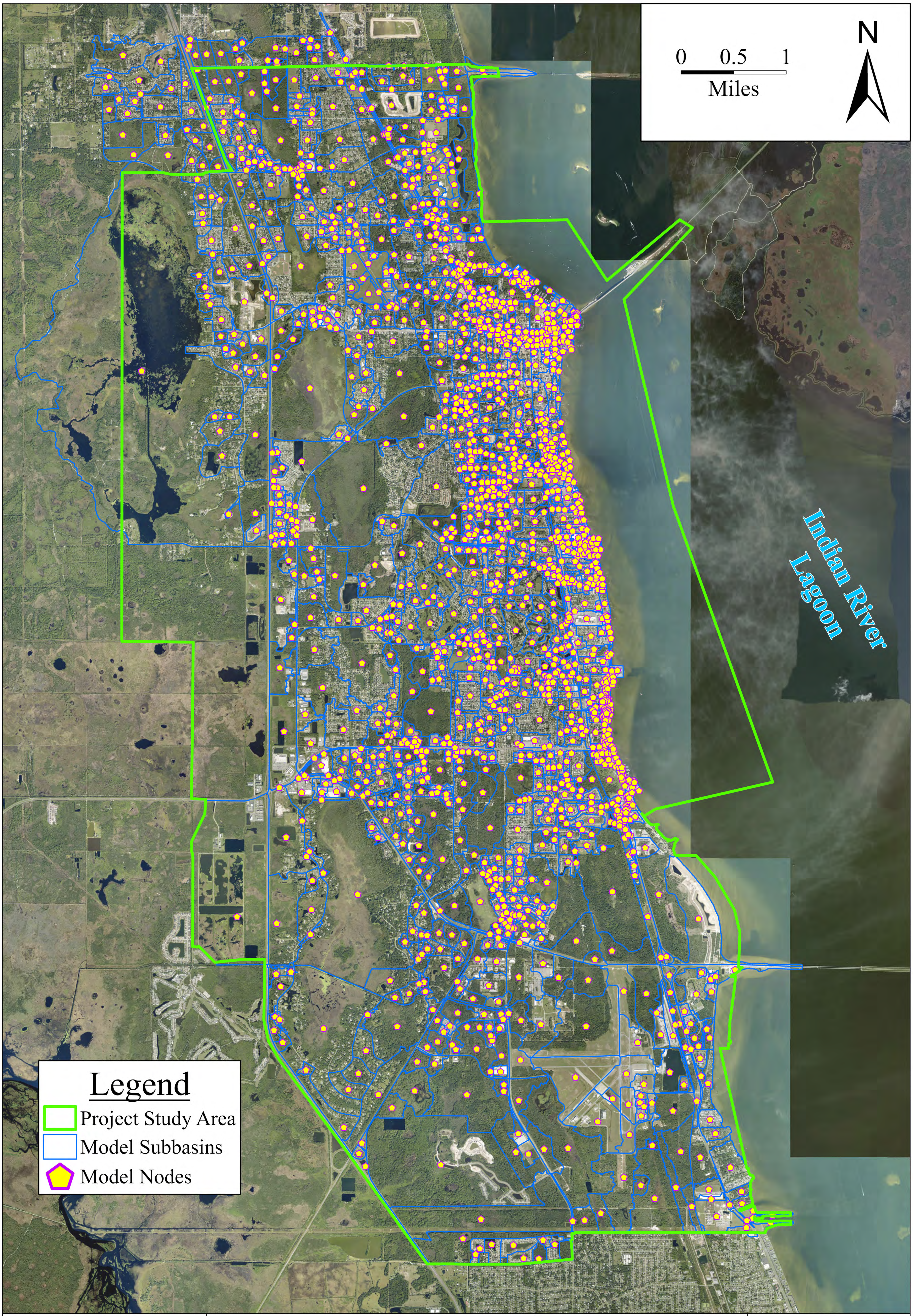

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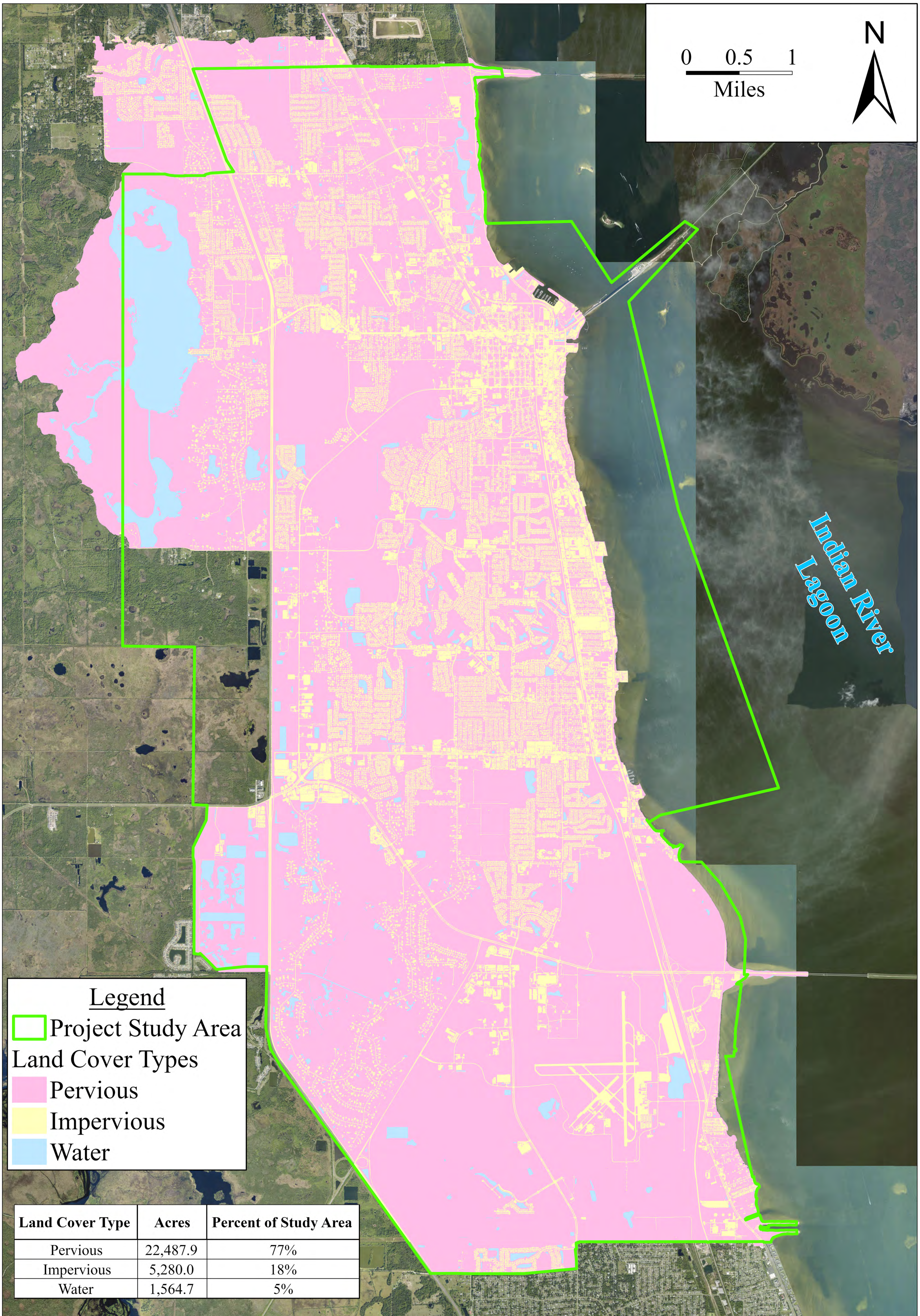
Figure 3.6 - Model Network



Land Cover Type	Acres	Percent of Study Area
Pervious	22,487.9	77%
Impervious	5,280.0	18%
Water	1,564.7	5%

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Figure 3.7 - Land Cover

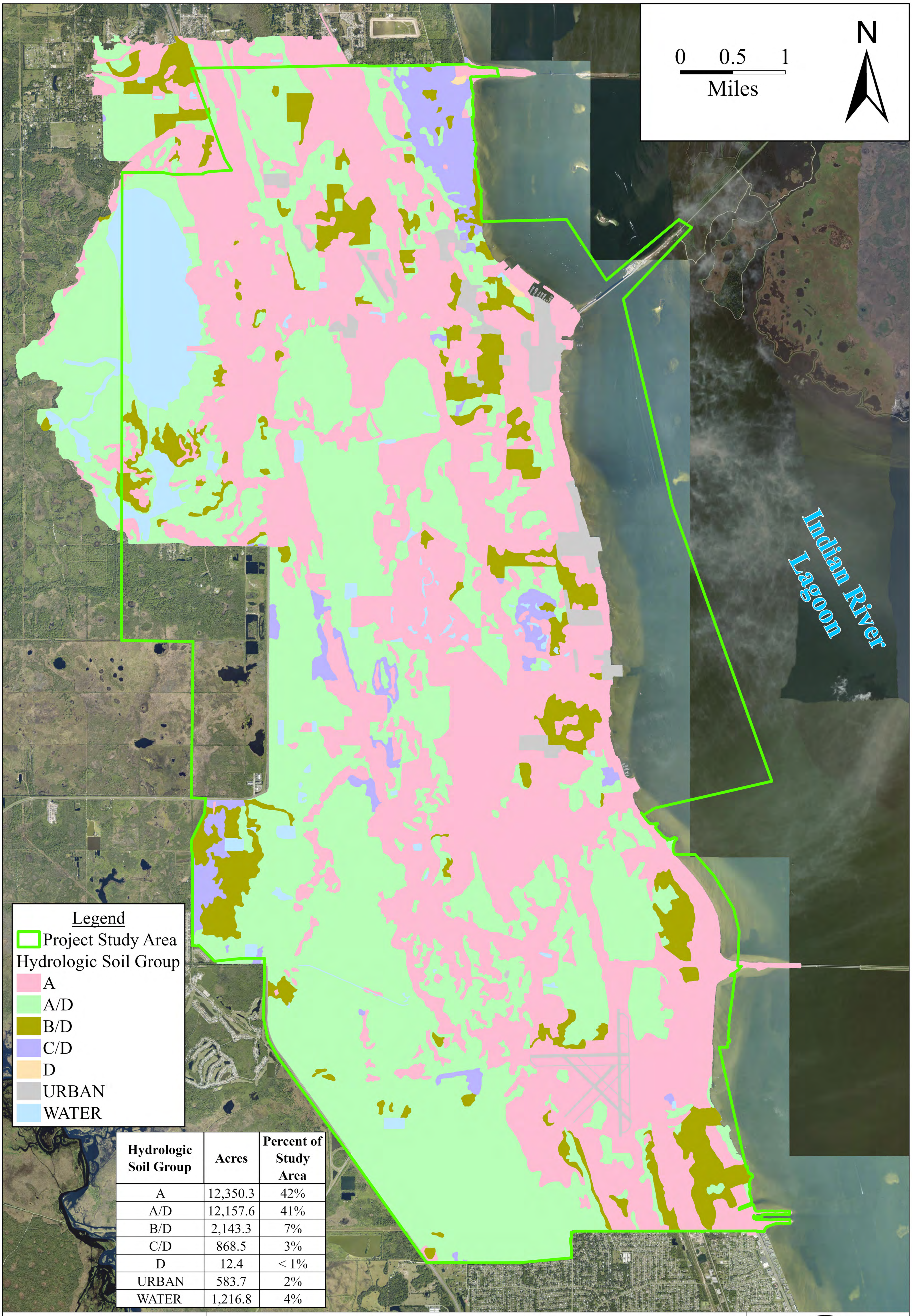
Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration. Based on infiltration rates, the NRCS has divided soils into four hydrologic soil groups (HSG):

1. Group A soils. Have a low runoff potential due to high infiltration rates. These soils consist primarily of deep, well- drained sands and gravels.
2. Group B soils. Have a moderately low runoff potential due to moderate infiltration rates. These soils consist primarily of moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse textures.
3. Group C soils. Have a moderately high runoff potential due to slow infiltration rates. These soils consist primarily of soils in which a layer exists near the surface that impedes the downward movement of water or soils with moderately fine to fine texture.
4. Group D soils. Have a high runoff potential due to very slow infiltration rates. These soils consist primarily of clays with high swelling potential, soils with permanently high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material.

Also found within the study area were areas in which the soils were assigned a dual classification of A/D. For purposes of developing runoff curve numbers, these areas were treated as having a HSG classification of "D". The distribution of hydrologic soil groups in the project area, for development of curve numbers, is shown in **Figure 3.8** along with a table showing the percent distribution of each. The dominant soil type throughout the project area is Type A, which has high infiltration rates, followed by type A/D, whose infiltration rates are reduced based on high water table.

Runoff CNs were developed from land cover and HSG data for the project area. Each land cover-HSG combination in pervious areas found within the study area was assigned a pervious CN value based on NRCS guidance taken from NRCS TR-55, which provides guidance on curve-number selection based on the land cover and hydrologic condition and the hydrologic soil group. Impervious and water areas were assigned a CN of 98. An average antecedent condition (AMC II) was employed for the baseline scenario. Also, each land cover classification was assigned percent impervious cover. For the purposes of land cover representation, direct impervious area coverages were leveraged from the NOAA C-CAP high resolution land cover dataset. The soil-land cover combinations are all assigned a CN based on look-up tables within Stormwise. The CN and percent impervious tables are shown in **Table 3.3** and **Table 3.4**. An area-weighted CN is then calculated for each sub-basin.

Rainfall amounts for the existing condition simulations utilized NOAA Atlas 14 Point Precipitation Frequency Estimates for specific storm event analyses. The rainfall amounts shown correspond to the centroid of the study area per NOAA Atlas 14. The existing condition simulations included the 100-year/24-hour and the 500-year/24-hour storm events. **Table 3.5** presents the rainfall depths used for each in the existing condition model. Rainfall distributions utilized include the Modified NRCS-Type II Distribution for 24-hour events.



Hydrologic Soil Group	Acres	Percent of Study Area
A	12,350.3	42%
A/D	12,157.6	41%
B/D	2,143.3	7%
C/D	868.5	3%
D	12.4	< 1%
URBAN	583.7	2%
WATER	1,216.8	4%

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Figure 3.8 - Soils

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TABLE 3.3: CURVE NUMBERS BY LAND COVER CLASSIFICATION AND HYDROLOGIC SOIL GROUP FOR EXISTING CONDITION MODEL

Land Cover	Soil Type	Curve Number
Impervious	A	98
Impervious	A/D	98
Impervious	B/D	98
Impervious	C/D	98
Impervious	D	98
Impervious	BEACH	98
Impervious	URBAN	98
Impervious	WATER	98
Pervious	A	49
Pervious	A/D	84
Pervious	B/D	84
Pervious	C/D	84
Pervious	D	84
Pervious	BEACH	39
Pervious	URBAN	49
Pervious	WATER	98
Water	A	98
Water	A/D	98
Water	B/D	98
Water	C/D	98
Water	D	98
Water	BEACH	98
Water	URBAN	98
Water	WATER	98

TABLE 3.4: IMPERVIOUS PARAMETERIZATION BY LAND COVER CLASSIFICATION

Land Cover	Percent Impervious	Percent DCIA
Pervious	0	0
Impervious	100	100
Water	100	100

TABLE 3.5: EXISTING AND FUTURE CONDITION RAINFALL DEPTHS

Storm Event	Existing (inches)	2050 (inches)	2080 (inches)
100 year/24 hour	13.2	16.37	17.69
500 year/24 hour	18.3	23.70	25.71

3.2.2 Future Condition Stormwise Model

For the future condition, the only changes to the Stormwise model parameterization were modifications to the curve numbers by land cover to approximately represent loss of soil storage under a future condition of assumed higher groundwater levels. The future condition curve numbers by land cover are provided in **Table 3.6**.

To simulate the impacts of rainfall-induced flooding for future model scenarios (2050 and 2080), the rainfall depths for the future conditions leveraged research on expected future precipitation patterns by the USGS, summarized in the following web publication:

> *Change factors to derive projected future precipitation depth-duration-frequency (DDF) curves at 242 National Oceanic and Atmospheric Administration (NOAA) Atlas 14 stations in Florida (ver. 2.0, May 2024) (https://www.sciencebase.gov/catalog/item/64663405d34ec11ae4a794c2)*

The spreadsheet data included with the USGS project deliverables comprise future change factors for a variety of design storms and durations for Atlas 14 stations across Florida. Values are included for both the 2040 and 2070 future planning horizons. To develop rainfall change factors for the 2050 and 2080 planning horizons, linear interpolation and extrapolation were used for each timeframe, respectively. Values from this source were representative of the 50% percentile change and considering all climate models were used.

The change factors were applied to the existing conditions model rainfall depths listed in **Section 3.2.1** to represent future condition modeling horizons. The resulting change factors developed for the future modeling scenarios are summarized in **Table 3.7**. These change factors are multiplied by the existing conditions rainfall depths to derive rainfall depths for the 2050 and 2080 future planning horizons (**Table 3.5**).

TABLE 3.6: CURVE NUMBERS CHANGES BY LAND COVER CLASSIFICATION AND HYDROLOGIC SOIL GROUP

Land Cover	Soil Type	Curve Number
Impervious	A	98
Impervious	A/D	98
Impervious	B/D	98
Impervious	C/D	98
Impervious	D	98
Impervious	BEACH	98
Impervious	URBAN	98
Impervious	WATER	98
Pervious	A	69
Pervious	A/D	93
Pervious	B/D	93
Pervious	C/D	93
Pervious	D	93
Pervious	BEACH	59
Pervious	URBAN	69
Pervious	WATER	98
Water	A	98
Water	A/D	98
Water	B/D	98
Water	C/D	98
Water	D	98
Water	BEACH	98
Water	URBAN	98
Water	WATER	98

TABLE 3.7: FUTURE RAINFALL CHANGE FACTORS

Storm Event	2050	2080
100 year/24 hour	1.24	1.34
500 year/24 hour	1.295	1.405

3.3 Flood Inundation Mapping

For each of the flooding types (tidal, storm surge, rainfall-induced), inundation extent and depth raster coverages were developed utilizing the methods outlined in **Section 3.1**. For rainfall-induced flooding, the models described in **Section 3.2** were run with two different storm events, the 100-year/24-hour and the 500-year/24-hour. For each type of flooding, and the two different rainfall events, a total of five flooding scenarios were developed. These include existing conditions, 2050 conditions under the intermediate-low and intermediate sea level rise, and 2080 conditions under the intermediate-low and intermediate sea level rise. Maps of the raster coverages are provided in four exhibit groups following this section as outlined below.

Exhibit Group 1 - Tidal Flooding Inundation Depths

- Exhibit 1.1 – Titusville Tidal Flooding (Existing)
- Exhibit 1.2 – Titusville Tidal Flooding (2050-Intermediate Low)
- Exhibit 1.3 – Titusville Tidal Flooding (2050-Intermediate High)
- Exhibit 1.4 – Titusville Tidal Flooding (2080-Intermediate Low)
- Exhibit 1.5 – Titusville Tidal Flooding (2080-Intermediate High)

Exhibit Group 2 - 100-Year Surge Flooding Inundation Depths

- Exhibit 2.1 – Titusville 100-Year Surge Flooding (Existing)
- Exhibit 2.2 – Titusville 100-Year Surge Flooding (2050-Intermediate Low)
- Exhibit 2.3 – Titusville 100-Year Surge Flooding (2050-Intermediate High)
- Exhibit 2.4 – Titusville 100-Year Surge Flooding (2080-Intermediate Low)
- Exhibit 2.5 – Titusville 100-Year Surge Flooding (2080-Intermediate High)

Exhibit Group 3 - 100-Year 24-Hour Rainfall Flooding Inundation Depths

- Exhibit 3.1 – Titusville 100-Year 24-hour Rainfall Flooding (Existing)
- Exhibit 3.2 – Titusville 100-Year 24-hour Rainfall Flooding (2050-Intermediate Low)
- Exhibit 3.3 – Titusville 100-Year 24-hour Rainfall Flooding (2050-Intermediate High)
- Exhibit 3.4 – Titusville 100-Year 24-hour Rainfall Flooding (2080-Intermediate Low)
- Exhibit 3.5 – Titusville 100-Year 24-hour Rainfall Flooding (2080-Intermediate High)

Exhibit Group 4 - 500-Year 24-Hour Rainfall Flooding Inundation Depths

- Exhibit 4.1 – Titusville 500-Year 24-hour Rainfall Flooding (Existing)
- Exhibit 4.2 – Titusville 500-Year 24-hour Rainfall Flooding (2050-Intermediate Low)
- Exhibit 4.3 – Titusville 500-Year 24-hour Rainfall Flooding (2050-Intermediate High)
- Exhibit 4.4 – Titusville 500-Year 24-hour Rainfall Flooding (2080-Intermediate Low)
- Exhibit 4.5 – Titusville 500-Year 24-hour Rainfall Flooding (2080-Intermediate High)

The maps present the depth of flooding based on three depth intervals, 0 feet to 0.5 feet, 0.5 feet to 1.5 feet, and greater than 1.5 feet. The flooding extents and the flood depths will be overlain on the critical asset data presented in **Section 2: Background and Data Collection** for the Sensitivity Analysis to be submitted under separate cover.

3.4 Deliverables

Geosyntec provided the following:

- Flood depth maps for each of the simulated scenarios (baseline, 2050 and 2080).
- GIS files with results of the exposure analysis for each flood scenario as well as the appropriate metadata that identifies the methods used to create the flood layers. GIS files and associated metadata will adhere to FDEP's Resilient Florida Program's GIS data standards. Raw data sources shall be defined within the associated metadata.

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EXHIBITS

Exhibit Group 1:
Tidal Flooding Inundation Depths

Exhibit Group 2:
100-Year Surge Flooding Inundation Depths

Exhibit Group 3:
100-Year 24-Hour Rainfall Flooding Inundation Depths

Exhibit Group 4:
500-Year 24-Hour Rainfall Flooding Inundation Depths

Exhibit Group 1 - Tidal Flooding Inundation Depths

- Exhibit 1.1 – Titusville Tidal Flooding (Existing)
- Exhibit 1.2 – Titusville Tidal Flooding (2050-Intermediate Low)
- Exhibit 1.3 – Titusville Tidal Flooding (2050-Intermediate High)
- Exhibit 1.4 – Titusville Tidal Flooding (2080-Intermediate Low)
- Exhibit 1.5 – Titusville Tidal Flooding (2080-Intermediate High)

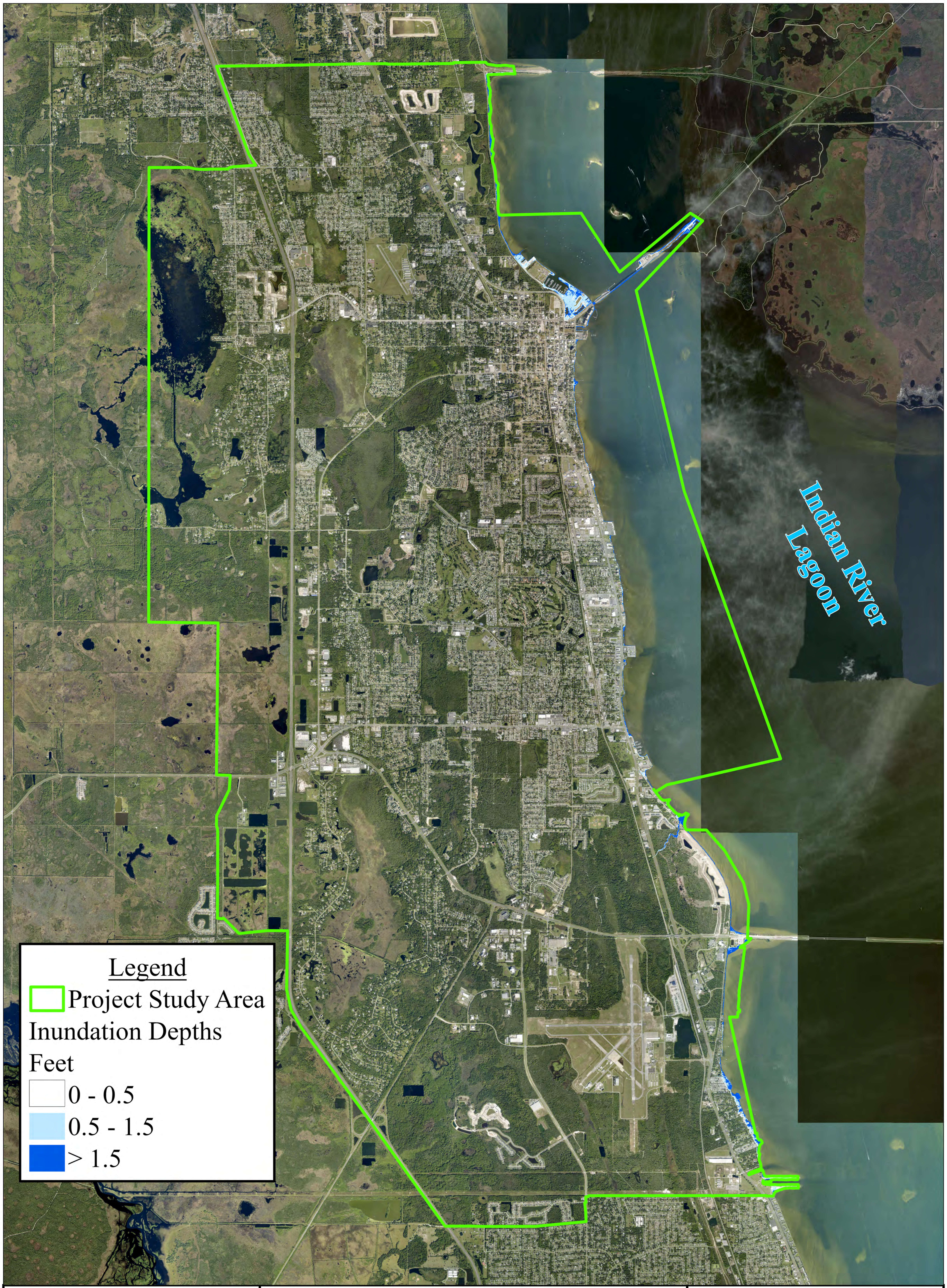

Exhibit 1.1

Tidal Flooding (2025 Existing)

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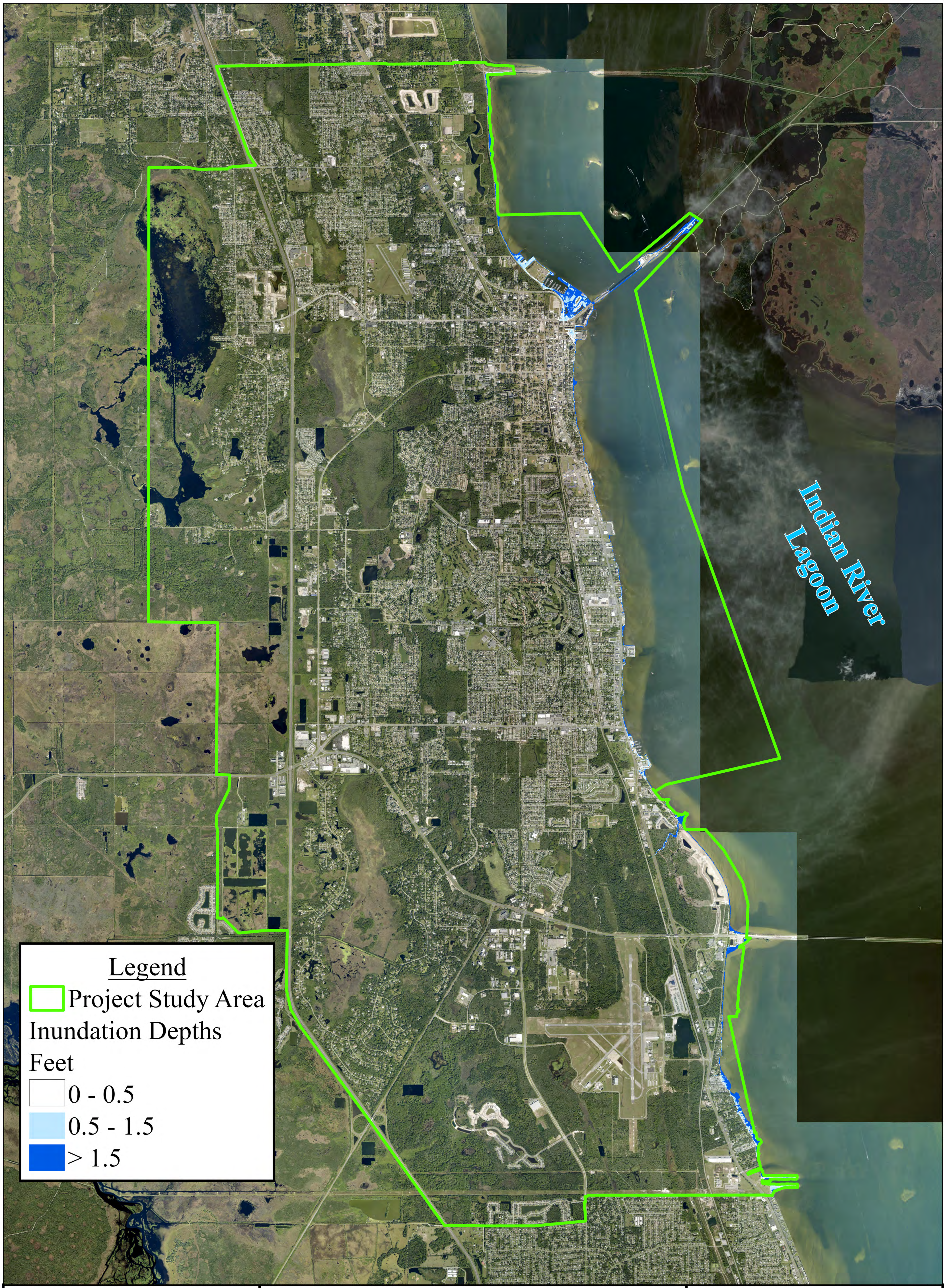

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Exhibit 1.2

Tidal Flooding (2050 Intermediate-Low)

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0 0.5 1
Miles
N

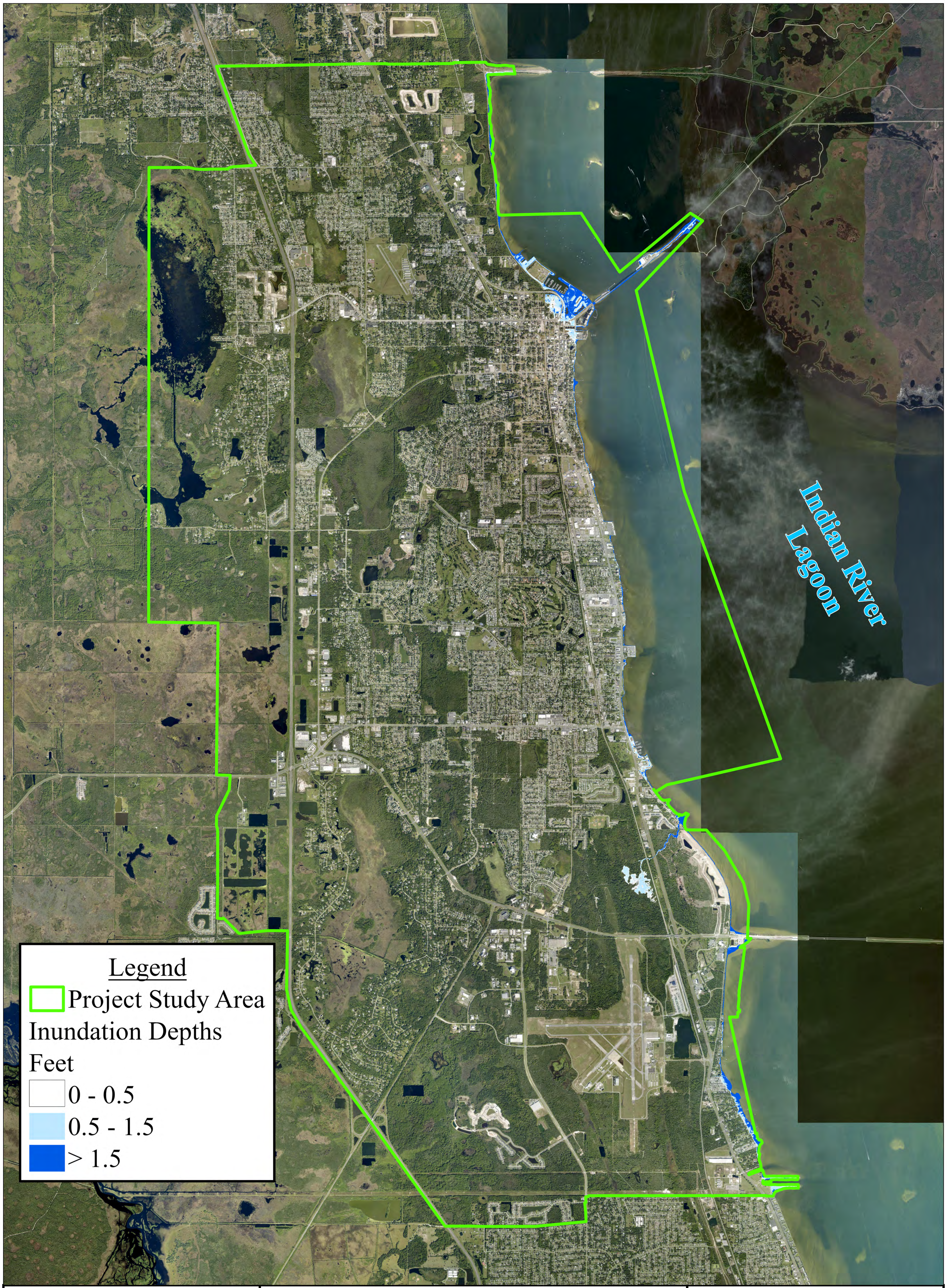

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Exhibit 1.3

Tidal Flooding (2050 Intermediate)

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0 0.5 1
Miles
N

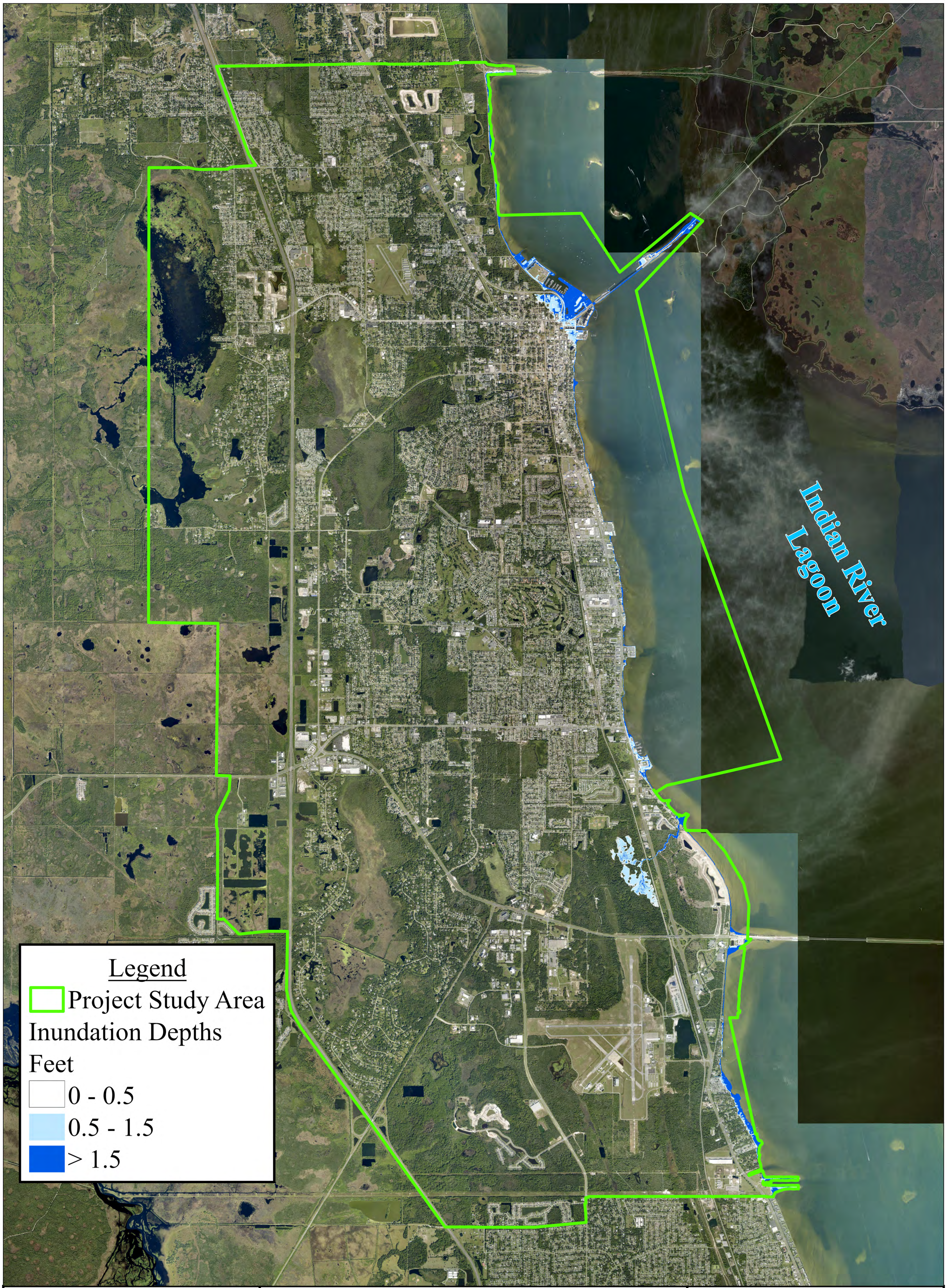

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Exhibit 1.4

Tidal Flooding (2080 Intermediate-Low)

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0 0.5 1
Miles
N

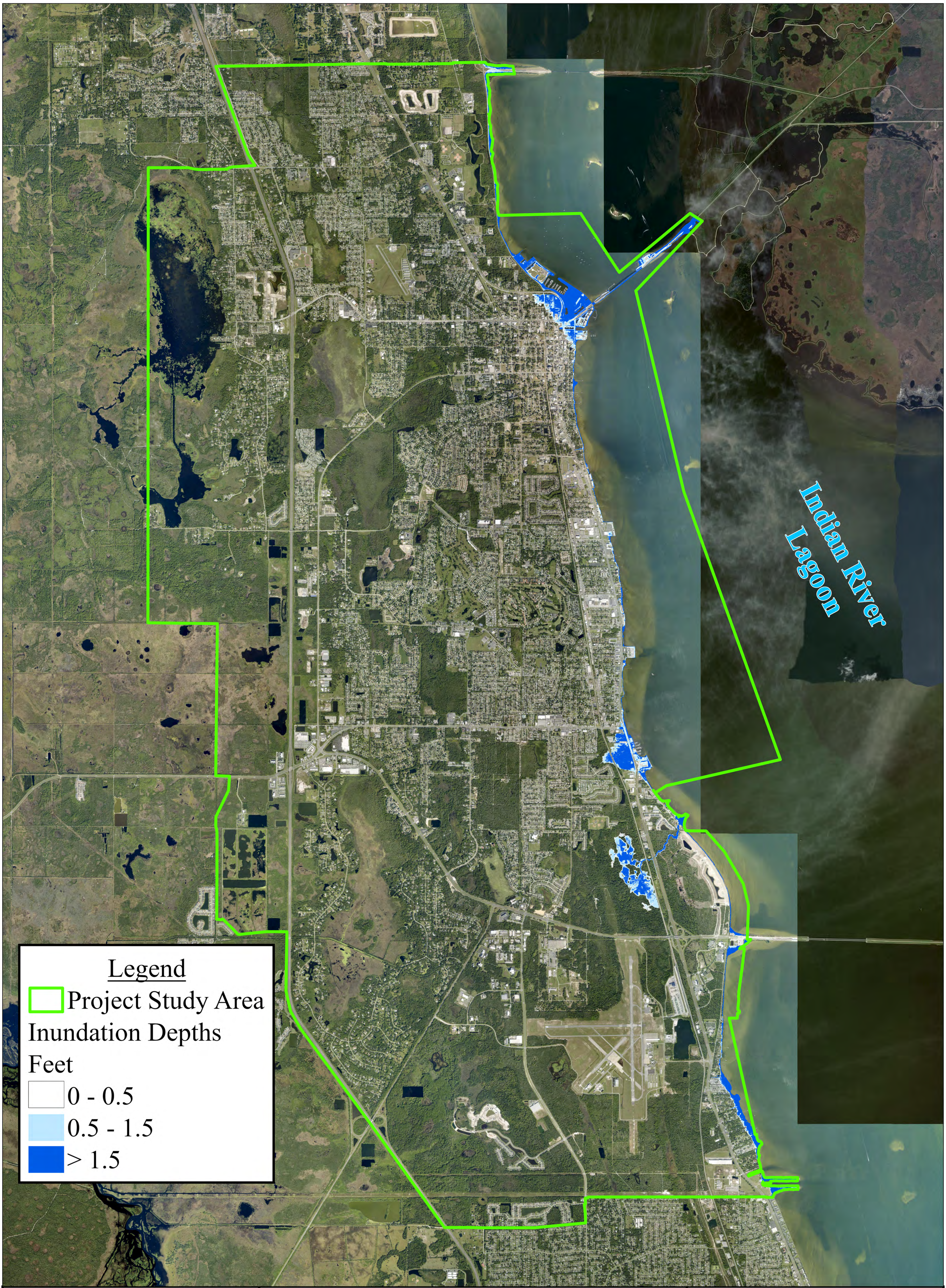

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Exhibit 1.5

Tidal Flooding (2080 Intermediate)

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0 0.5 1
Miles
N

Exhibit Group 2 - 100-Year Surge Flooding Inundation Depths

- Exhibit 2.1 – Titusville 100-Year Surge Flooding (Existing)
- Exhibit 2.2 – Titusville 100-Year Surge Flooding (2050-Intermediate Low)
- Exhibit 2.3 – Titusville 100-Year Surge Flooding (2050-Intermediate High)
- Exhibit 2.4 – Titusville 100-Year Surge Flooding (2080-Intermediate Low)
- Exhibit 2.5 – Titusville 100-Year Surge Flooding (2080-Intermediate High)

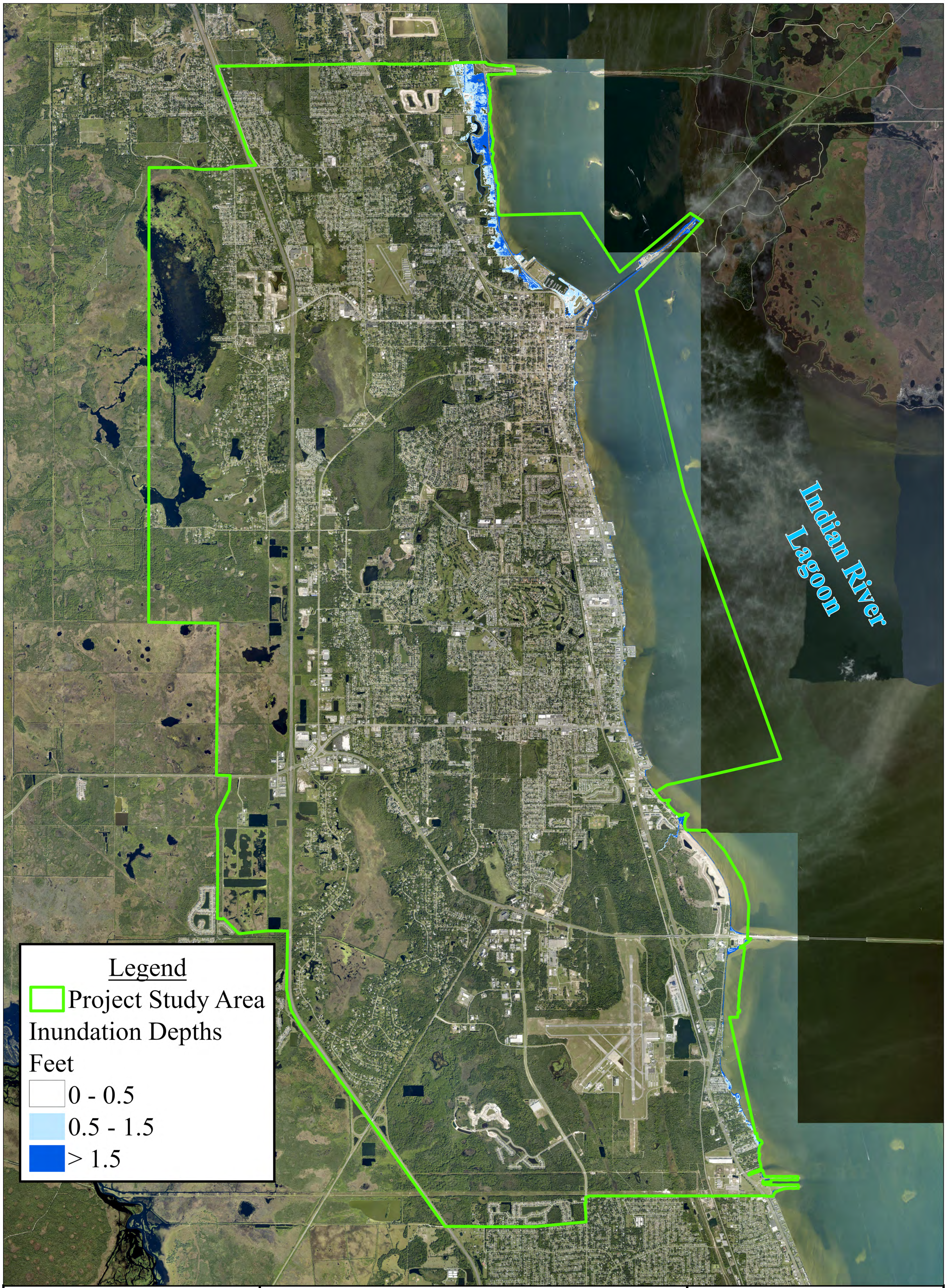

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Exhibit 2.1

100-Year Surge Flooding (2025 Existing)

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0 0.5 1
Miles
N

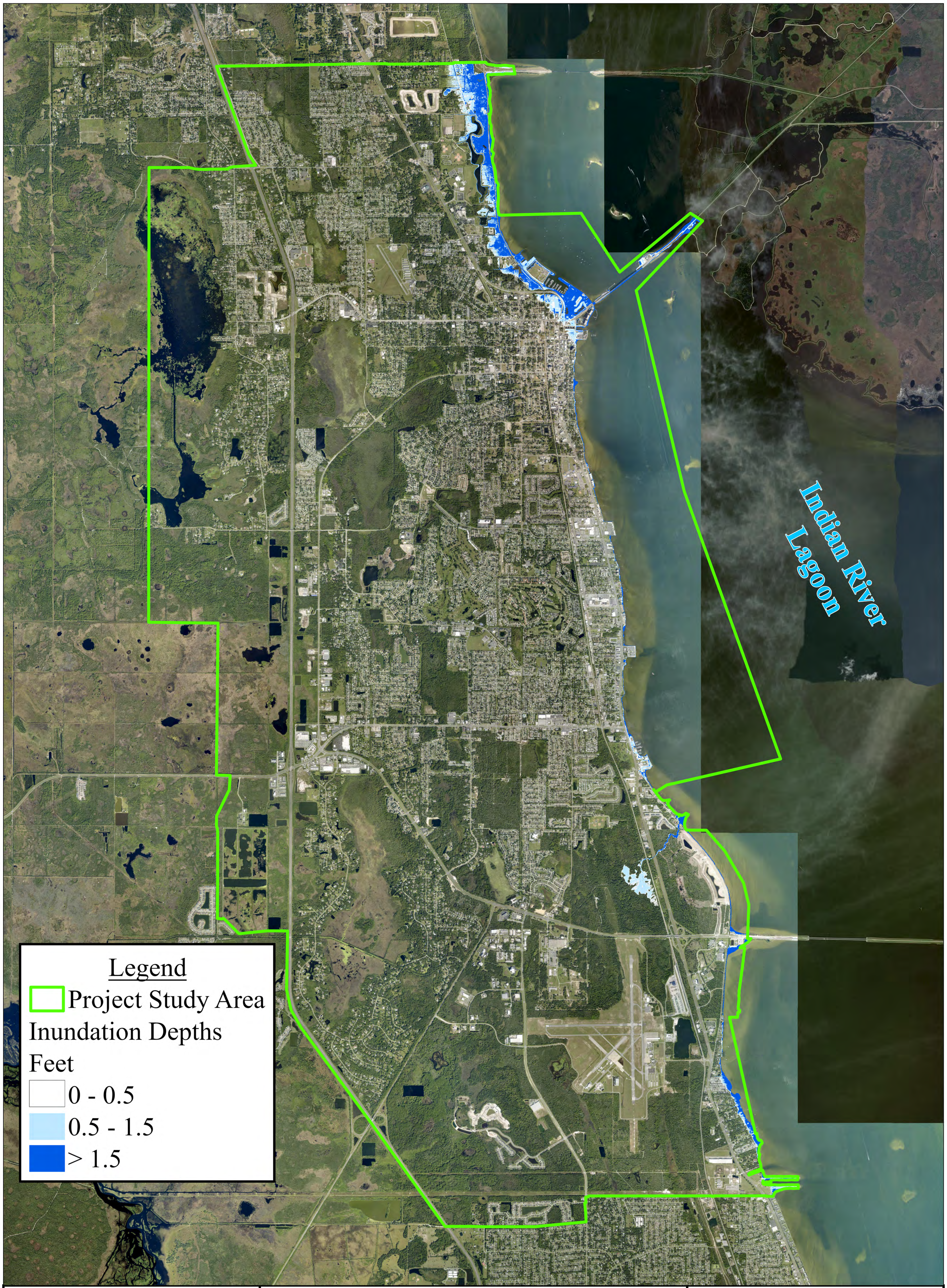

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Exhibit 2.2

100-Year Surge Flooding (2050 Intermediate-Low)

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0 0.5 1
Miles
N

Exhibit 2.3

100-Year Surge Flooding (2050 Intermediate)

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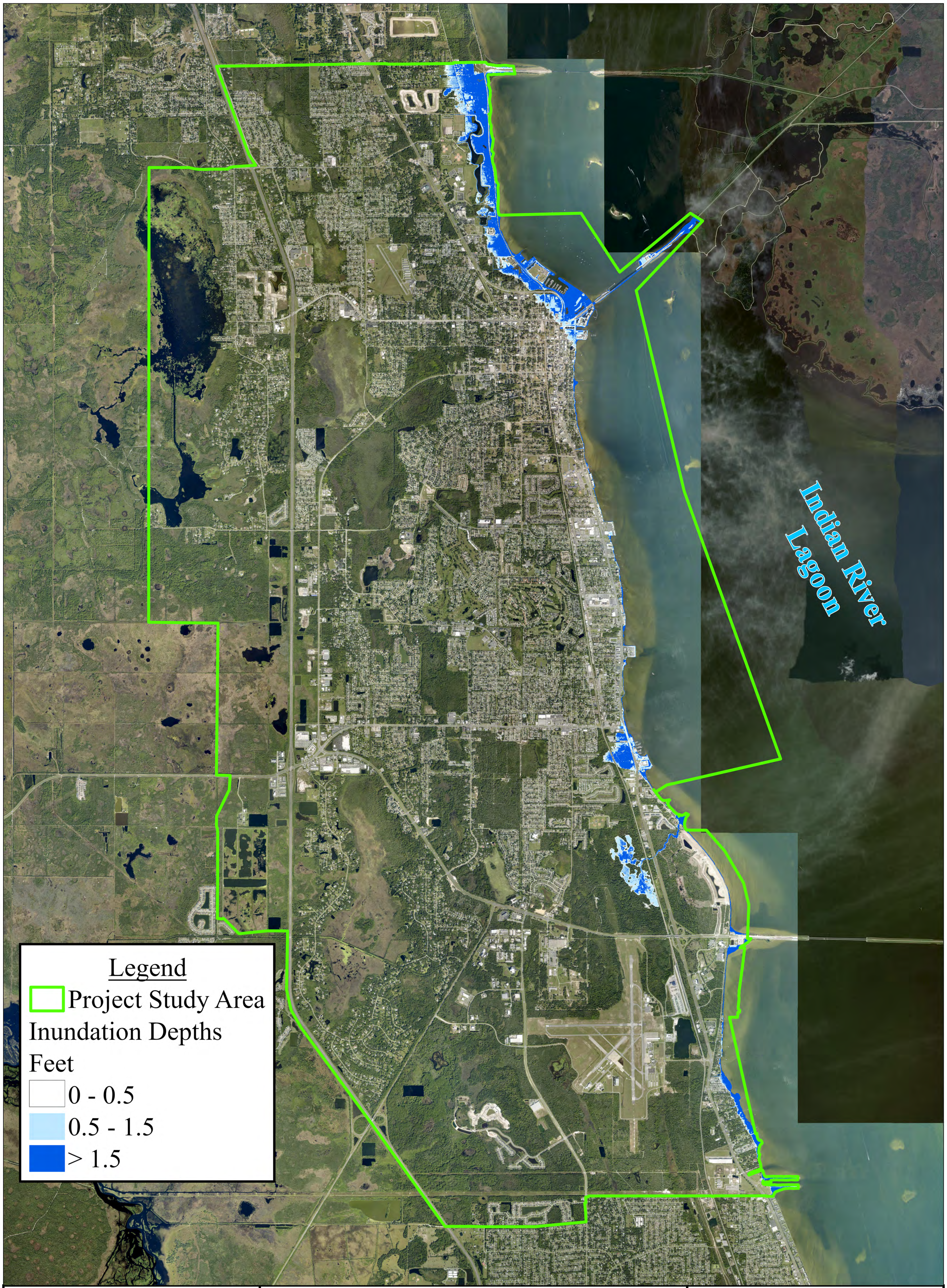

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Exhibit 2.4

100-Year Surge Flooding (2080 Intermediate-Low)

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0 0.5 1
Miles
N

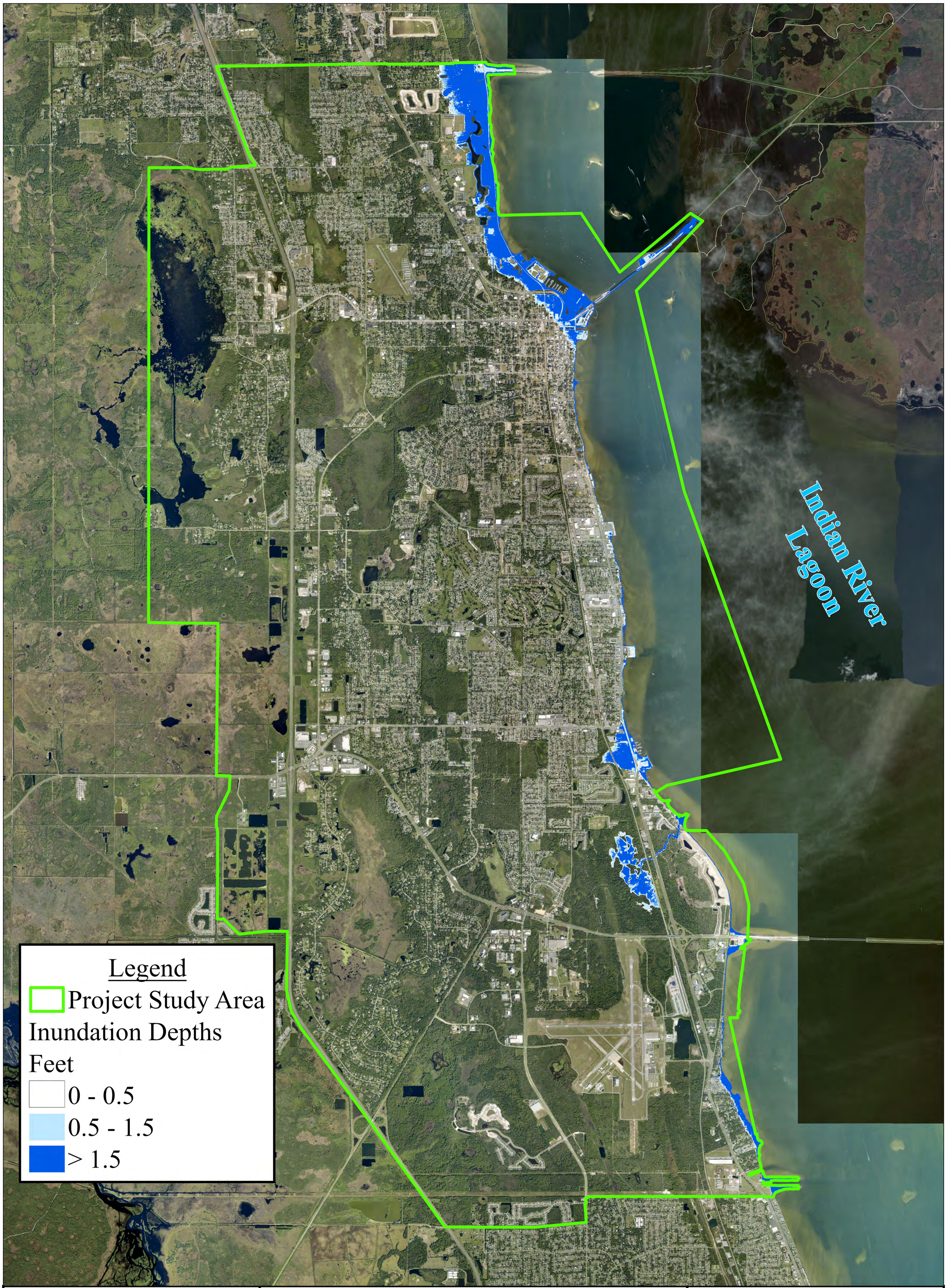

Exhibit 2.5

100-Year Surge Flooding (2080 Intermediate)

Vulnerability Assessment

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0 0.5 1
Miles
N

Exhibit Group 3 - 100-Year 24-Hour Rainfall Flooding Inundation Depths

- Exhibit 3.1 – Titusville 100-Year 24-hour Rainfall Flooding (Existing)
- Exhibit 3.2 – Titusville 100-Year 24-hour Rainfall Flooding (2050-Intermediate Low)
- Exhibit 3.3 – Titusville 100-Year 24-hour Rainfall Flooding (2050-Intermediate High)
- Exhibit 3.4 – Titusville 100-Year 24-hour Rainfall Flooding (2080-Intermediate Low)
- Exhibit 3.5 – Titusville 100-Year 24-hour Rainfall Flooding (2080-Intermediate High)

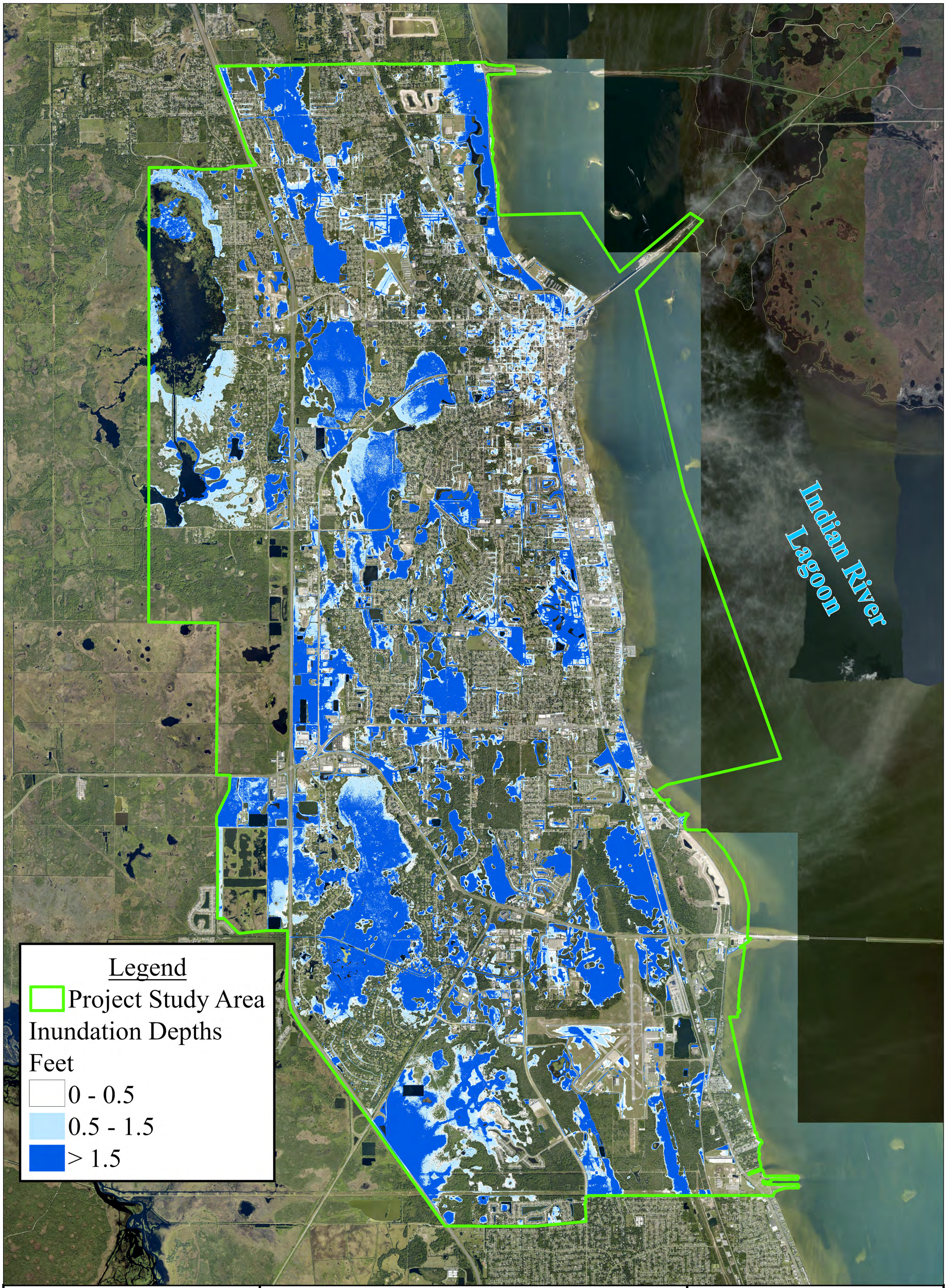


Exhibit 3.1

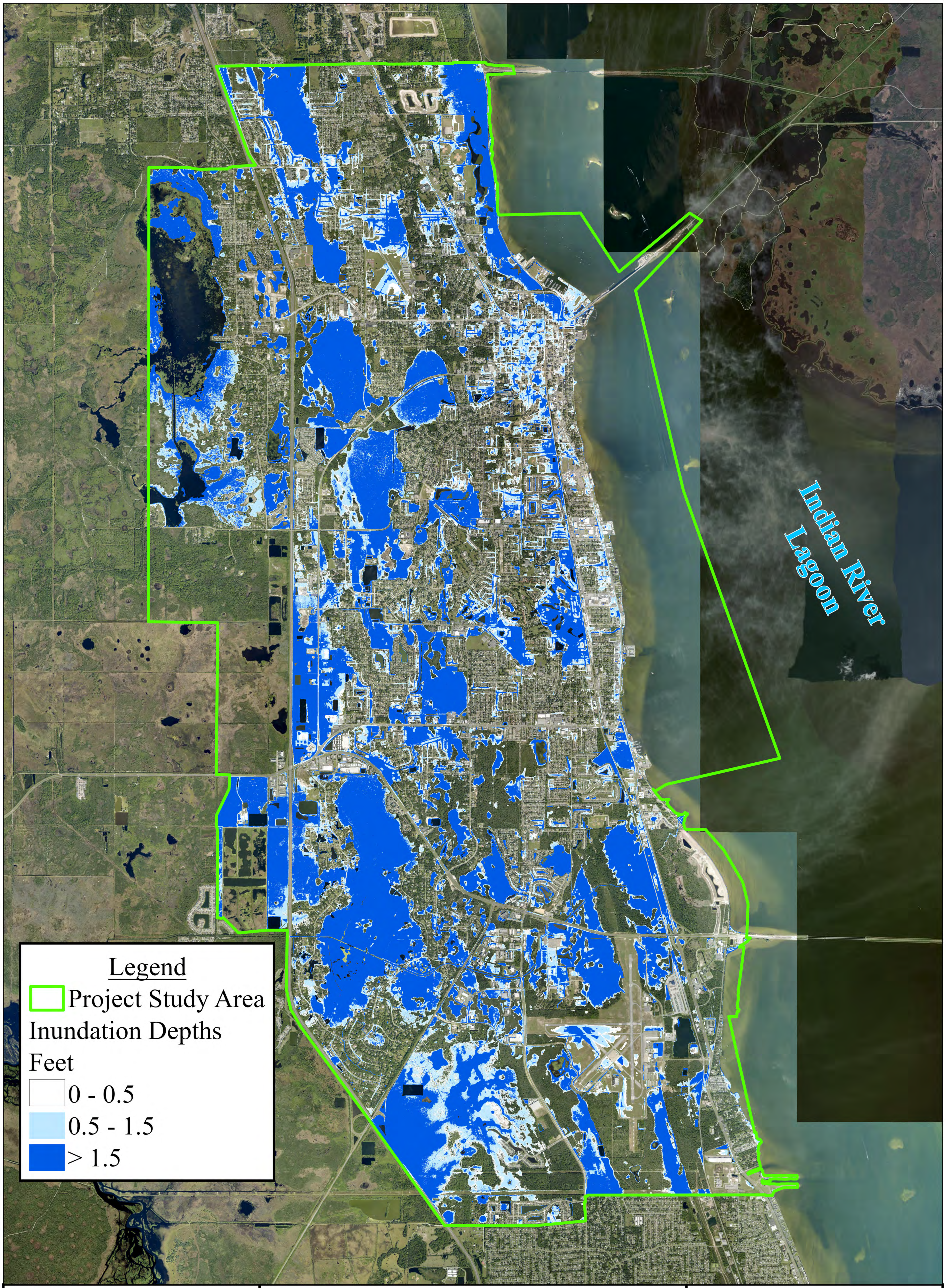
100-Year 24-hour Rainfall Flooding (2025 Existing)

Vulnerability Assessment

Titusville, Florida — Founded 1867

Geosyntec consultants

0 0.5 1
Miles
N



TITUSVILLE, FLORIDA
FOUNDED 1867

Exhibit 3.2

100-Year 24-hour Rainfall Flooding (2050 Intermediate-Low)

Vulnerability Assessment

Geosyntec consultants

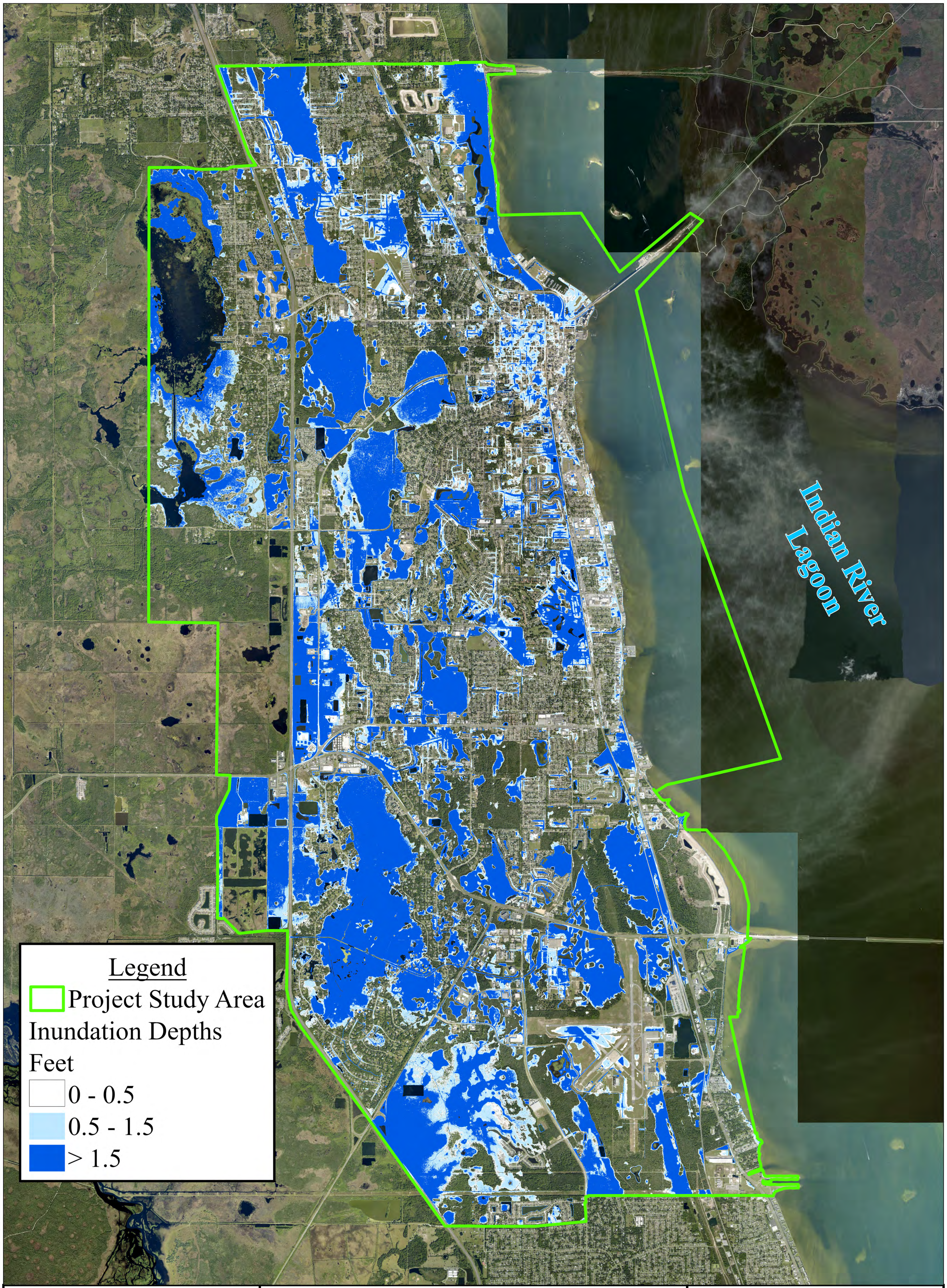


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Exhibit 3.3

100-Year 24-hour Rainfall Flooding (2050 Intermediate)

Vulnerability Assessment

Geosyntec consultants

0 0.5 1
Miles
N

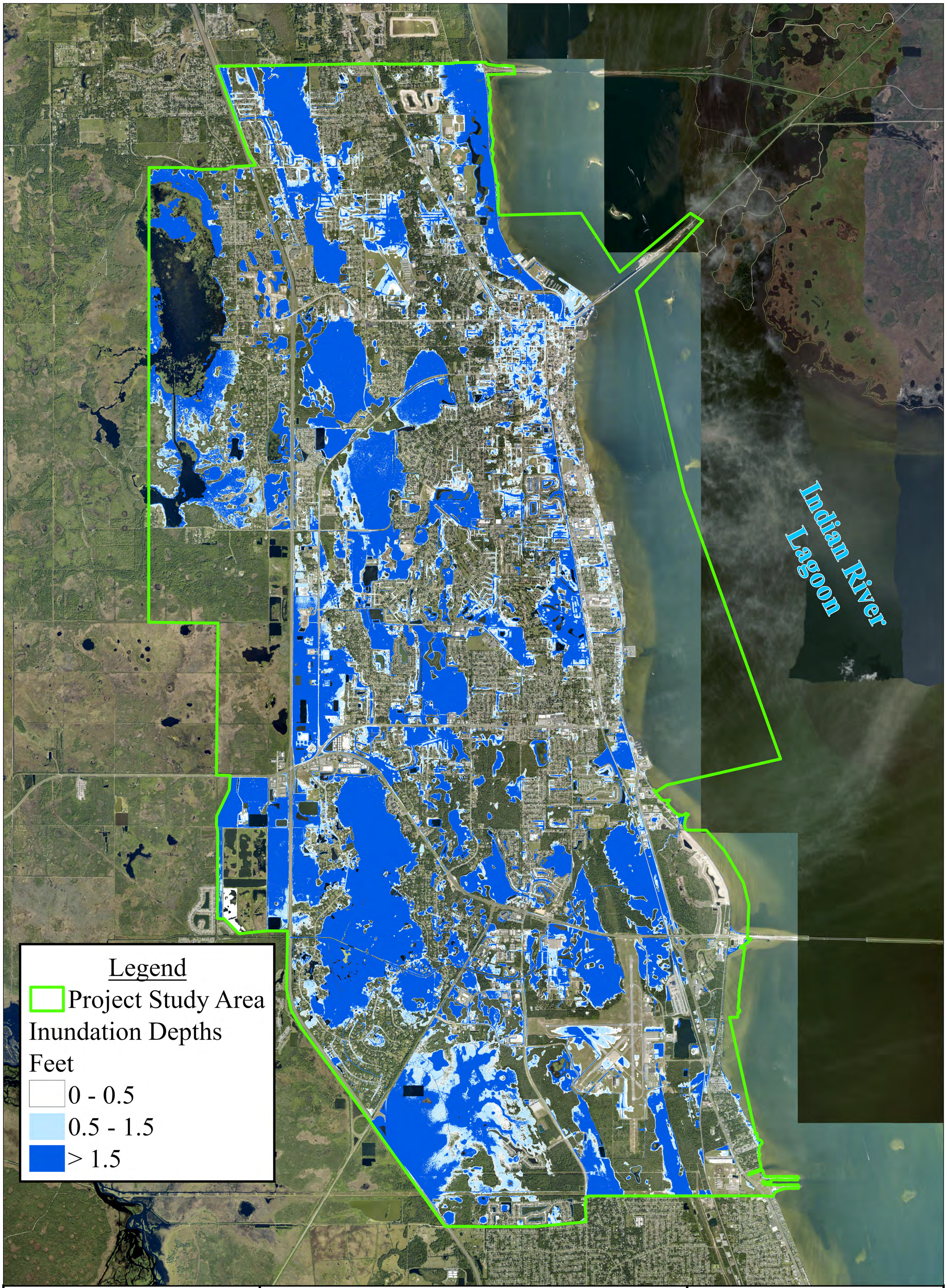
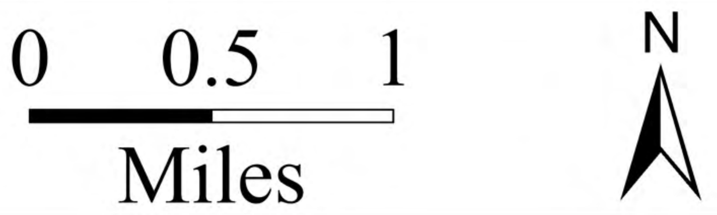


Exhibit 3.4

100-Year 24-hour Rainfall Flooding (2080 Intermediate-Low)

Vulnerability Assessment

Geosyntec consultants



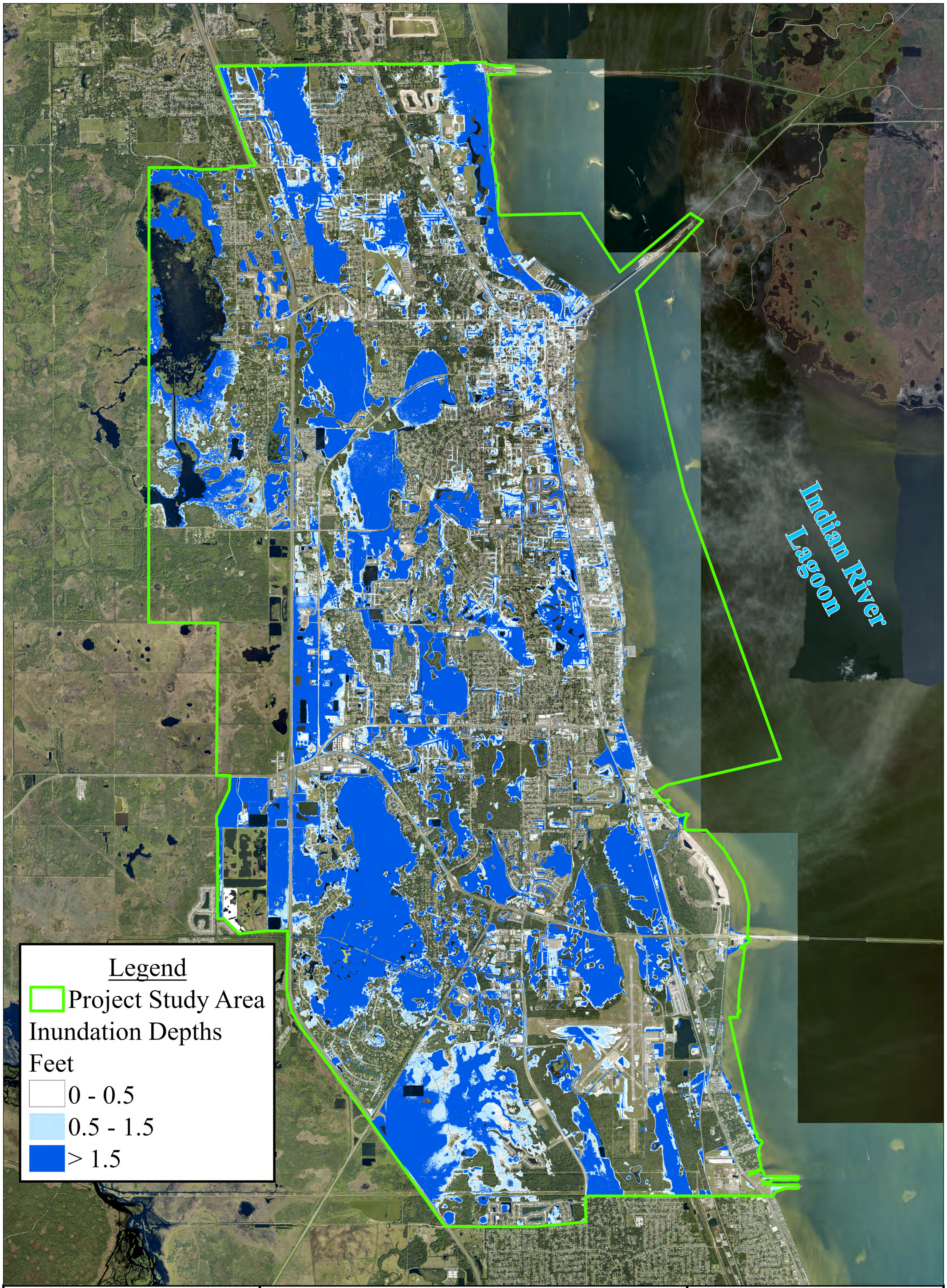


Exhibit 3.5

100-Year 24-hour Rainfall Flooding (2080 Intermediate)

Vulnerability Assessment

Geosyntec consultants

Exhibit Group 4 - 500-Year 24-Hour Rainfall Flooding Inundation Depths

- Exhibit 4.1 – Titusville 500-Year 24-hour Rainfall Flooding (Existing)
- Exhibit 4.2 – Titusville 500-Year 24-hour Rainfall Flooding (2050-Intermediate Low)
- Exhibit 4.3 – Titusville 500-Year 24-hour Rainfall Flooding (2050-Intermediate High)
- Exhibit 4.4 – Titusville 500-Year 24-hour Rainfall Flooding (2080-Intermediate Low)
- Exhibit 4.5 – Titusville 500-Year 24-hour Rainfall Flooding (2080-Intermediate High)

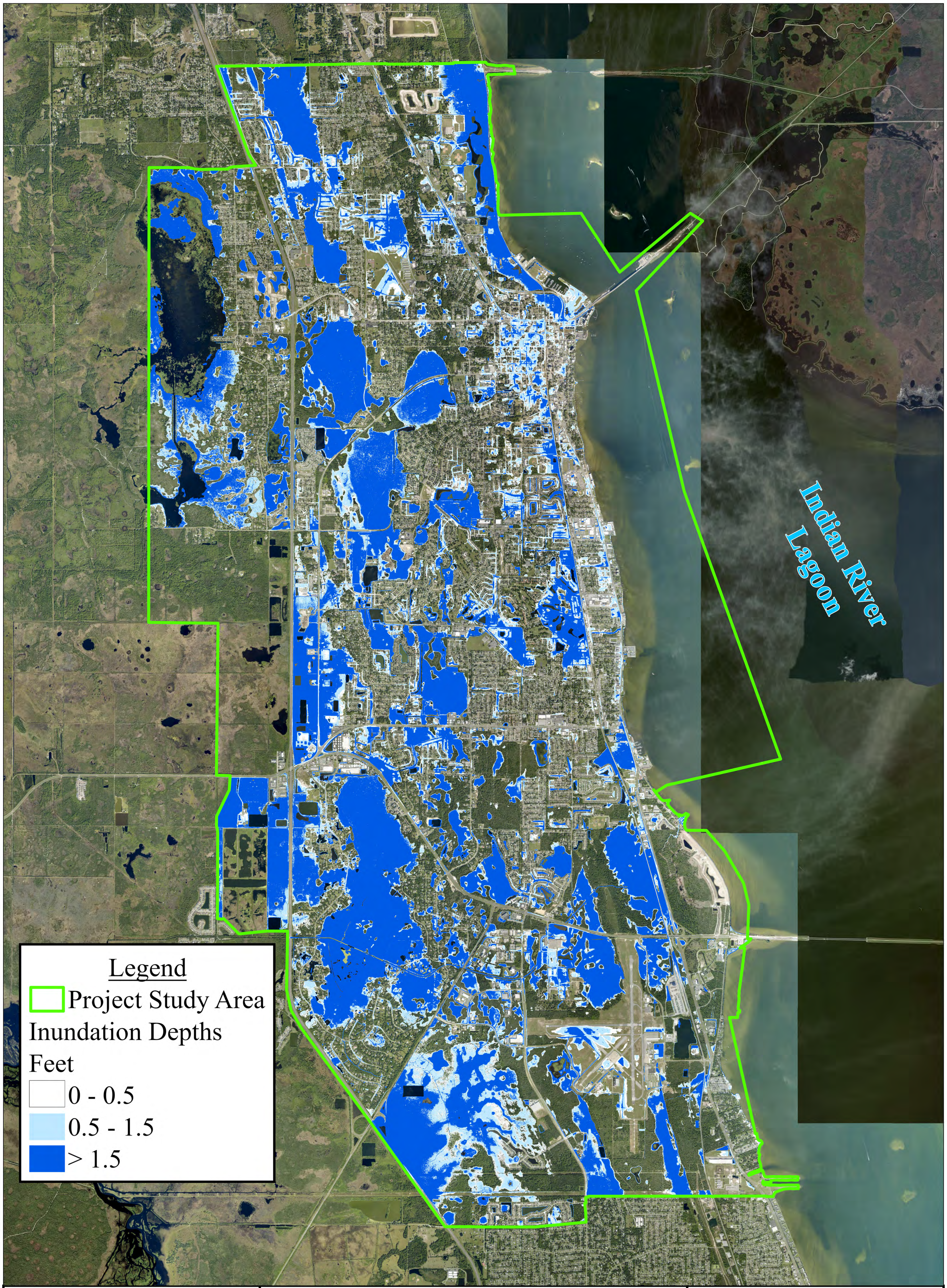


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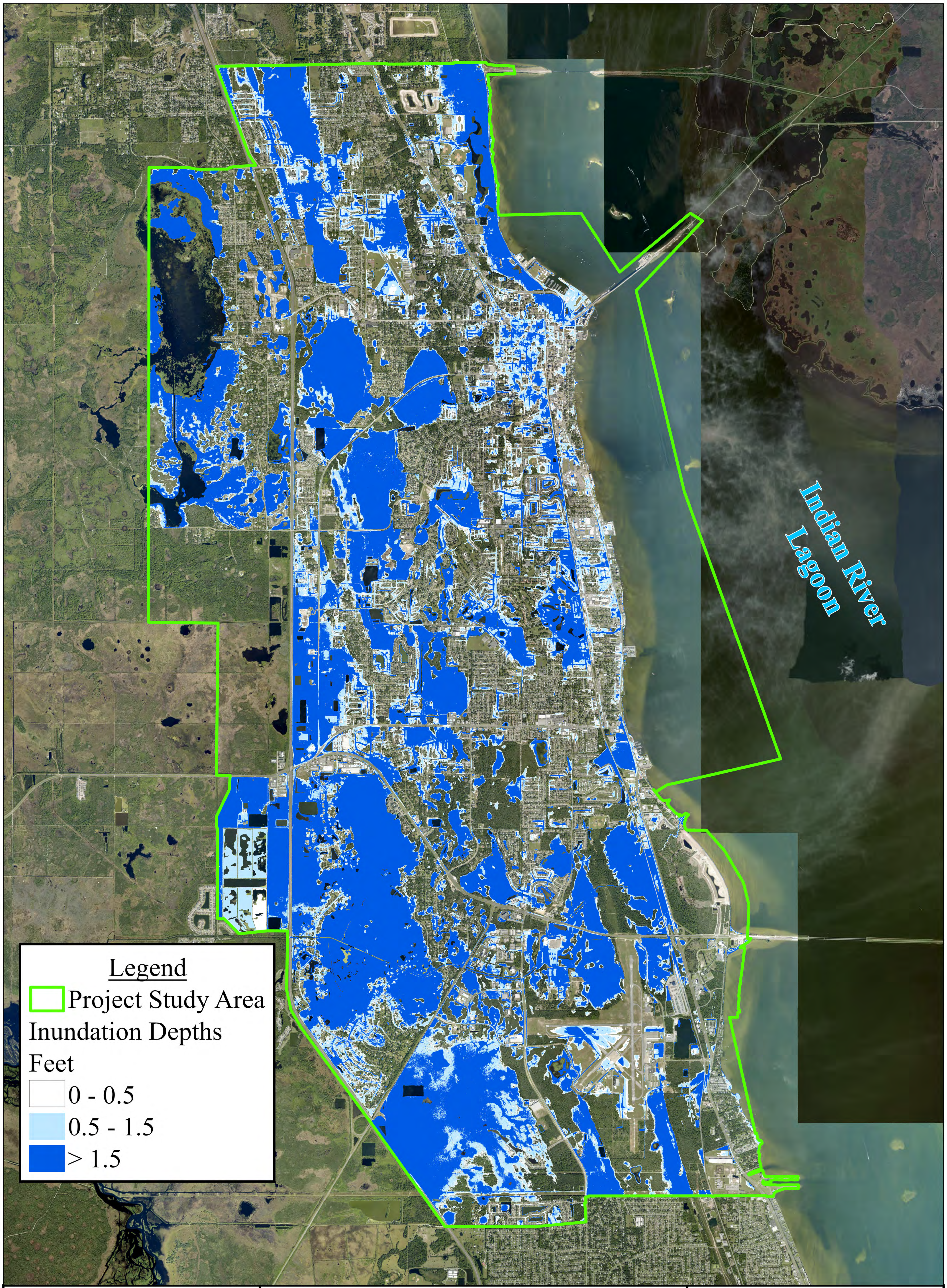
Exhibit 4.1

500-Year 24-hour Rainfall Flooding (2025 Existing)

Vulnerability Assessment

Geosyntec consultants

0 0.5 1
Miles
N



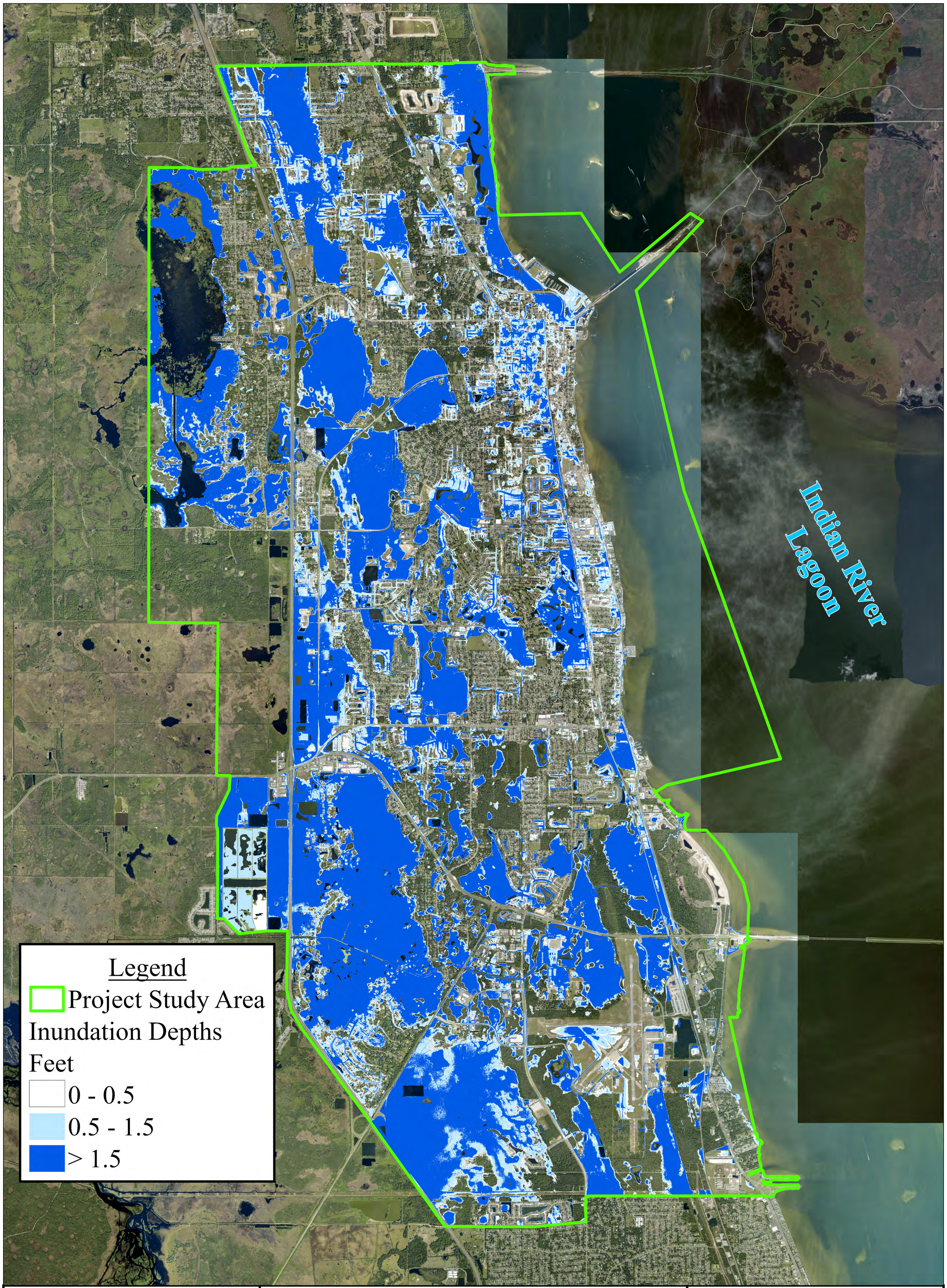
TITUSVILLE, FLORIDA FOUNDED 1867

Exhibit 4.2

500-Year 24-hour Rainfall Flooding (2050 Intermediate-Low)

Vulnerability Assessment

Geosyntec consultants



TITUSVILLE, FLORIDA
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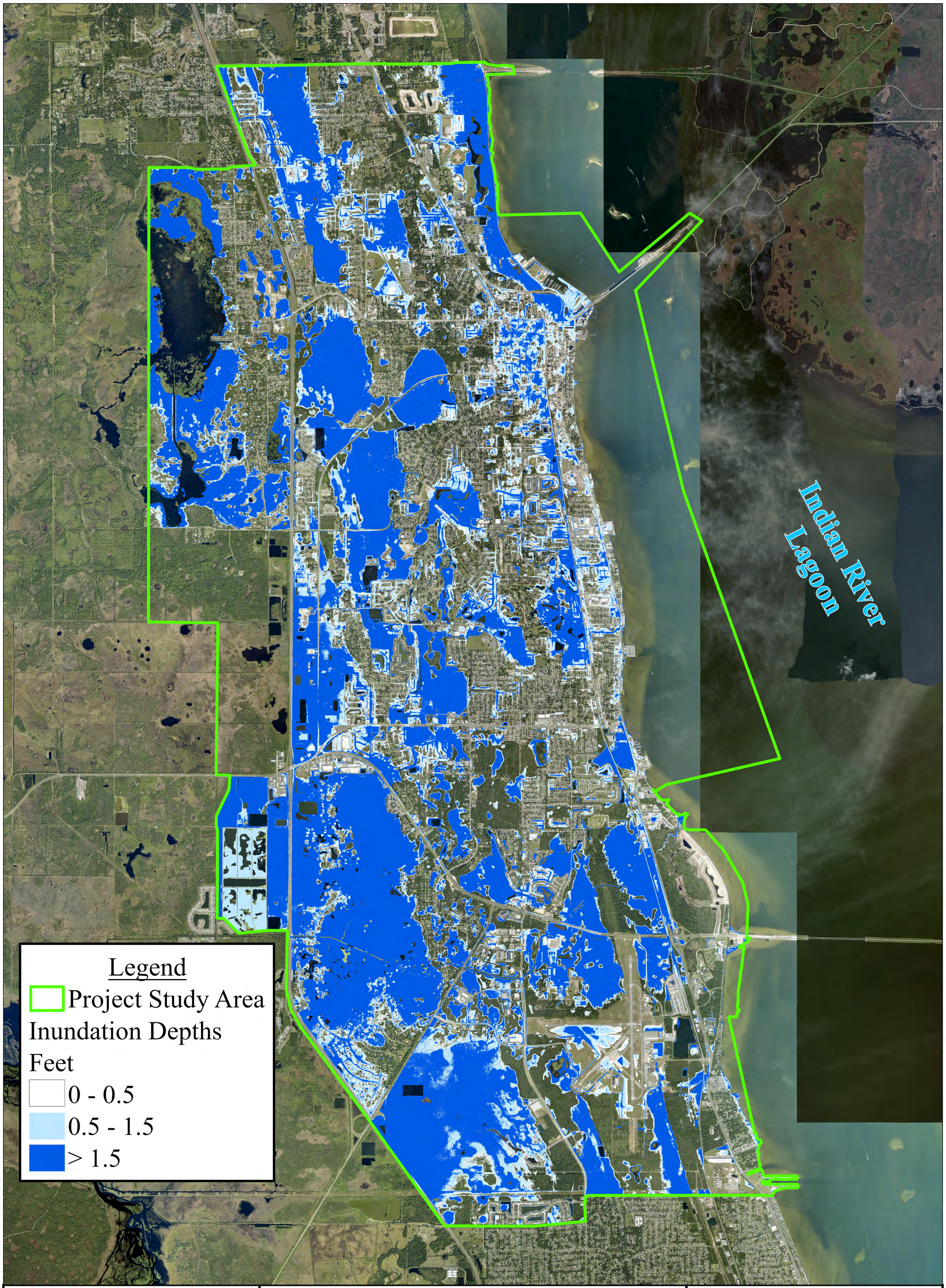
Exhibit 4.3

500-Year 24-hour Rainfall Flooding (2050 Intermediate)

Vulnerability Assessment

Geosyntec consultants

0 0.5 1
Miles
N



TITUSVILLE, FLORIDA
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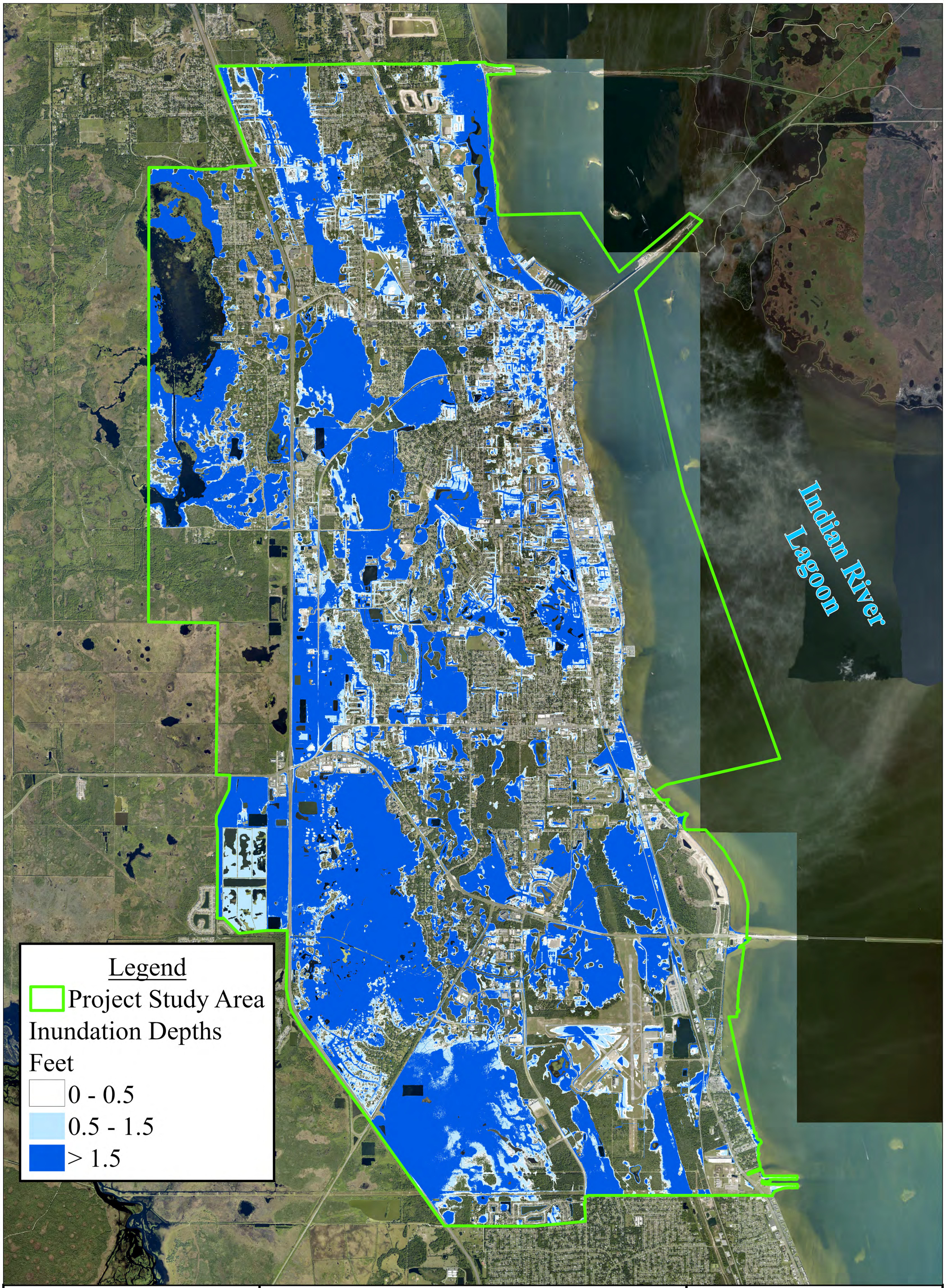
Exhibit 4.4

500-Year 24-hour Rainfall Flooding (2080 Intermediate-Low)

Vulnerability Assessment

Geosyntec consultants

0 0.5 1
Miles
N



TITUSVILLE, FLORIDA
FOUNDED 1867

Exhibit 4.5

500-Year 24-hour Rainfall Flooding (2080 Intermediate)

Vulnerability Assessment

Geosyntec consultants

0 0.5 1
Miles
N

APPENDIX A
Titusville VA Water Level Approach

Geosyntec consultants

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Titusville, FL 32780
PH 321.269.5880
www.geosyntec.com

24 June 2025

Saed Johnson, Environmental Specialist II
Resilient Florida Program
Florida Department of Environmental Protection
3900 Commonwealth Blvd
Tallahassee, FL 32399-3000

Subject: Cocoa Beach Vulnerability Assessment – Request for Use of Alternate Tide Gages and Technical Approach for Mean Water Level, Tidal Flooding, and Rainfall Induced Tailwater for Areas Adjacent to the Banana River Lagoon

Dear Mr. Johnson:

This letter is a follow up to our Teams meeting on Wednesday, June 4, 2025, where Geosyntec presented our technical approach for dealing with water levels in the Banana River Lagoon (BRL) for use in the Cocoa Beach Vulnerability Assessment Exposure Analyses. Attendees at the meeting other than yourself included Max Farfan (FDEP), Steven Peene (Geosyntec), Mark Ellard (Geosyntec), and Nico Pisarello (Geosyntec). The purpose of the meeting was to present to FDEP some unique aspects of water level conditions in the BRL and how Geosyntec proposes to address those and provide the analyses for specific components of the Vulnerability Assessment. The specific components of the water level that were presented and discussed in the meeting included:

- The appropriate mean sea level (MSL) within the BRL in relation to offshore conditions,
- How to address Tidal Flooding, with specific focus on determination of an equivalent mean higher high water (MHHW) and MHHW plus 2 feet per F.S. 380.093, and
- A technically defensible water level within the BRL to use as the tailwater condition for the rainfall-induced flooding of areas within Cocoa Beach that drain to the BRL.

This letter, and the request to consider alternate water level gages, measurements and analyses, is focused on those areas of the City of Cocoa Beach (City) that either have the potential for flooding from, or drain to, the BRL. Those areas that have the potential for flooding from, or that drain to, the offshore areas would be handled in the standard manner using the Trident National Oceanic and Atmospheric Administration (NOAA) gage, which is discussed below.

In the Wednesday, June 4, 2025, meeting, PowerPoint slides were presented to support the analyses for each of the three components listed above. The PowerPoint slides are provided as an attachment to this letter. The following summarizes what was presented in the slides and how it supports determinations for each of the three components listed above.

Mean Sea Level (MSL) Within the BRL Versus Offshore

Slides 3 through 9 present data, plots, and analyses to show the unique nature of the water levels within the BRL along with determination of the appropriate MSL to use within the BRL. Slide 4 presents a map showing the water level stations that are utilized in the analyses. There are four locations with measured water levels from 2011 through 2025 (a 14-year period). All data are presented in feet relative to North American Vertical Datum of 1988 (NAVD88). The Trident Pier NOAA station is located on the Atlantic coast just north of Cocoa Beach and provides continuous water level measurements (every 6 minutes) representative of offshore conditions. The BRL station is located at the Cocoa Beach public dock within the BRL. The BRL data are manually read water levels taken generally once per day by City staff, usually in the morning. The two other stations presented are Haulover Canal located at the northern end of the Indian River Lagoon (IRL) and Wabasso located just south of Sebastian Inlet which is the nearest inlet to the BRL. These stations collect continuous (15 minute) data and are maintained by the United States Geologic Survey (USGS). A plot of the data from the four stations is presented for the full period of record. The plot provides the first look at the "unique" aspects of the water levels in the BRL and IRL versus offshore. The plot shows the significant degree of damping of the daily tidal fluctuations at the interior stations.

Slides 5 through 7 present plots of the data for 1-month intervals. These plots show the nature of each station. Wabasso, the nearest station to Sebastian Inlet, shows significant damping of the tidal fluctuations but still shows some tidal signal. Haulover, on the other hand, shows basically no tidal signal. Another point to note is that the BRL station follows the conditions measured at Haulover. This is important because Haulover has continuous data that provides a more complete dataset for analyses.

Slide 8 provides a correlation analysis between the Haulover and BRL measurements. For the plot, the BRL data were matched with Haulover data taken at the same time. The correlation plot shows very good agreement between the two stations, providing further indication that Haulover provides a reasonable dataset for use in the BRL. **Based on this, it is requested that the USGS Haulover station, and for some aspects of the analyses the BRL station, be allowed as substitute gages**

for the Cocoa Beach Vulnerability Assessment for those areas which either drain to or are impacted by flooding from the BRL. For all areas of the City that are flooded by, or drain to, the Atlantic side, the Trident gage will be utilized.

Slide 9 presents the original plot provided in Slide 4 along with calculated mean water levels (MWLs) for each of the stations for the period of record from 2011 to 2025. These are the ones labeled "Geo." Additionally, the NOAA-calculated MWL over the full epoch of 30 years is presented. **Comparison of the MWL for the recent period shows that the interior stations (Haulover and BRL) have MWLs that are around 0.25 foot higher than the offshore**. This type of "super-elevation" condition is common for interior lagoon areas with restricted inlets.

<u>MHHW Calculation and Use for Tidal Flooding</u>

Slides 10 through 13 present data, plots and analyses to develop an equivalent MHHW condition within the BRL for use in the tidal flooding component of the vulnerability assessment. It is noted that, based on the lack of a tidal signal in the BRL, the high-water conditions represented from this calculation reflect wind driven events rather than typical king tide flooding.

Initially, a standard MHHW calculation was applied to the Haulover Canal data (based on equivalency with the BRL data and the need for a continuous dataset to use). Slide 11 presents this calculation along with plots of the data and results. The calculated MHHW from the data did not reflect an equivalent MHHW condition. Based on this, an alternate approach was utilized, which calculated the percentile that the MHHW condition represents for the dataset at Trident. Slide 12 presents the calculations and plots. The determined percentile for the Trident data was 93.5 percent. Applying this to the Haulover data gave an equivalent MHHW at Haulover of 0.39 ft-NAVD88. This value is plotted on Slide 12 and represents a reasonable equivalent MHHW. Per F.S. 380.093, tidal flooding is to be the MHHW plus 2 feet. Again, using the MHHW plus 2 feet at Trident gives a percentile of 99.98. Applying this to the equivalent MHHW for Haulover gives a value of 1.94 ft-NAVD88. This value is plotted on Slide 13 and represents a reasonable level for assessing tidal flooding conditions in the BRL with a similar level of exceedance as was seen for the tidal flooding level that would be used for the Trident station. **Therefore, a value of 1.94 ft-NAVD will be utilized for assessing tidal flooding in the BRL**.

<u>Determination of the Appropriate Tailwater Condition for the Areas Draining to the BRL</u>

The final water level calculation to support the vulnerability assessment is the tailwater in the BRL for the rainfall-induced flooding assessment. Slides 14 through 20 present data, plots and analyses to support the determination of the tailwater. For this analysis, rainfall data were gathered for the period of the Haulover and BRL water level data. The rainfall data came from a station on Merritt Island. Daily precipitation totals, along with the water level, are plotted on Slide 15. The tailwater needs to reflect the high-water levels that could occur in the BRL at the time of the peak rainfall and maximum localized flooding. To assess the occurrence of high-water conditions in the BRL that coincide with large daily rainfalls, various events were evaluated. Figures 16 through 20 present those events. The events are associated with passing hurricanes. Slide 16 presents a plot of water levels and daily rainfall around Hurricane Ian. Slides 17 and 18 present zoomed-in views of specific high-water periods around Hurricane Ian. Slide 19 presents a plot around the time of Hurricane Milton. Slide 20 presents a more zoomed-in view. The plots show a similar pattern for each storm. First, as the storms pass, wind-driven set down and set up occur. This can be seen in the Haulover continuous data. After the storm passes, there is filling up of the northern IRL and BRL due to runoff coming in. Over time, the BRL drains out, generally over a period of 4 to 6 days. It is noted that the limited BRL data matches what is seen in the Haulover data. Looking at the rainfall data, the daily peaks generally coincide with the wind-driven set up period. In slides 17, 18, and 20. the period of the peak daily rainfalls are shown as the green bars, which supports this assertion. The water levels during the time of the highest daily rainfall range between 1.5 and 2.3 ft-NAVD88. **Based on these observations, the determination was made that the MHHW plus 2-foot condition (1.94 ft-NAVD88) represents a reasonable tailwater condition for the rainfall-induced flooding**. Based on the analyses of the events, this also addressed the issue of compound flooding.

Geosyntec appreciates FDEPs support in developing technically defensible water level conditions within the BRL based on the lagoon's unique characteristics outlined above. The specific requests and determinations that we would like FDEP to review are those bolded items above, which are summarized below.

- Utilization of alternate water level gages/measurements (Haulover and BRL stations) for analyses of the BRL.
- MSL within the BRL at 0.25 foot higher than the offshore for surge analyses.
- Equivalent MHHW plus 2 feet of 1.94 ft-NAVD88 for tidal flooding in the BRL.
- Tailwater condition of 1.94 ft-NAVD88 for rainfall-induced flooding for areas draining to the BRL.

If you have any questions or wish to discuss any aspects of the analyses and determinations, please do not hesitate to contact me at 727.385.7852.

Sincerely,
Geosyntec Consultants, Inc.

Scott Deitche
Senior Principal / Project Manager
sdeitche@geosyntec.com

Steven J. Peene
Senior Principal
speene@appliedtm.com

Attachment:	Cocoa Beach Vulnerability Assessment: Exposure Analysis Approach
Copy to:	Morgan Zuhlke, City of Cocoa Beach

1

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COCOA BEACH VULNERABILITY ASSESSMENT: EXPOSURE ANALYSIS APPROACH

2

Purpose

- Exposure Analysis Needs
  - Surge – Mean Sea Level (MSL)
  - Tidal Flooding – Mean Higher High Water (MHHW)
  - Rainfall Induced Flooding - Tailwater
- Future Flooding Conditions
  - Incorporation of projected sea level rise **(SLR)** onto elevation values for **MSL, MHHW, Tailwater**

Determination of appropriate conditions for **MSL, MHHW** and **Tailwater** is *fundamental* to the Vulnerability Assessment

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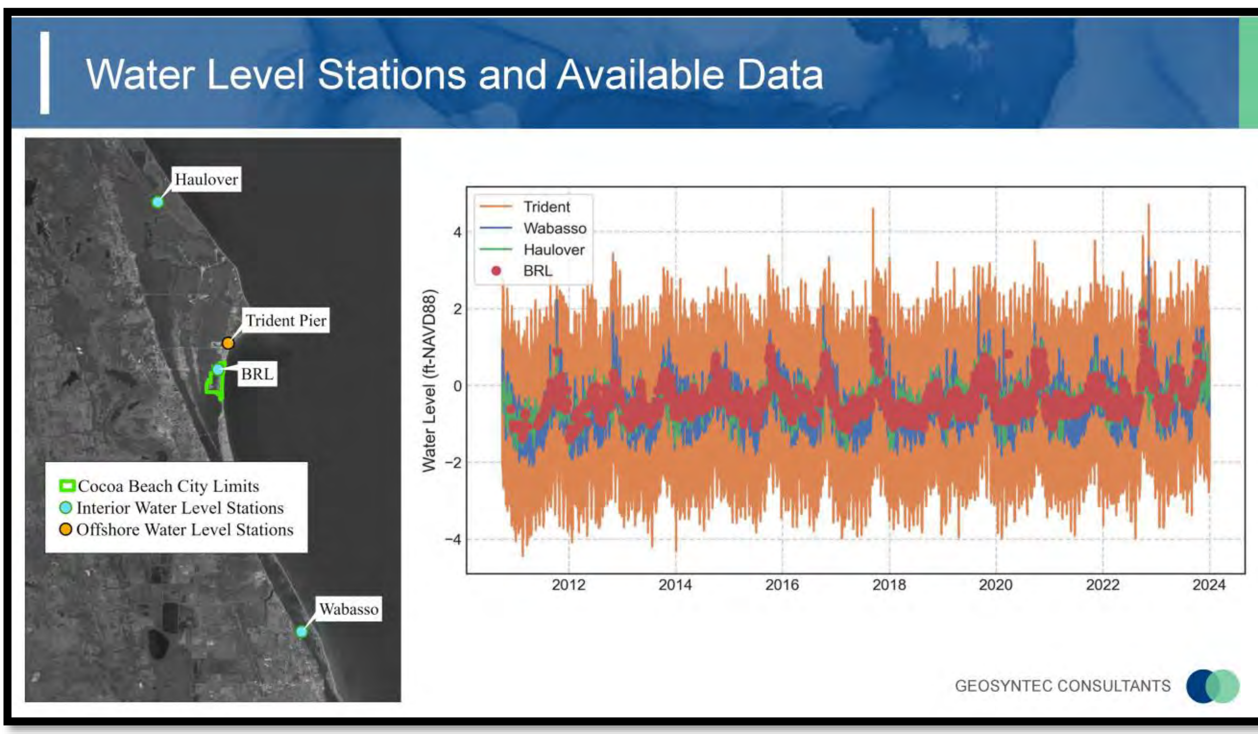
Water Level Stations and Data
Offshore and Interior
Cocoa Beach City Limits
Offshore Waters
Interior Waters

4


Water Level Stations and Available Data
Haulover
Trident Pier
BRL
Cocoa Beach City Limits
Interior Water Level Stations
Offshore Water Level Stations
Wabasso
Trident
Wabasso
Haulover
BRL
Water Level (ft-NAVD88)
4
2
0
−2
−4
2012
2014
2016
2018
2020
2022
2024
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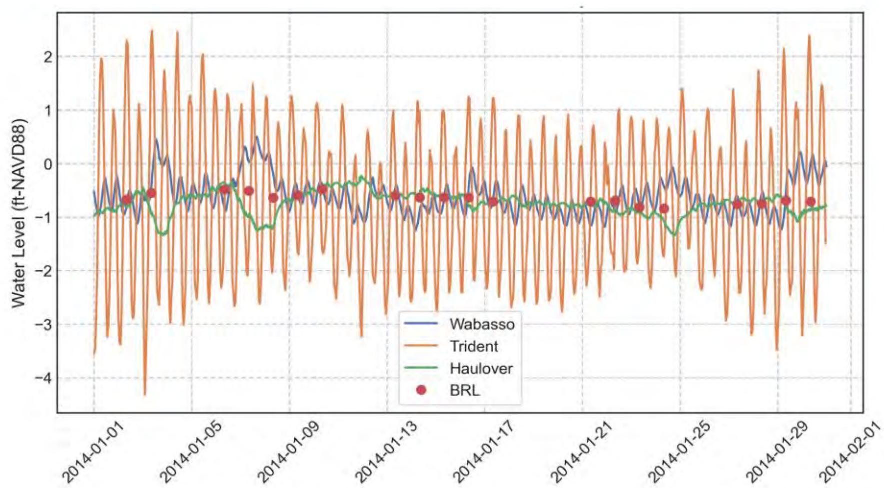
FW11197

5

Water Levels



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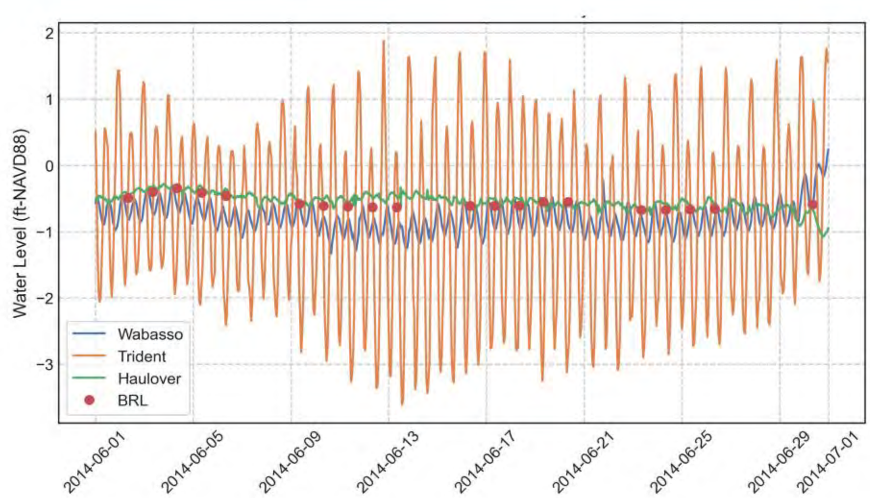
Water Levels



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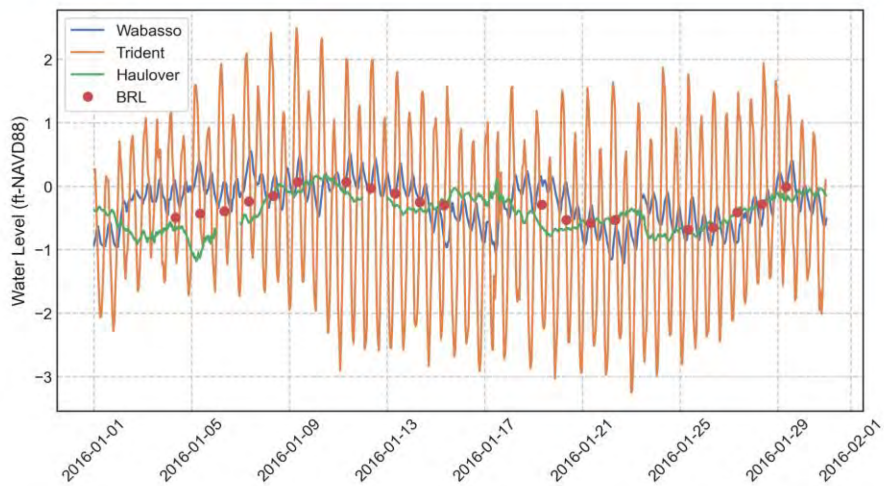
Water Levels



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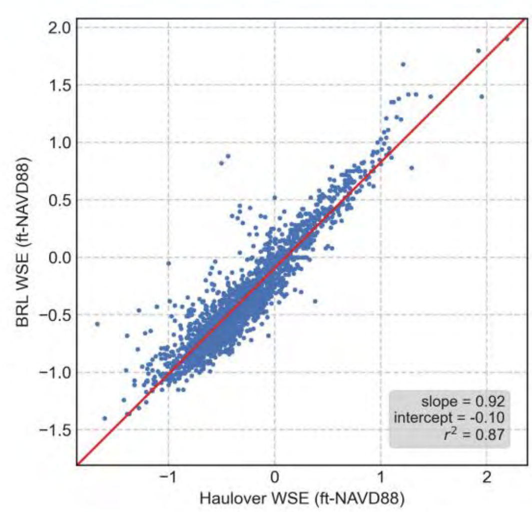
8

Haulover versus BRL

BRL represented by Cocoa Beach public dock data

- Some BRL times were unknown and assumed to be 8 AM.

Haulover appears to be representative of BRL



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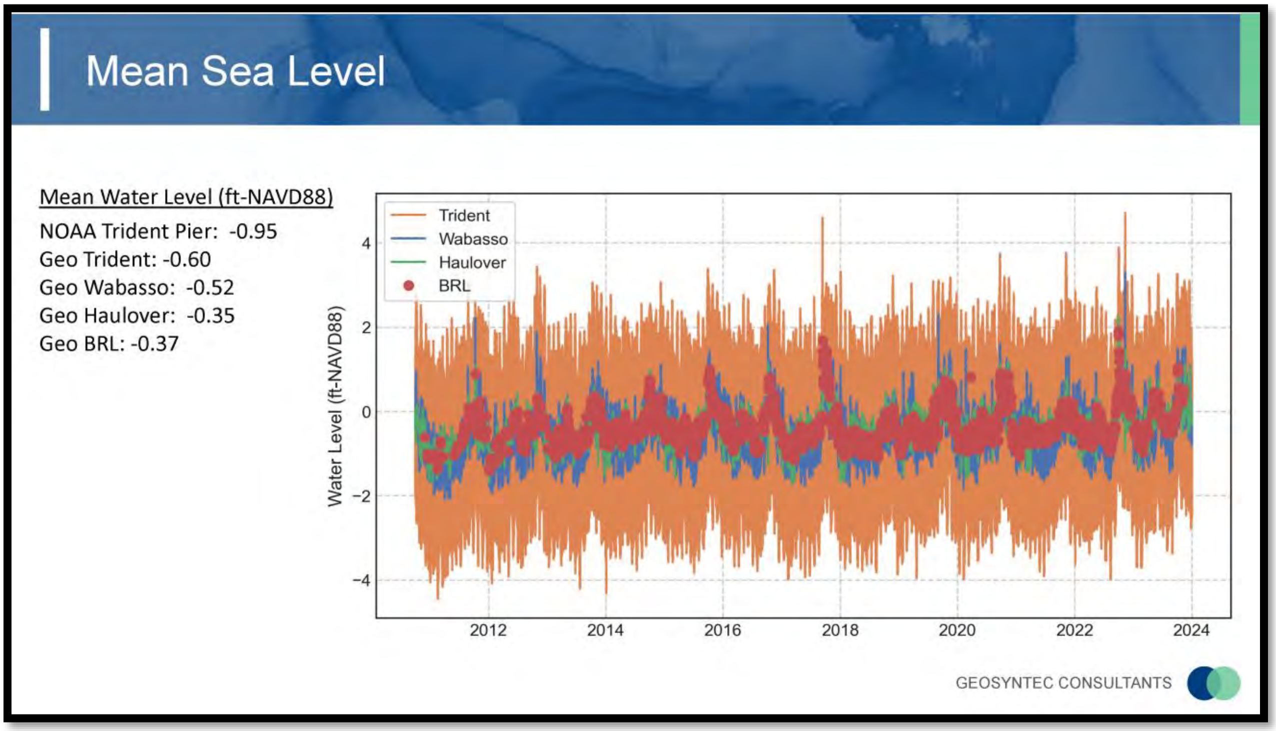
9


Mean Sea Level
Mean Water Level (ft-NAVD88)
NOAA Trident Pier: -0.95
Geo Trident: -0.60
Geo Wabasso: -0.52
Geo Haulover: -0.35
Geo BRL: -0.37
Trident
Wabasso
Haulover
BRL
Water Level (ft-NAVD88)
4
2
0
−2
−4
2012
2014
2016
2018
2020
2022
2024
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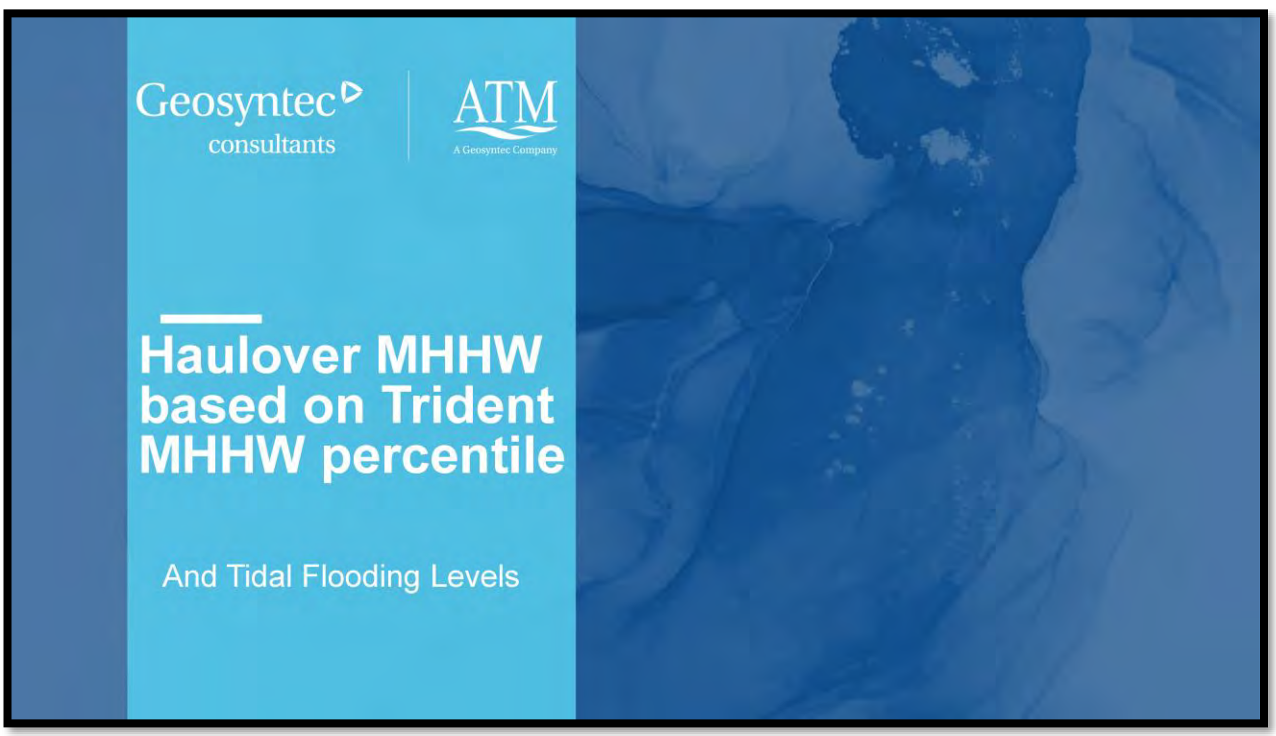
10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Haulover MHHW based on Trident MHHW percentile
And Tidal Flooding Levels

FW11197

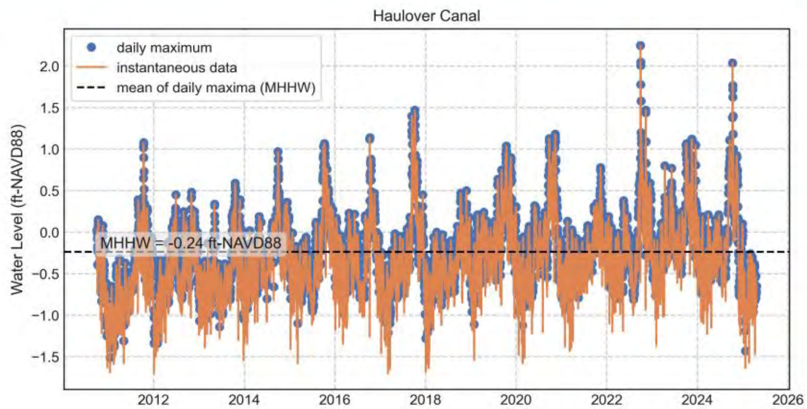
11

Standard MHHW Calculation

Using the continuous Haulover Canal data, a standard calculation of the MHHW based on the mean of the daily maxima was performed.

The value was -0.24 ft-NAVD88.

This value was not deemed a reasonable "equivalent" MHHW condition.



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12

Percentile-Corresponding MHHW

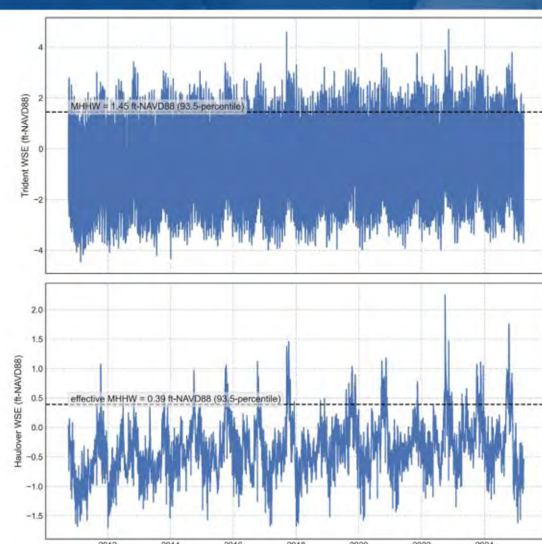
Utilized an equivalent percentile of the Trident Pier MHHS.

This analysis is based on the period when Trident and Haulover have overlapping data.

The MHHW of the Trident gage is 1.45 ft-NAVD88.

The calculated percentile of the Trident MHHW is 93.5%.

The 93.5% percentile of the Haulover gage is 0.39 ft-NAVD88.



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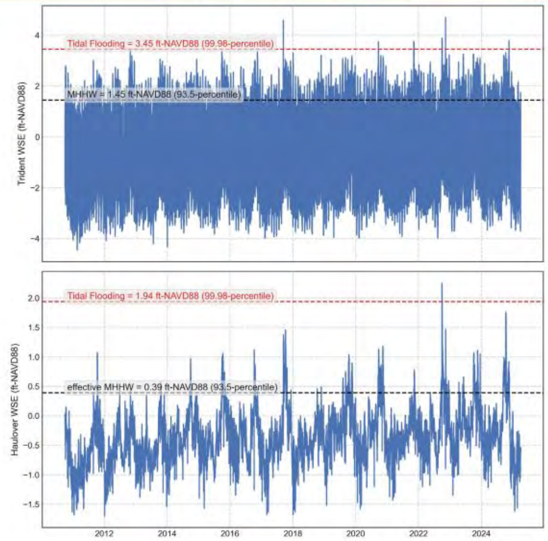
13

Percentile-Corresponding Tidal Flooding

Tidal Flooding for the Trident gage is 3.45 ft-NAVD88 (MHHW + 2 ft).

The calculated percentile of the Trident TF is 99.98%.

The 99.98% percentile of the Haulover gage is 1.94 ft-NAVD88 (effective MHHW + 1.55 ft; calculated MHHW + 2.18 ft).



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14

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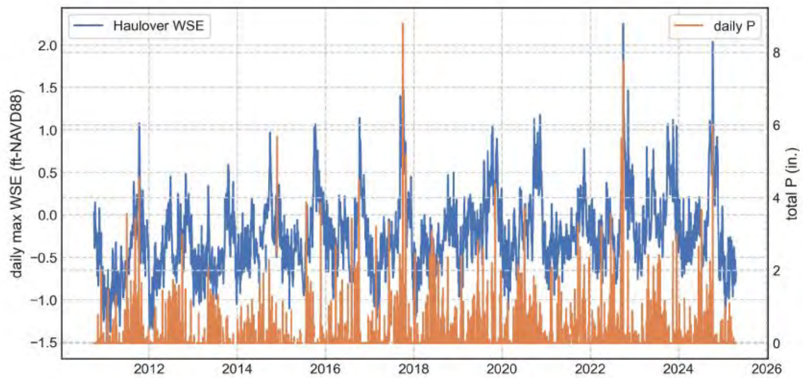
Tailwater Analyses

And Tidal Flooding Levels

15

Water Level and Precipitation

- Precipitation (P) data from NOAA
  - Merritt Island (US1FLBV0036)
  - 82% coverage for period of overlap with Haulover data (10-01-2010 – 04-21-2025)



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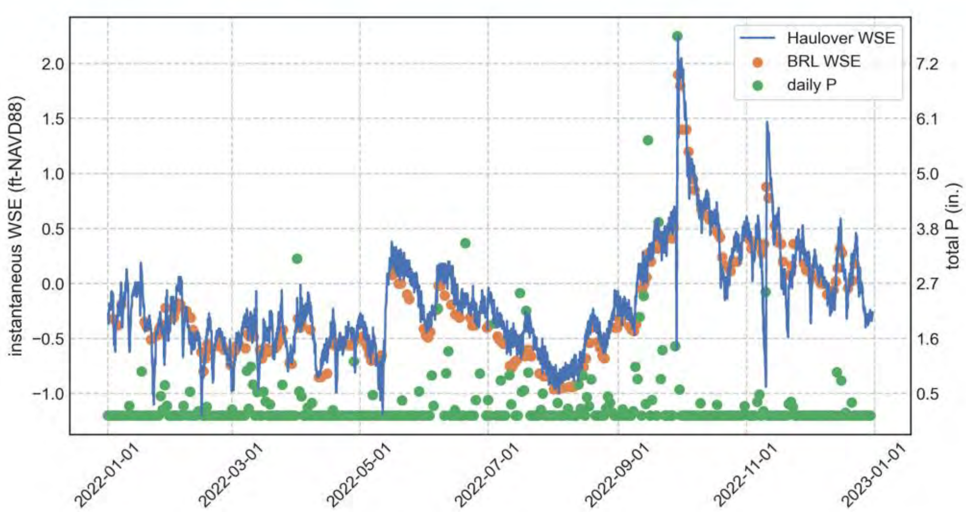
WSE and P Timeseries - Ian



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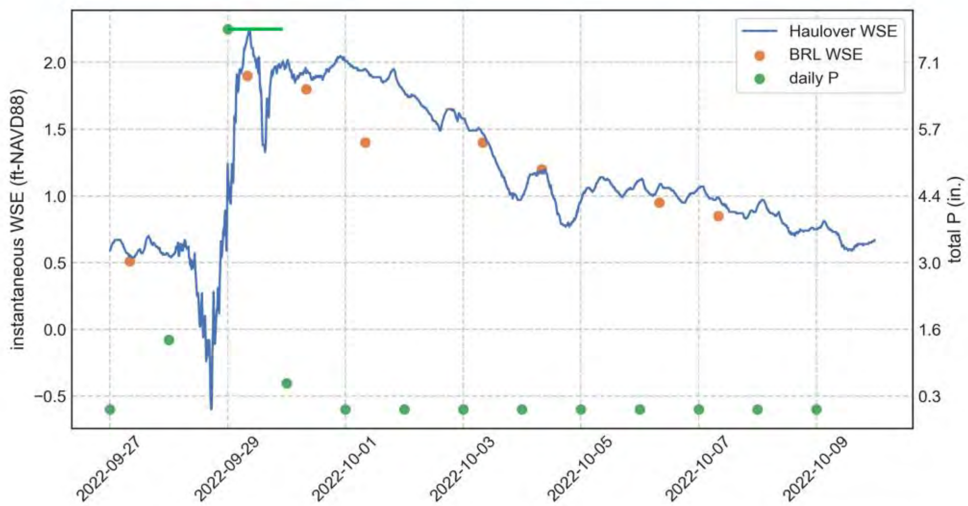
17

WSE and P Timeseries - Ian



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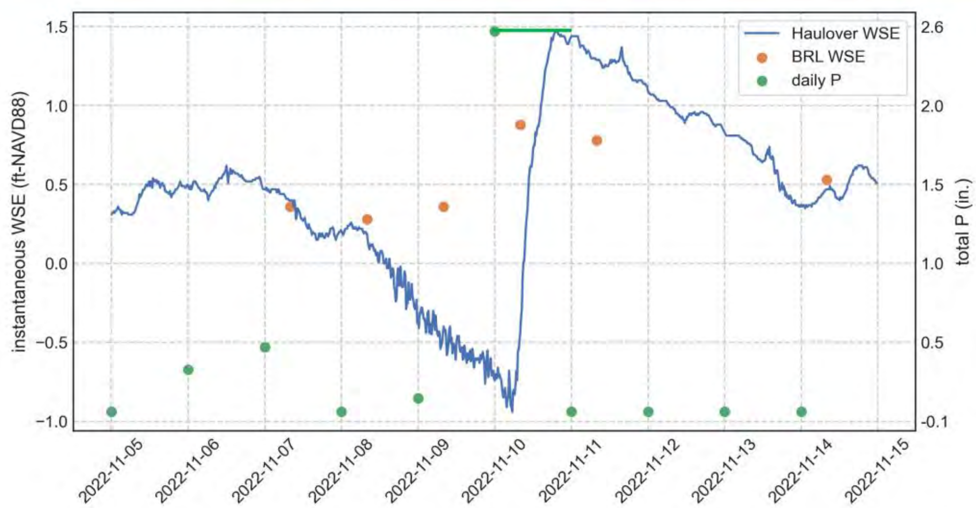
18

WSE and P Timeseries



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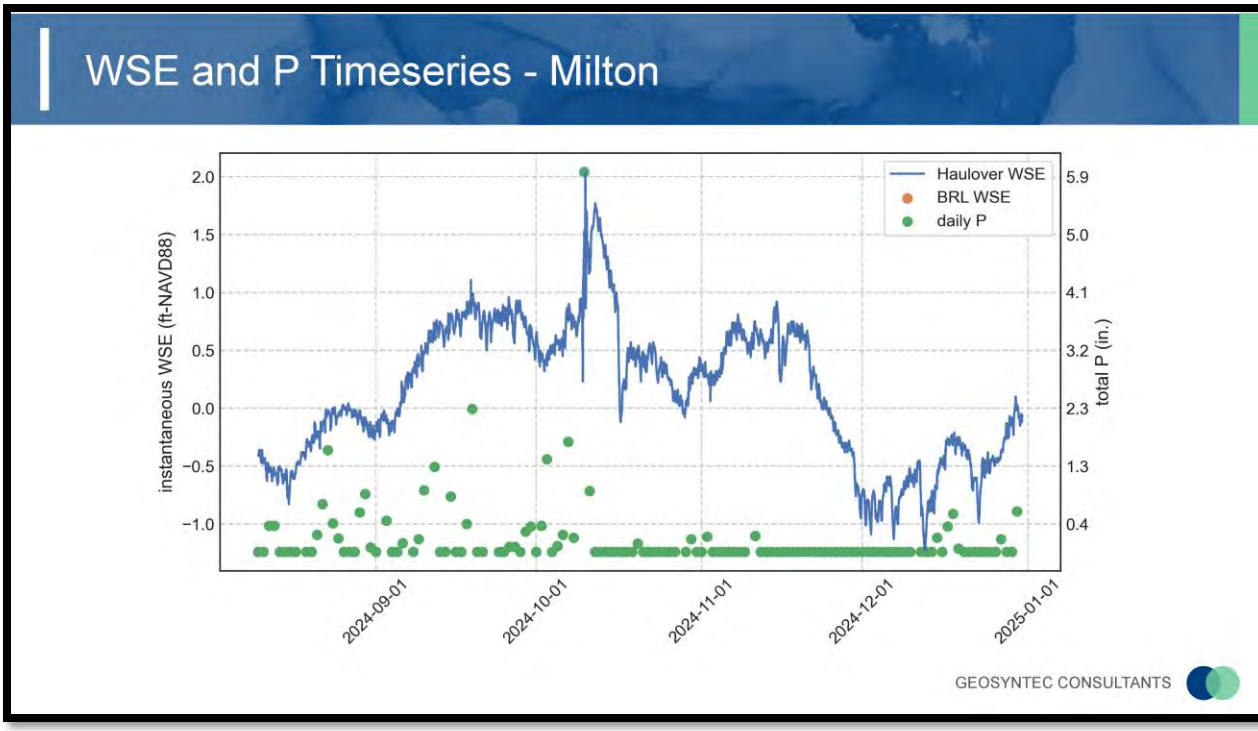
19


WSE and P Timeseries - Milton
Haulover WSE
BRL WSE
daily P
instantaneous WSE (ft-NAVD88)
total P (in.)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
5.9
5.0
4.1
3.2
2.3
1.3
0.4
2024-09-01
2024-10-01
2024-11-01
2024-12-01
2025-01-01
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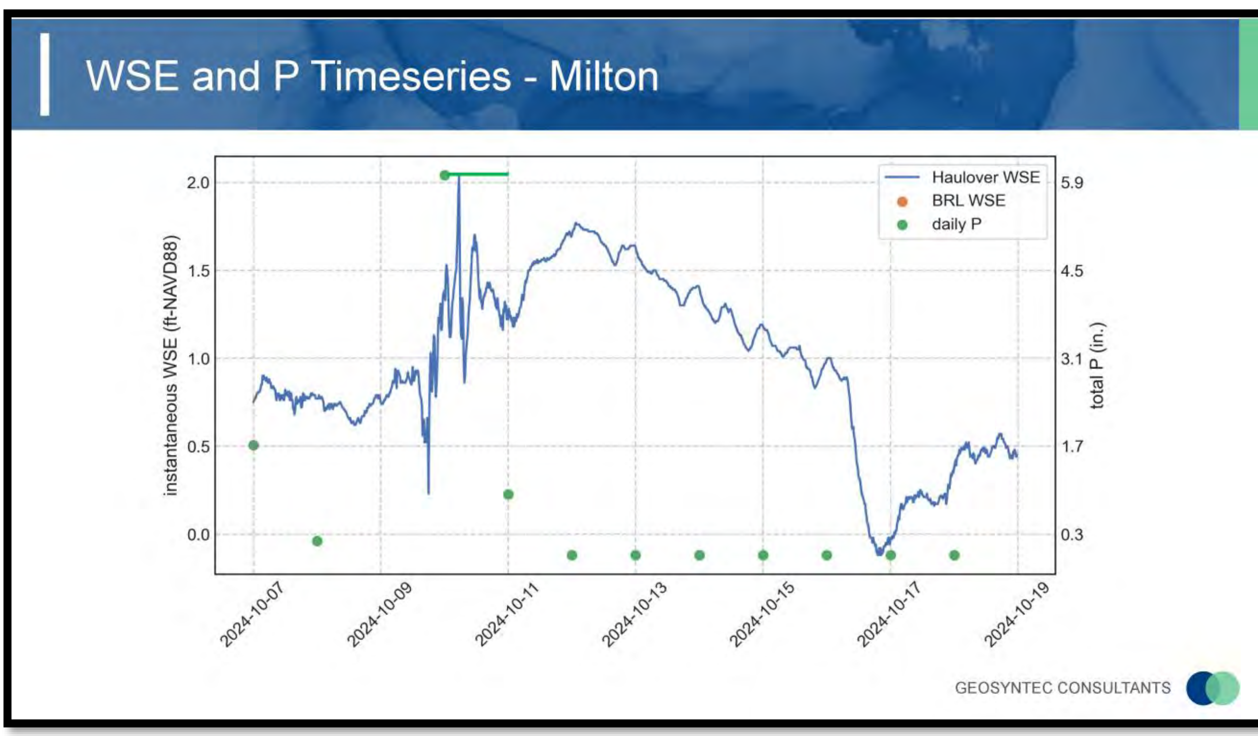
20


WSE and P Timeseries - Milton
Haulover WSE
BRL WSE
daily P
instantaneous WSE (ft-NAVD88)
total P (in.)
2.0
1.5
1.0
0.5
0.0
5.9
4.5
3.1
1.7
0.3
2024-10-07
2024-10-09
2024-10-11
2024-10-13
2024-10-15
2024-10-17
2024-10-19
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Conclusions/Recommendations

- Offshore and interior conditions are not similar due to lack of tidal fluctuations in the Banana River Lagoon
- Geosyntec Recommendations
    - Surge: MSL – Interior is 0.25 feet higher than Trident
    - Tidal Flooding: 1.94 ft NAVD88 based on percentile analysis (equivalent to MHHW + 2)
    - Tailwater: Utilize tidal flooding elevation (1.94 ft NAVD88) based on analyses of storms

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