Task 5 Final Report: Town of Belleair - Bluff Restoration and Erosion Abatement

May 30, 2025

Owner's Contract Number: ADM22-01

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ACRONYMS AND ABBREVIATIONS

EX	**Example**
BMP	Best Management Practices
CFS	Cubic Feet Per Second
CO-OPS	Center of Operational Oceanographic Products and Services
ERS	Environmental Science Associates
FDOT	Florida Department of Transportation
ICWW	Intercoastal Waterway
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
MW	Monitoring Well
NAVD	North American Vertical Datum
NDBC	National Data Buoy Center
NWIS	National Water Information System
OF	Outfall
RCP	Reinforced Concrete Pipe
SAV	Submerged Aquatic Vegetation
SWFWMD	Southwest Florida Water Management District
USGS	United States Geological Survey

EXECUTIVE SUMMARY

The Belleair Bluff Preservation and Erosion Abatement Project aims to address the ongoing erosion threatening the Hallett Park shoreline, caused by wave activity and groundwater discharge, and maximize natural systems restoration and improve water quality through nutrient reduction Best Management Practices (BMPs). Coastal erosion poses significant risks to the stability of the bluff, the surrounding ecosystem, and water quality. Without intervention, the shoreline is anticipated to continue degrading, leading to potential land loss, infrastructure damage, and further environmental harm.

To combat these issues, the project is designed to restore and stabilize the bluff while improving water quality through a strategic and resilience-based approach. This project identifies, evaluates, and recommends management options and alternatives that provide measurable benefits. A comprehensive assessment was conducted, analyzing metocean conditions, erosion mechanisms, and water quality impacts. Based on this data, multiple design alternatives were developed, each considering environmental preservation, engineering feasibility, and cost-effectiveness. The recommended approach integrates structural resilience with ecological restoration, ensuring a long-term solution for shoreline stabilization.

Once implemented, the project will mitigate further erosion, protect the natural integrity of the bluffs, and enhance water quality by reducing pollutant loading into surrounding waters. Additionally, it will contribute to the conservation of critical coastal habitats, supporting biodiversity and long-term environmental health. The selected design alternative aligns with the Town of Belleair’s commitment to sustainable coastal management and resilience planning.

This initiative is essential for preserving the shoreline, protecting local infrastructure, and ensuring a healthier coastal environment. Through collaboration with stakeholders, including the Town of Belleair and the Southwest Florida Water Management District (SWFWMD), this project aims to set a precedent for proactive shoreline management. Moving forward, the findings and recommendations outlined in this report will serve as a framework for implementation, guiding the next steps in restoring and safeguarding the bluffs for future generations.

1. FIELD DATA COLLECTION

Summary of Observed Erosional Trends

A review of historical aerial imagery and previous topographic surveys reveals a clear trend of shoreline retreat and bluff erosion over the past decades. APTIM performed topographic surveys of the bluff in November 2023 and March 2025, using 17 transects spaced 200-ft apart along the bluff (**Figure 1**). The pink line in **Figure 1** signifies the bluff crest in 2023 and blue line denotes the bluff crest in March 2025. Although minor areas of accretion were observed, the bluff crest has receded inland by approximately 6–8 feet in certain locations, equating to an average erosion rate of roughly 3.5 feet per year. **Figure 2** overlays the 1997 shoreline (depicted by the yellow solid line) and the 2023 surveyed bluff crest (green line) onto a 1997 historical aerial image. A visual comparison between the 1997 and 2025 shoreline positions clearly illustrates significant inland retreat along the Hallett Park shoreline. These erosional trends reflect the ongoing influence of coastal processes such as wave action, storm surges, and potential human-induced impacts. If the current rate of retreat continues, it could pose increasing risks to nearby properties and may eventually threaten the structural integrity of Bayview Drive. Continued monitoring through updated topographic surveys, drone imagery, and hydrodynamic modeling will be critical for informing future mitigation and stabilization efforts in the area.

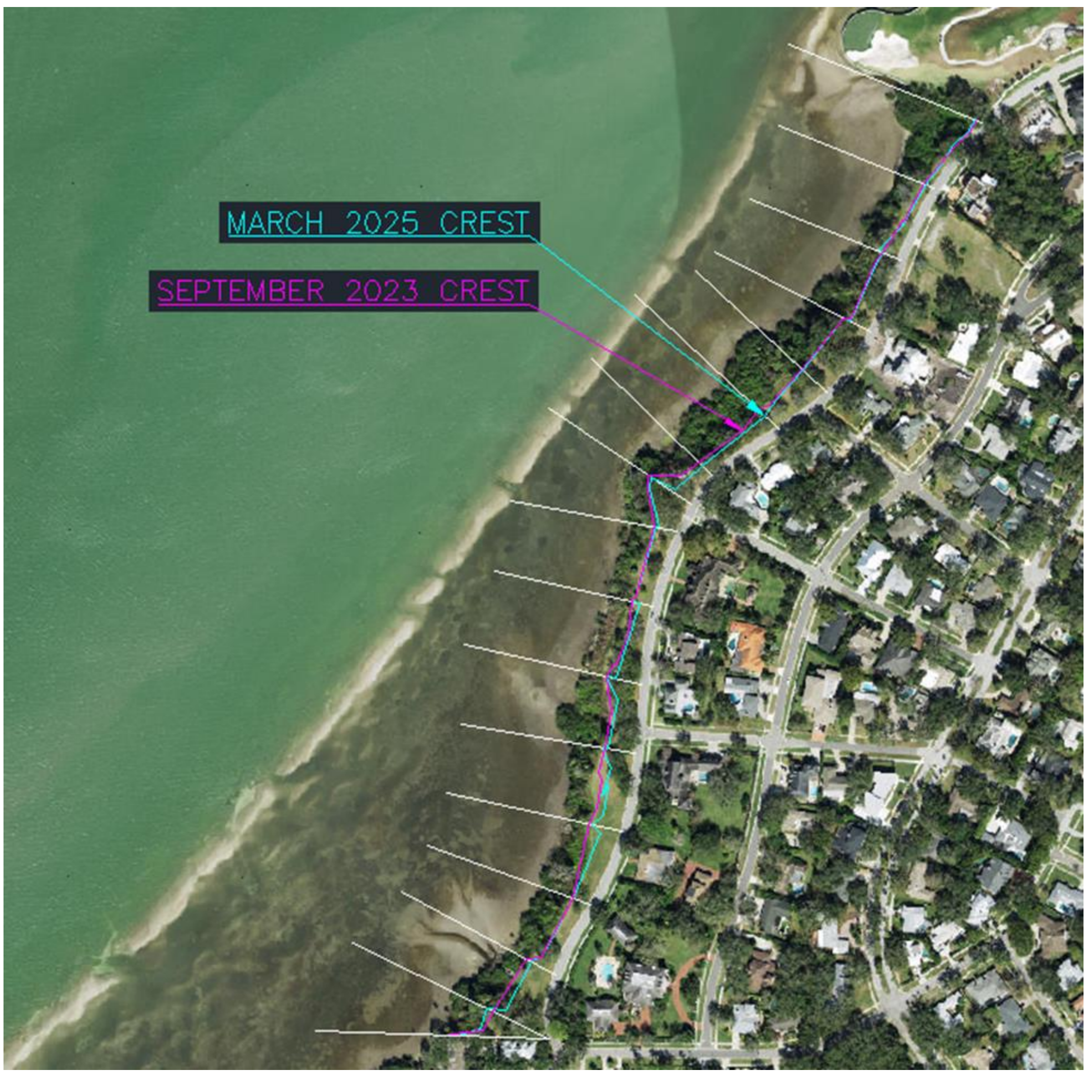

Figure 1: Surveyed Bluff Crest Lines from September 2023 (pink) vs March 2025 (blue)

Figure 2: 1997 Historical Bluff Aerial, 1997 Shoreline (yellow line) and 2023 Bluff Crest (green line)

1.1 Meteorological Data

APTIM has collected meteorological data. **Figure 3** shows rainfall data for the Hallett Park project area over the past 12 months (January 2024 – 2025), with an estimated total of 30.8 inches for 2023, well below the area's typical annual average of 46.0 inches. **Figure 4** illustrates average monthly rainfall from 1995 to the present, highlighting the variability (standard deviation) and showing the most active rainfall months, typically from June to September. **Figure 5** depicts annual rainfall trends from 1995 to 2024. Notable peaks occurred in 2004 (59.7 inches), 2016 (59.7 inches), and 2019 (62.7 inches), with the lowest totals recorded in 2000 (27.1 inches) and 2024 (24.0). While fluctuations have persisted historically, 2022–2024 exhibit a declining trend in total rainfall.

These trends are essential to analyze because they directly impact stormwater management and erosion control. Rainfall data assists the design process, as the information allows for accurate structural design to address the necessary issues.

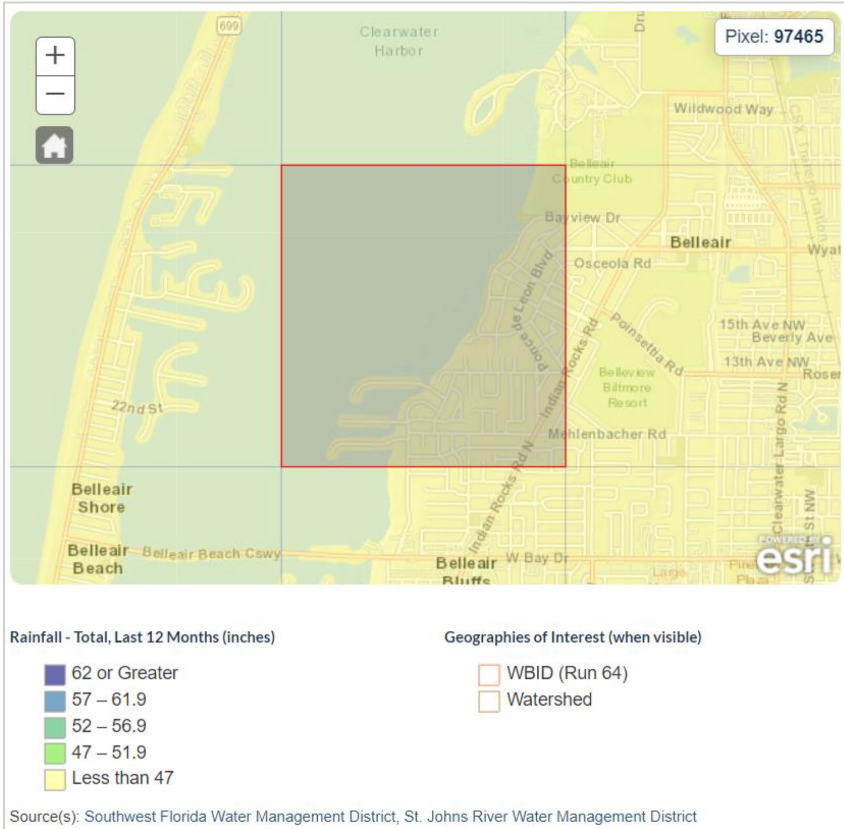

Figure 3: (Pixel 97465): Location of Rainfall Data

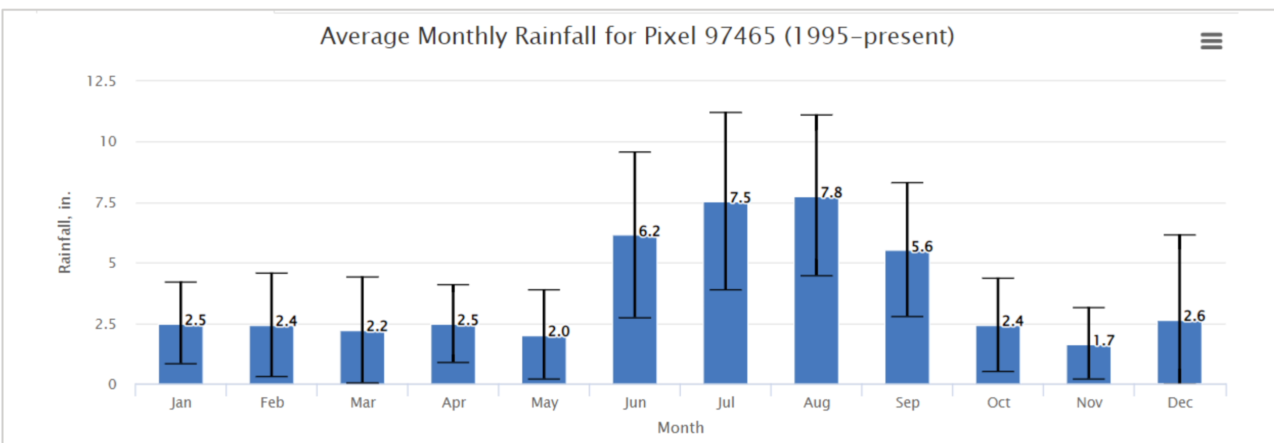

Figure 4: (Pixel 97465): Average Annual Rainfall from 1995 to the Present

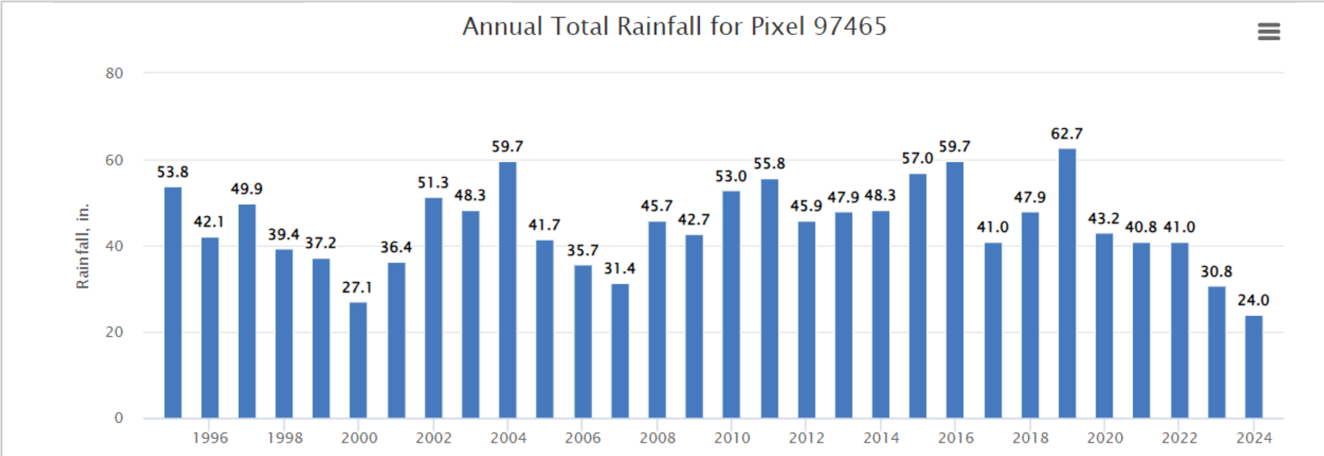

Figure 5: (Pixel 97465): Annual total Rainfall from 1995 to the Present

1.1.1 Specific Yearly Rainfall Comparisons

This section assesses the monthly rainfall distribution in years 1995, 2014, and 2024 to gain a big picture understanding of the historic rainfall trends and seasonality.

Figure 6 highlights **1995** monthly rainfall compared to the historical average (1995–2024). The highest rainfall occurred in July (10.1 inches) and August (10.2 inches), with significant amounts in June (7.6 inches) and October (7.4 inches). The lowest was in May (0.2 inches), while November and December received 1.7 inches and 1.0 inches, respectively. Other months saw moderate rainfall between 2.8 to 3.8 inches. Overall, summer had the most rainfall, while spring and late fall were drier. These trends help refine stormwater management strategies by addressing seasonal variations and ensuring infrastructure meets peak demands.

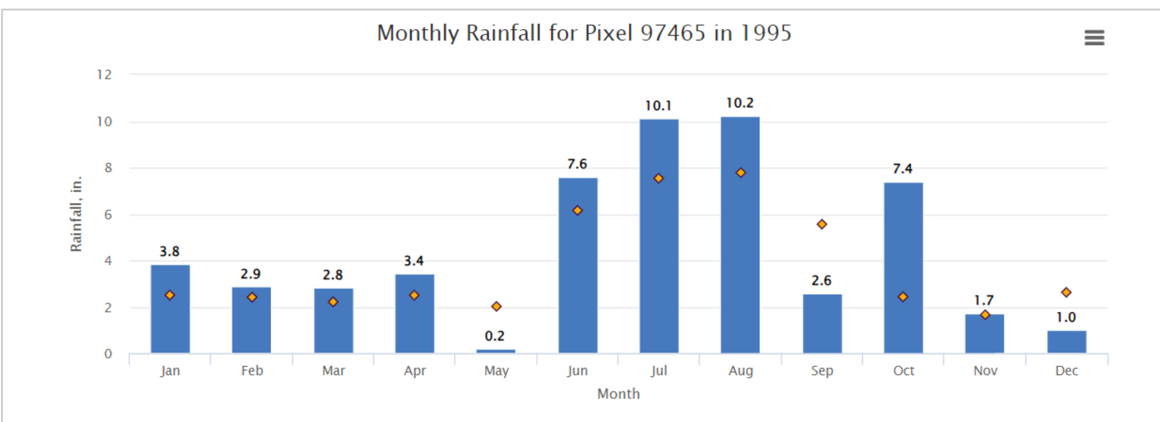

Figure 6: (Pixel 97465): 1995 Monthly Rainfall

Figure 7 shows **2014** monthly rainfall against the historical average. September (10.9 inches) recorded the highest rainfall, with substantial amounts in March (6.8 inches), July (5.3 inches), and November (5.0 inches). The lowest was in February (1.4 inches), with June and December also low at 2.2 inches and 1.8 inches. Other months ranged between 2.4 to 3.8 inches. The summer and fall months had the heaviest rainfall, while winter was notably drier.

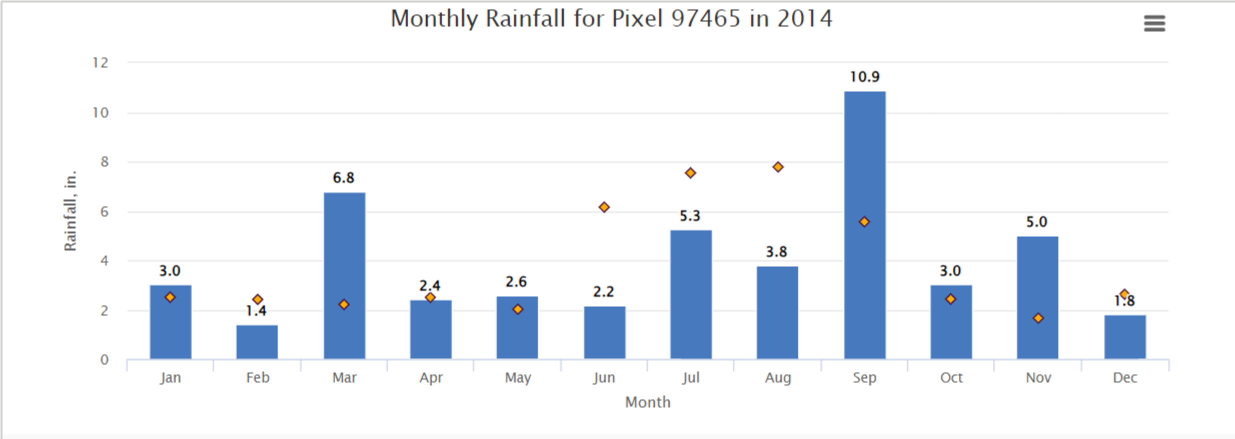

Figure 7: (Pixel 97465): 2014 Monthly Rainfall

Figure 8 displays monthly rainfall for **2024** compared to the historical average. The highest rainfall occurred in August (18.6 inches) and October (12.3 inches), while July (6.9 inches), September (7.5 inches), and June (5.7 inches) also received substantial amounts. The lowest rainfall was in April (1.6 inches**)** and May (1.1 inches), with January, February, and March showing moderate rainfall of 2.6 to 3.1 inches. The year has seen significant rainfall in late summer and early fall.

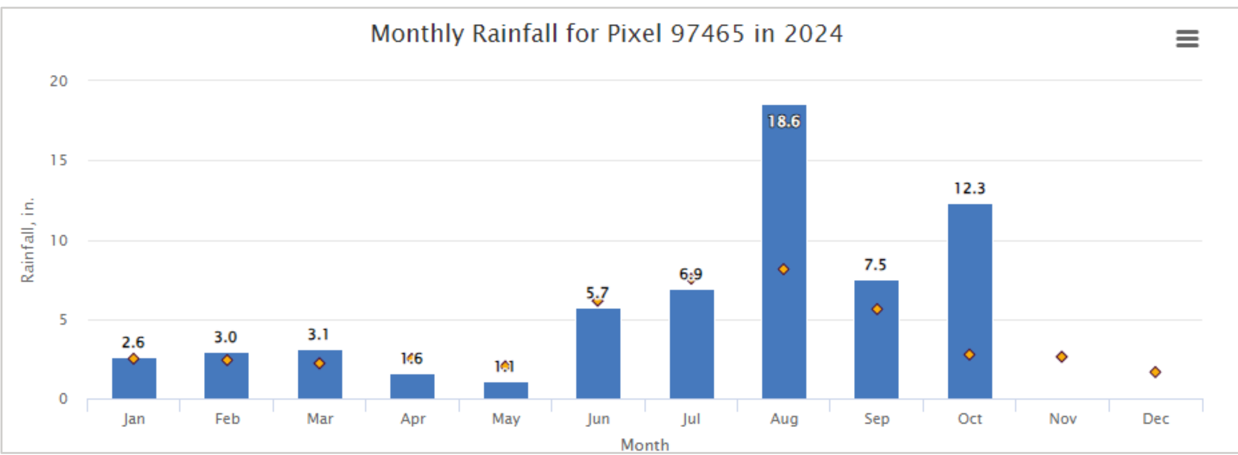

Figure 8: (Pixel 97465): 2024 Monthly Rainfall

Understanding these seasonal rainfall patterns is essential in design, as it ensures that stormwater management systems can handle peak rainfall periods. By incorporating historical and recent rainfall data, infrastructure can be designed to be capable of addressing seasonal extremes and long-term trends, protecting coastal areas from flooding and environmental degradation.

1.1.2 Rattlesnake Creek Flow and Gage Data

Rattlesnake Creek is located in Town of Belleair, originating near County Road 233 (Indian Rocks Road) and discharging to Intercoastal Waterway (ICWW), approximately 0.7 miles North of the study area **(Figure 9)**.

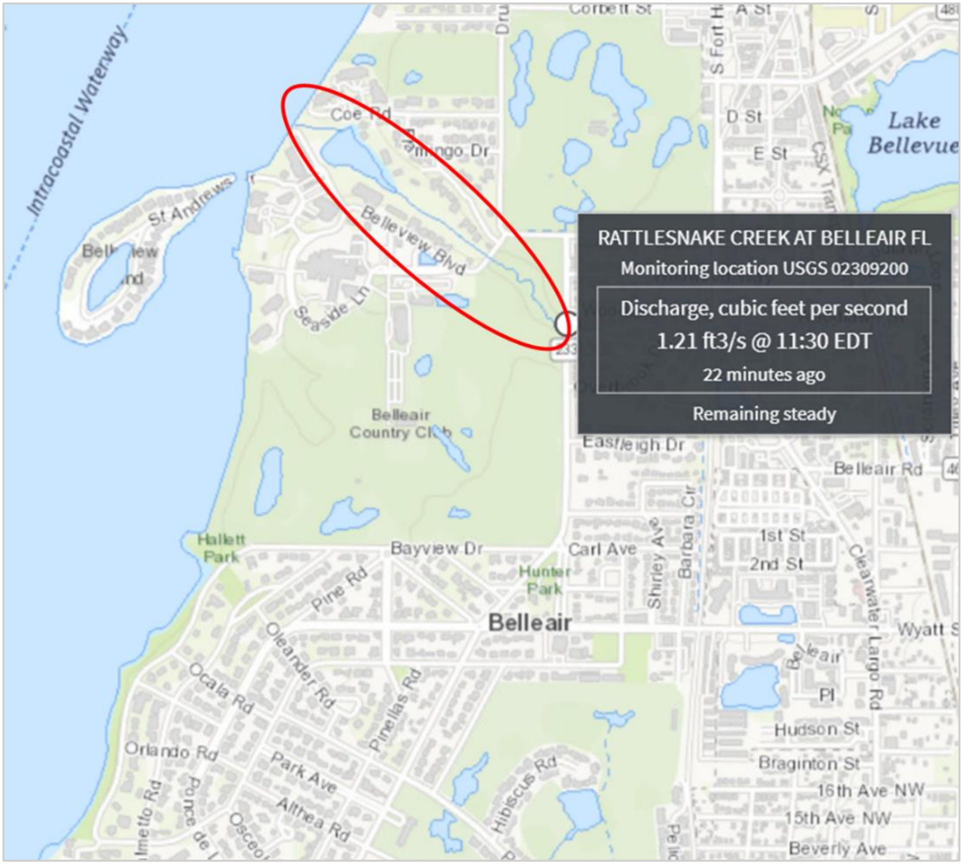

Figure 9: Location of Rattlesnake Creek in reference to Hallett Park

The discharges of this creek can impact erosion patterns in Hallet Park shorelines. Flow data for Rattlesnake Creek from January 2017 to March 2025 **(Figure 10)** shows high fluctuating discharge patterns. The daily mean discharges range from 0.1 to 100 cfs, representing a variety of water dynamics in the area. This indicates a site with high variable flow patterns, from minimal base flow during dry conditions to significantly higher flows during storm events or runoff, suggesting potential flooding risks and erosion. This variability also impacts aquatic habitats, sediment transport, and water resource management, requiring adaptive strategies to address the fluctuating water. Gage height data for Rattlesnake Creek, shown in **Figure 11**, was collected from January 2017 to March 2025 and the fluctuations are likely caused by seasonal influences and/or extreme rainfall events. The instability in flow and gage height data demonstrates the importance of designing stormwater management systems that can accommodate both frequent low-flow conditions and occasional high-discharge events.

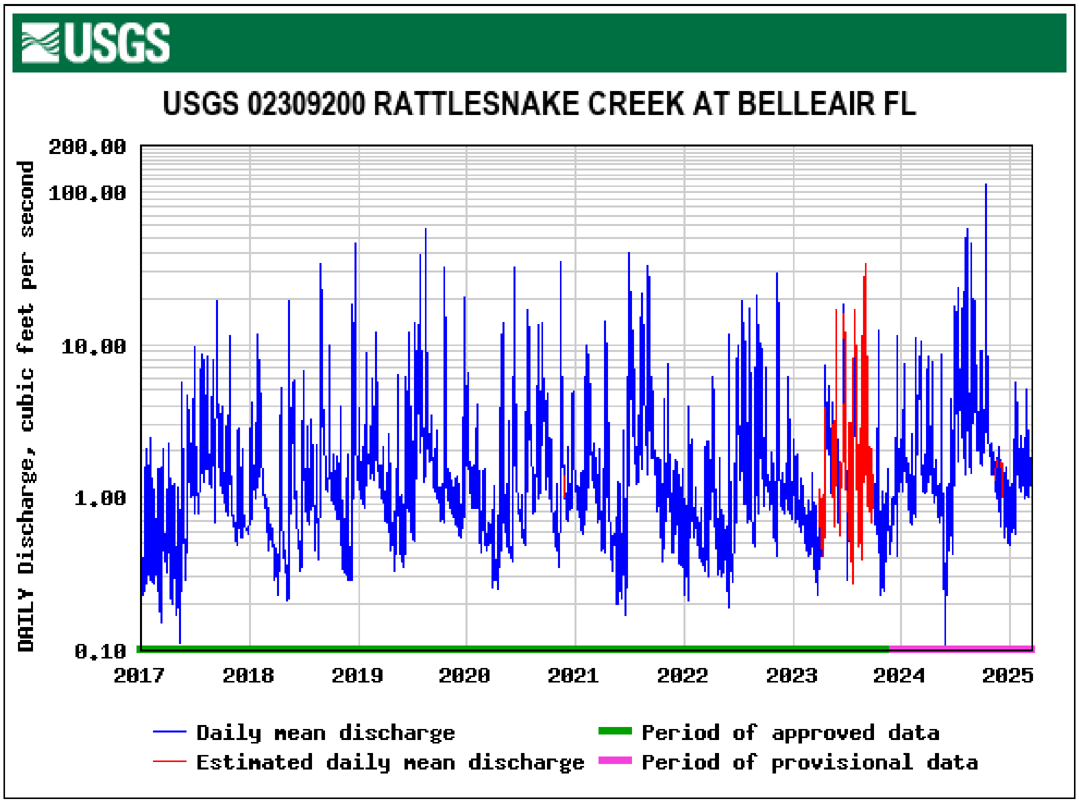

Figure 10: (USGS 02309200): Rattlesnake Creek Daily Discharge (in cfs) from 2017 to 2025

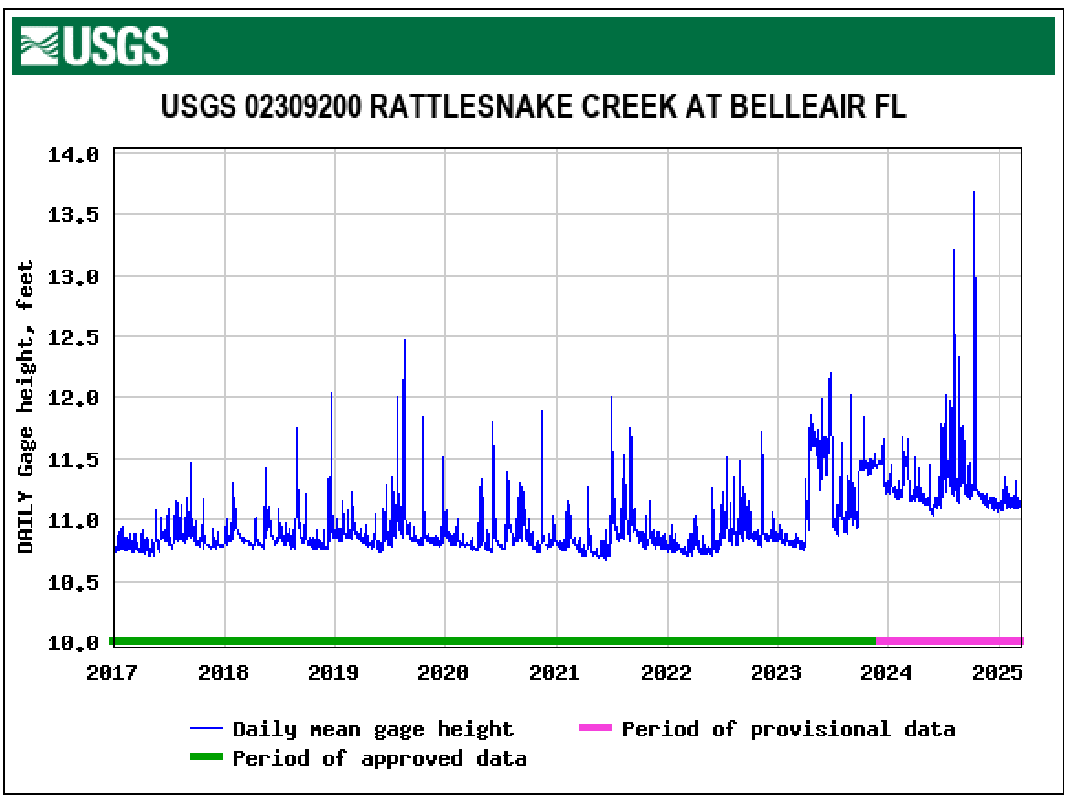

Figure 11: (USGS 02309200)): Rattlesnake Creek Daily Gage Height from 2017 to 2025

1.1.3 Monitoring Well Locations

Field data collection for the Belleair Bluff Erosion Abatement project involved the installation of three permanent groundwater monitoring wells (MW-1, MW-2, MW-3 – locations shown in **Figure 12**) on February 20, 2024. These wells were scattered along the project area at the following locations:

- **MW-1** was installed near the southernmost outfall along Bayview Drive,
- **MW-2** was placed along Bayview Drive between the Belleair Country Club seawall and the intersection of Bayview drive and Ocala Road, and
- **MW-3** was placed inland at the intersection of Sarasota Road and Ponce De Leon Blvd.

Figure 12: Well Monitoring Locations

Ongoing measurements, starting in February of 2024, were taken every three weeks for 13 months to monitor seasonal rainfall and stormwater fluctuations. Last measurement is scheduled to be collected on March 28, 2025. The wells were constructed using 2-inch Schedule 40 PVC casings, with screened sections (0.010-inch slot width, 10-foot screens for MW-1 and MW-3, and a 15-foot screen for MW-2). They were installed to a depth of approximately 30 feet, stabilized with silica sand backfill, and sealed with a cement/bentonite grout layer. Concrete pads and lockable manholes were added to ensure durability and security. Initial water level measurements were recorded during installation based on soil saturation, with ongoing measurements taken every three weeks for 13 months to monitor seasonal rainfall and stormwater fluctuations. The analysis of these monitoring well results are discussed in Section 2 of this report and presented in **Appendix E: ARDAMAN Final Well Readings.**

1.2 Metocean Data

1.2.1 Annual Sea Level Projections

Monthly average sea levels measured at NOAA Clearwater Beach gage from 1973 to 2023 are presented in **Figure 13**. The values are adjusted to remove typical seasonal variations caused by factors like ocean temperature, salinity, and atmospheric pressure. The relative sea level trend is represented alongside its 95% confidence interval, which provides a range of values within which the true trend is expected to fall with 95% certainty. The estimated relative sea level rise is 4.33 mm per year, with a margin of error of ±0.52 mm per year. The data is based on the latest Mean Sea Level reference established by CO-OPS.

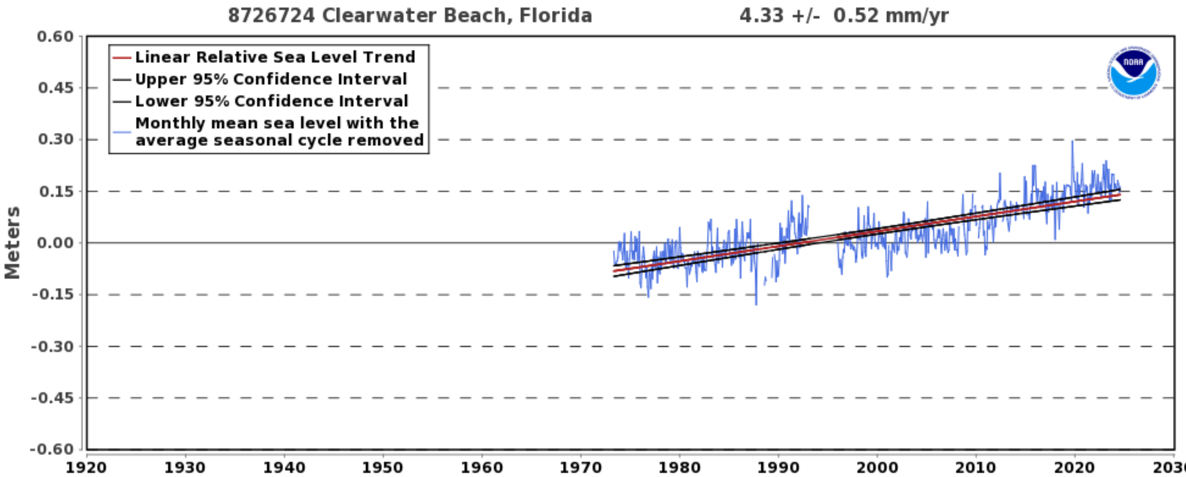

Figure 13: (Station 8726724): Relative Sea Level Trend

Figure 14 displays the station's annual average sea level since 1960, overlaid with five regional sea level rise scenarios. These scenarios are based on a 1996-2014 baseline period, meaning that observed sea levels during those years were used as a reference for projecting future changes. However, this baseline is not directly depicted on the graph. Instead, the graph uses 2005—the midpoint of the 1996-2014 period—as the "zero" reference point, meaning all sea level projections are shown relative to the average sea level during that year. Additionally, the graph includes the relative positions of key datums:

- The Mean Sea Level (MSL) datum, established by CO-OPS, which serves as a long-term tidal reference.
- The NAVD88 datum, which is the standard geodetic reference for land elevation measurements.

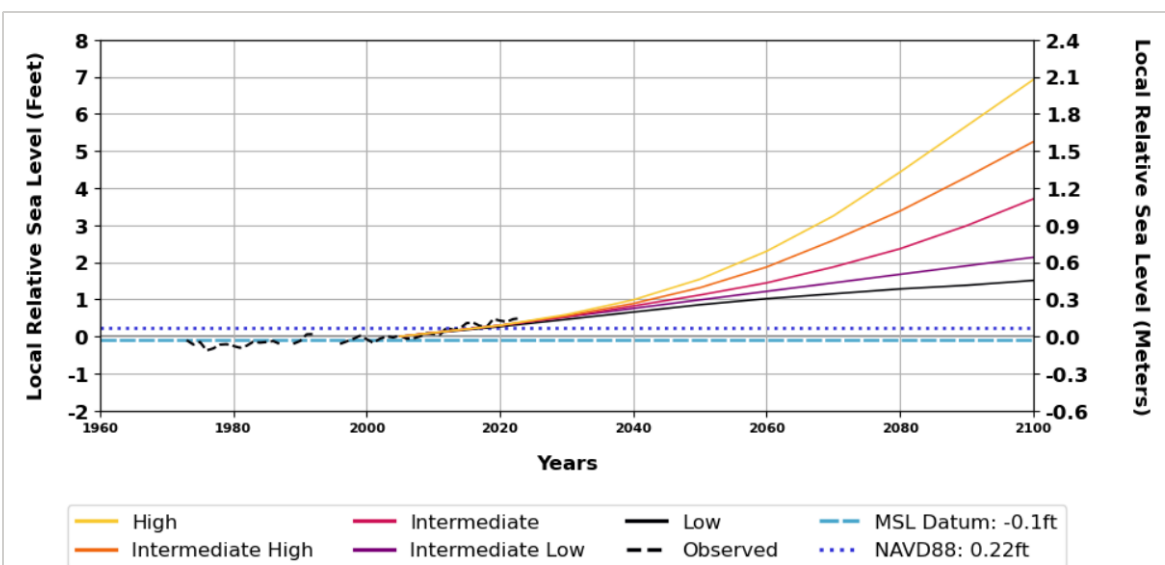

Figure 14: (Station 8726724): Annual Relative Sea Level Since 1960 and Projections

This information helps visualize how observed and projected sea level changes compare to established elevation references. Understanding sea level trends is critical for coastal engineering, as rising water levels can exacerbate flooding, erosion, and storm surges. This data supports the need for future planning when it comes to coastal structures and environments.

1.2.2 Interannual Variations and Seasonal Cycles

Figure 15, obtained from NOAA, shows how monthly mean sea levels, taken near the project area, have varied from year to year since 1996, with a five-month average. Both the seasonal cycles and the long-term sea level trend are excluded. Fluctuations are influenced by irregular factors like changes in ocean temperature, salinity, winds, atmospheric pressure, and currents. These variations are often tied to the El Niño Southern Oscillation. Solid vertical lines indicate major nearby earthquakes, while dashed lines mark questionable data periods or potential reference level changes.

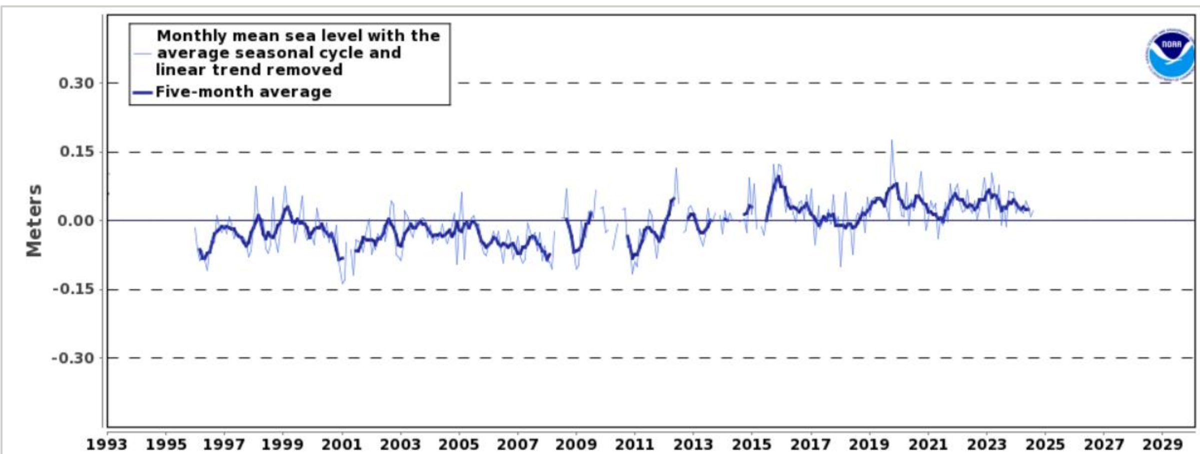

Figure 15: (Station 8726724): Interannual Variation Since 1996

Figure 16 shows the average seasonal cycle of mean sea level at the project area from 1996 to 2024. The results are affected by factors such as coastal temperature, salinity, winds, atmospheric pressure, and ocean currents. A 95% confidence interval is included for each month, showing the expected range of seasonal fluctuations. The information gathered from these figures aid coastal engineers, as they can account for both short-term and seasonal sea level changes when designing infrastructure.

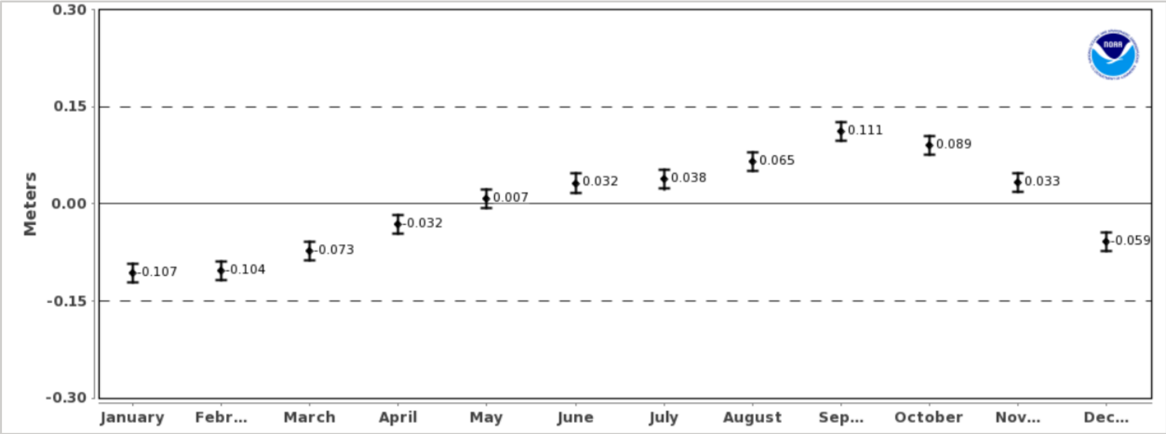

Figure 16: (Station 8726724): Average Seasonal Cycle (1993-2024)

1.2.3 Extreme Water Levels and Exceedance Probabilities

Figure 17 and **Figure 18** show the extreme water levels for Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) from 1973 to 2023. The data includes monthly highest and lowest water levels, along with annual exceedance probabilities (1%, 10%, 50%, and 99%), represented in red, orange, blue, and purple. These levels incorporate the Mean Sea Level (MSL) trend, which is rising at 4.33 mm per year (±0.52 mm), equivalent to a change of 1.42 feet over 100 years.

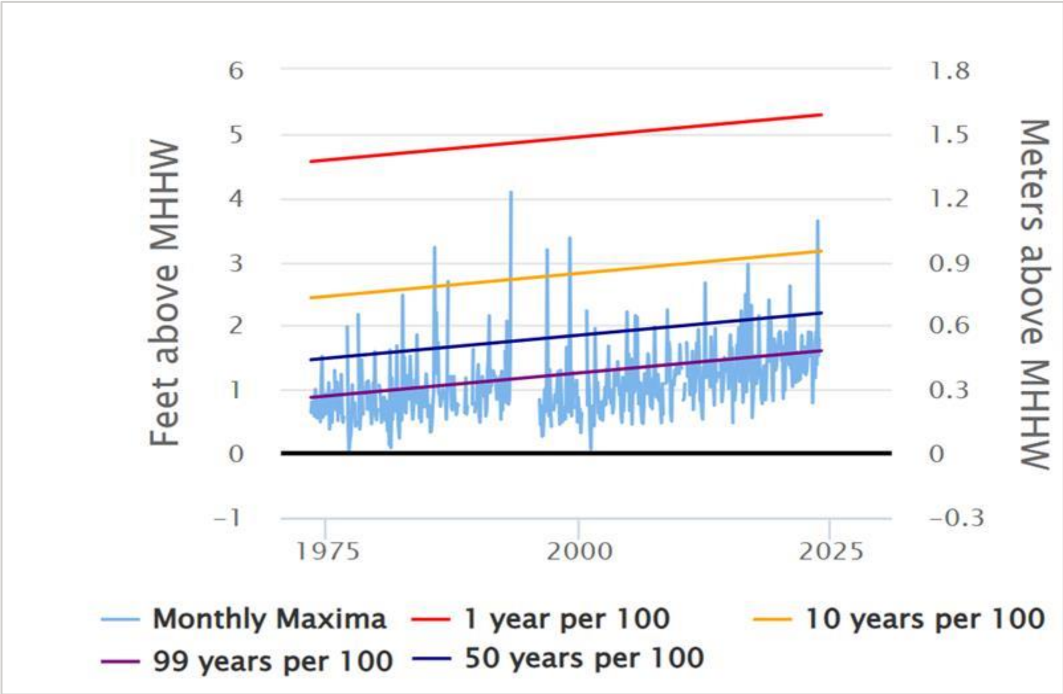

Figure 17: (Station 8726724): MHHW 1973-2023 Extreme Water Levels

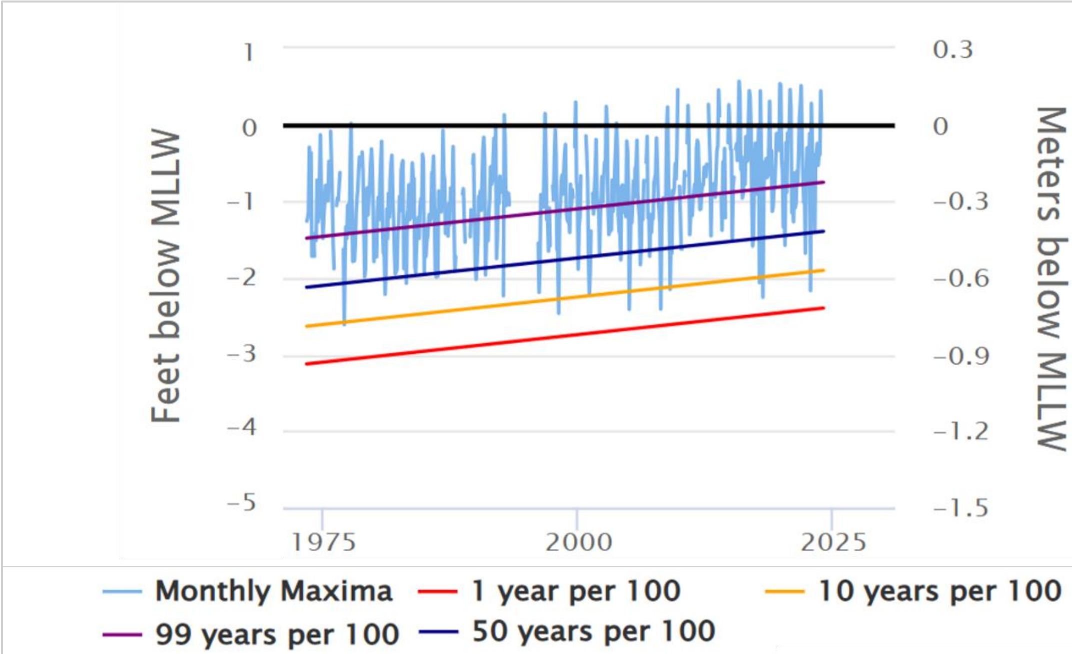

Figure 18: (Station 8726724): MLLW 1973-2023 Extreme Water Levels

Figure 19 and **Figure 20** display the annual exceedance probabilities for MHHW and MLLW. For MHHW, the 1% probability level is 1.45 meters (4.76 feet) above MHHW. For MLLW, it is -0.86 meters (-2.82 feet) below MLLW. The bold black line shows the annual exceedance probability curve, with a lower and higher 95% confidence interval, and the blue dots mark annual extremes adjusted for the sea level trend.

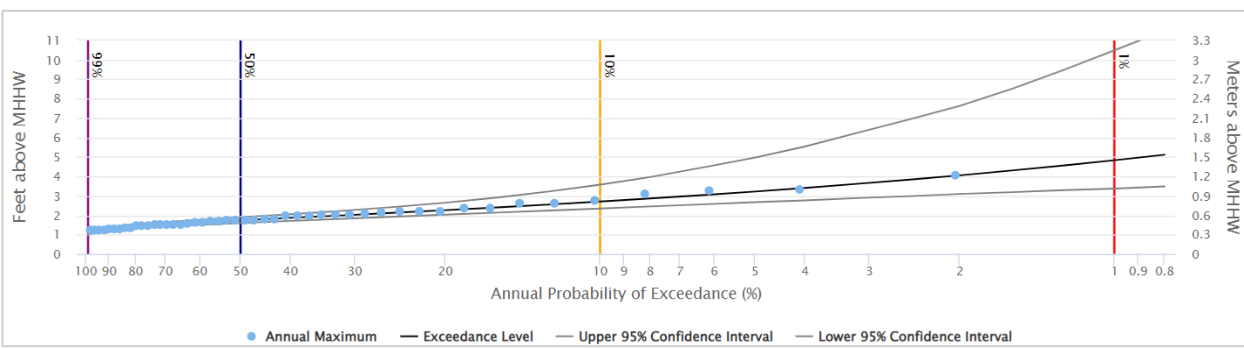

Figure 19: (Station 8726724): MHHW Annual Exceedance Probability

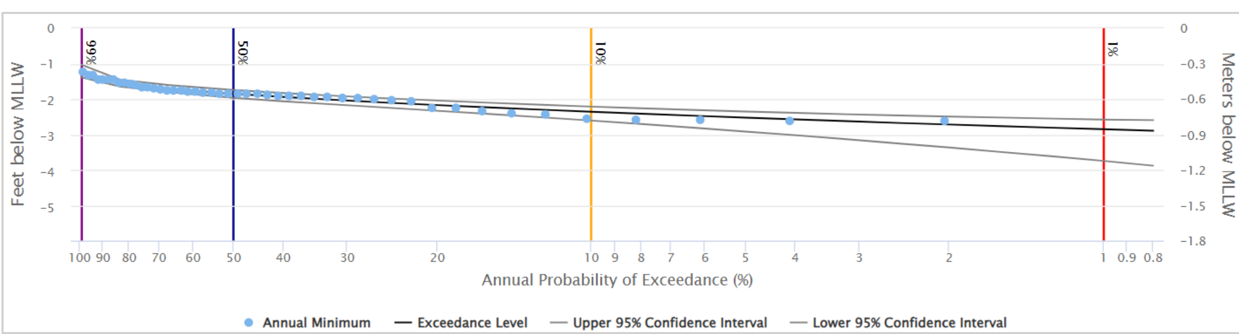

Figure 20: (Station 8726724): MLLW Annual Exceedance Probability

Figure 21 and **Figure 22** depict the seasonal variation of exceedance probability levels for MHHW and MLLW, respectively. The 1%, 10%, 50%, and 99% probabilities are shown in red, orange, blue, and purple. These values, calculated monthly, reveal when extreme water levels are most likely to occur throughout the year. Summer through fall provided the highest water levels, while winter through spring provided the lowest.

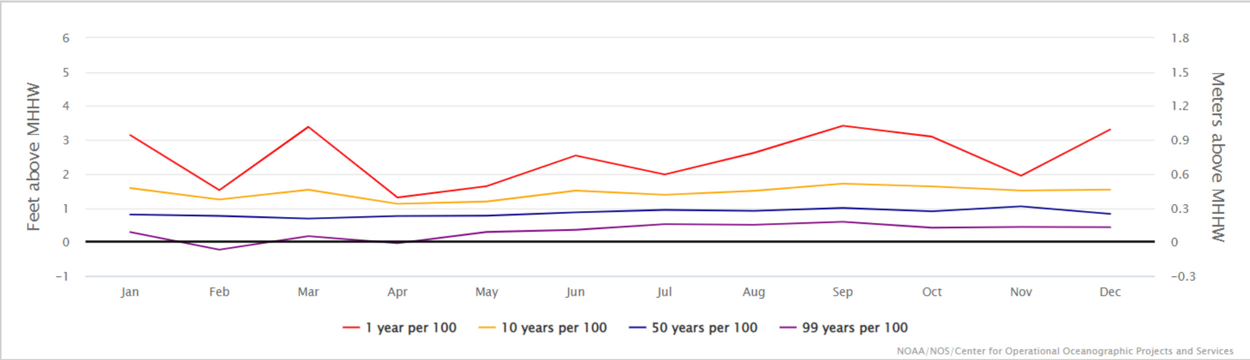

Figure 21: (Station 8726724): MHHW Seasonal Variation of Exceedance Probability Levels

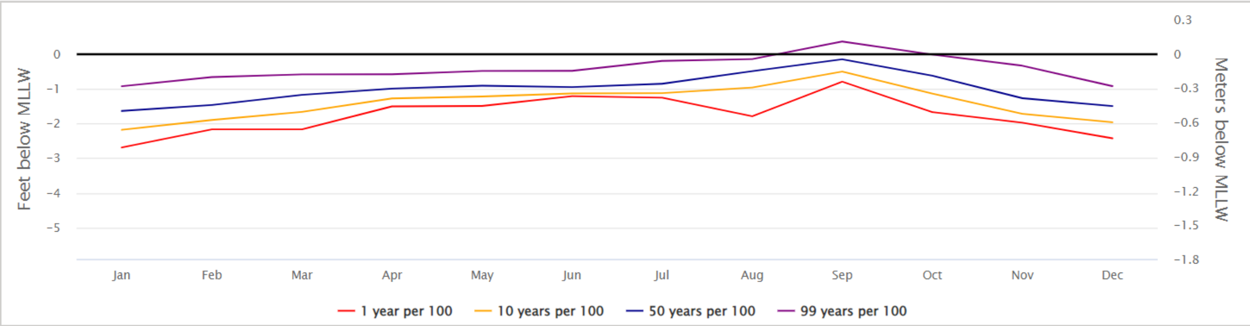

Figure 22: (Station 8726724): MLLW Seasonal Variation of Exceedance Probability Levels

Figure 23 - Figure 26 present annual exceedance probability levels relative to tidal datums and the geodetic North American Vertical Datum for 1992, 2014, 2024, and 2030. The left projections show average levels based on the 1983–2001 National Tidal Datum Epoch, while the right projects exceedance probability levels and tidal datums.

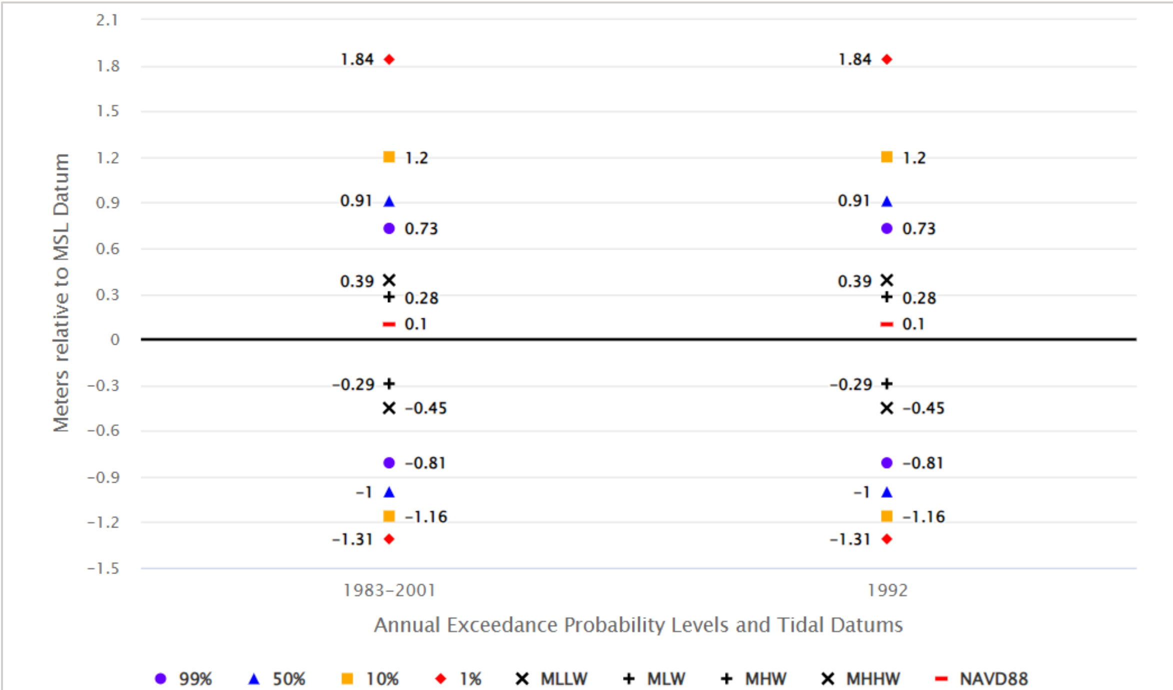

Figure 23: (Station 8726724): 1992 Tidal Datums and Exceedance Probability Levels

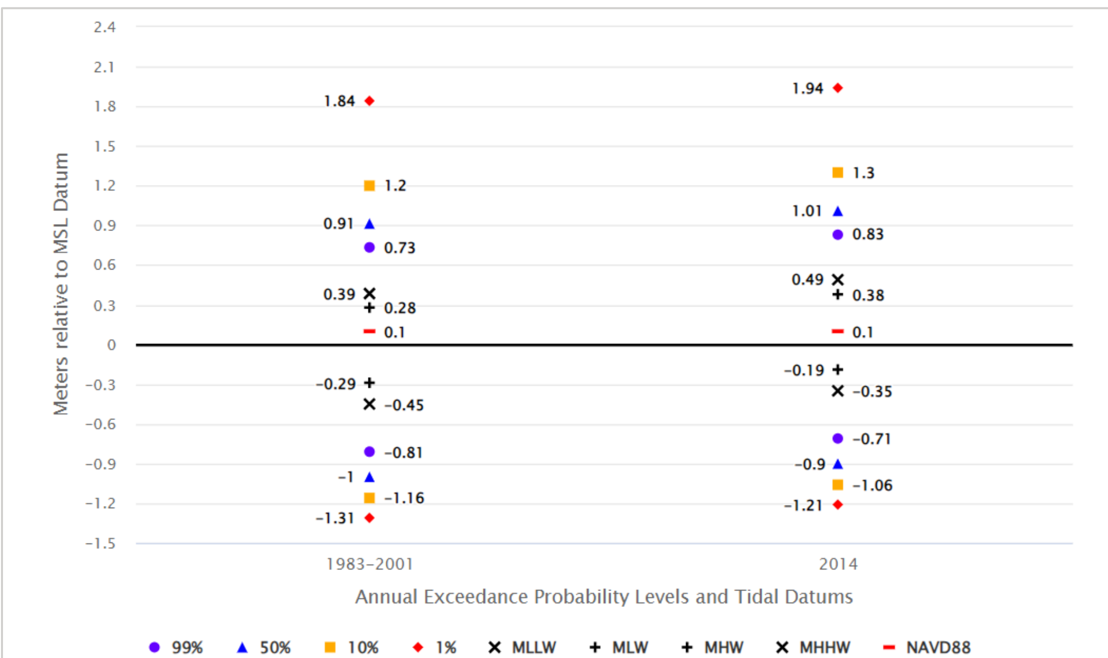

Figure 24: (Station 8726724): 2014 Tidal Datums and Exceedance Probability Levels

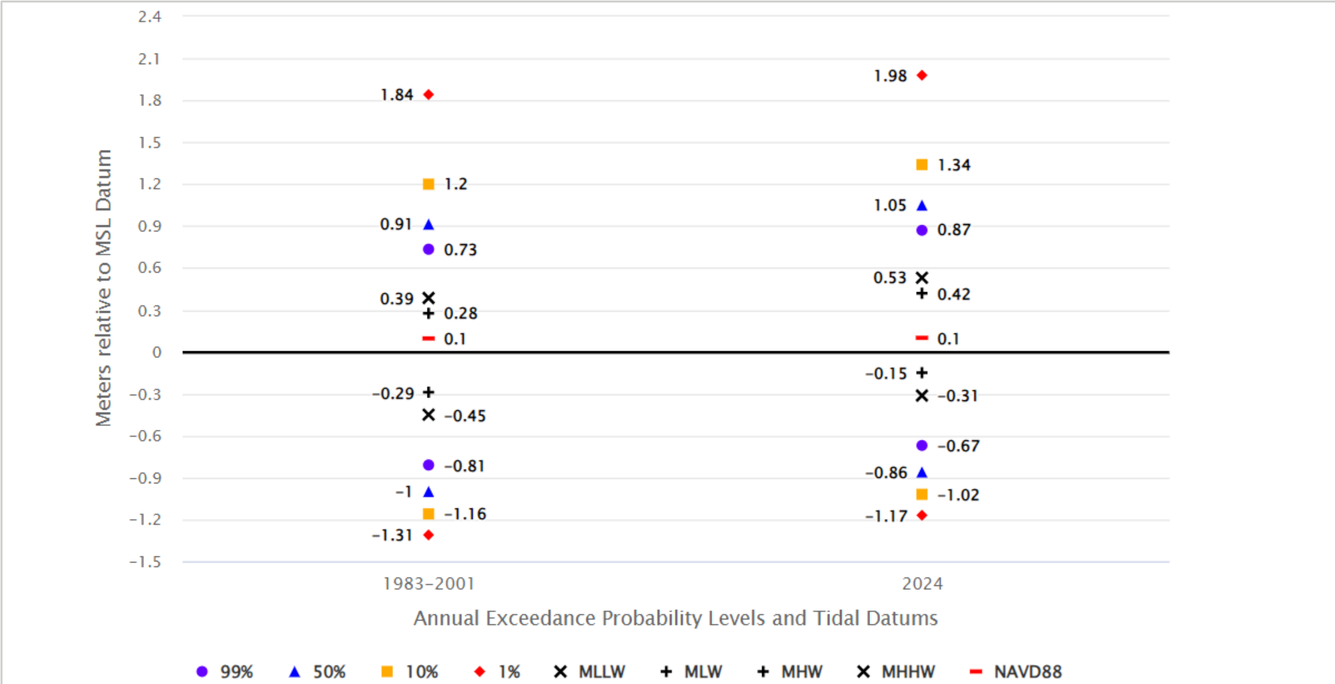

Figure 25: (Station 8726724): 2024 Tidal Datums and Exceedance Probability Levels

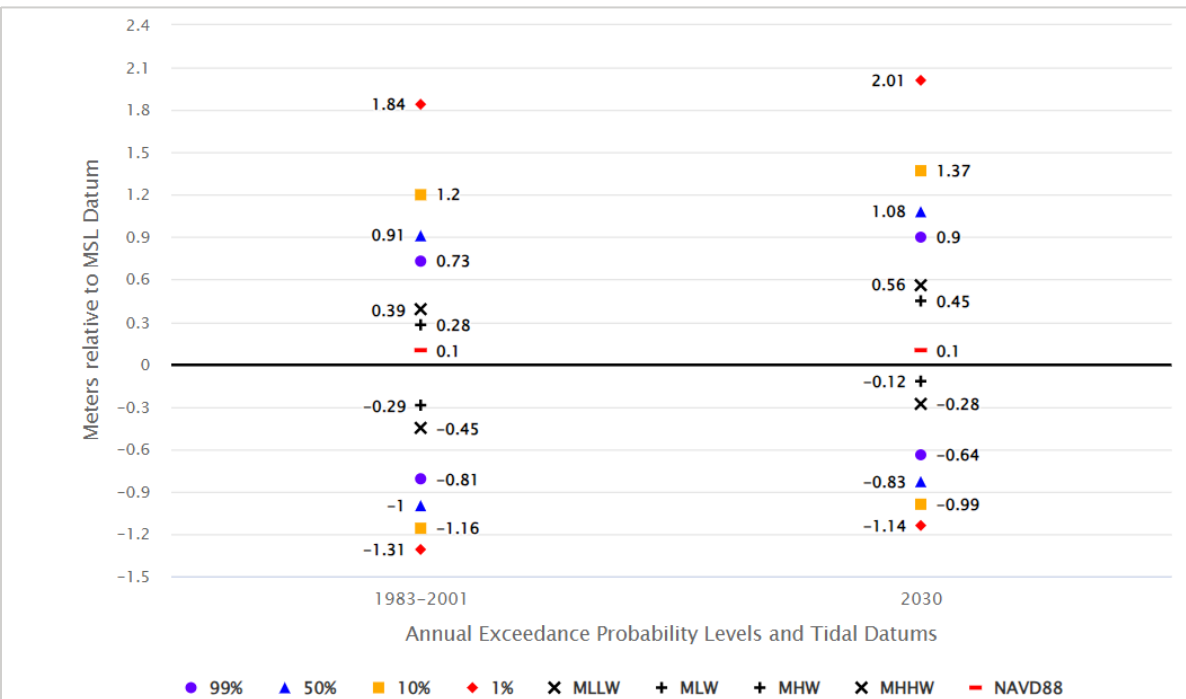

Figure 26: (Station 8726724): 2030 Tidal Datums and Exceedance Probability Levels

Extreme water level and exceedance probability modeling are essential to the engineering process. The data is critical in determining design parameters for any coastal structure, allowing it to withstand a high-water event. This information helps coastal communities plan ahead and attack problems before they arrive.

1.2.4 Design Water Levels

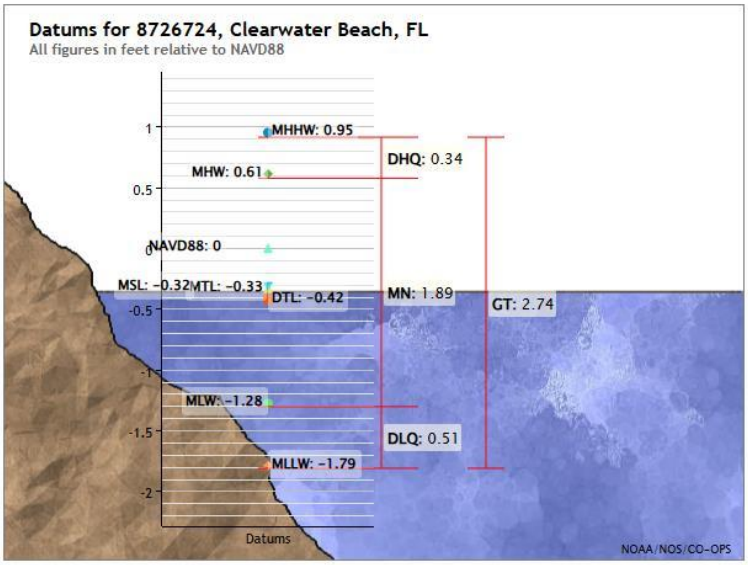

Figure 27: Clearwater Beach Datum (in ft-NAVD88)

Figure 27 provides the tidal datum information for station 8726724 located at Clearwater Beach, relative to the NAVD88 vertical datum. The diagram illustrates various tidal datums in feet, such as Mean High Water (MHW) at 0.61 feet, and Mean Low Water (MLW) at -1.28 feet. This data, based on the epoch from 1983 to 2001, is a key part of the coastal design process.

Design water levels are calculated using NOAA's Extreme Water Level database, which provides exceedance probability levels based on historical tidal data (**Figure 25**). These values, originally referenced to Mean Sea Level (MSL), are converted to the North American Vertical Datum of 1988 (NAVD88) by subtracting 0.32 feet (**Figure 27**), as specified by NOAA's datum conversion for the site. This ensures consistency in elevation references for engineering and planning purposes.

Annual Chance	Return Period (years)	NOAA 2024 (ft NAVD88)
50.0%	2	3.12
20.0%	5	3.67
10.0%	10	4.08
5.0%	20	4.71
4.0%	25	4.91
3.3%	30	5.08
2.0%	50	5.54
1.0%	100	6.18
0.2%	500	7.64

Table 1: Design Water Levels

1.2.5 Hurricane Wave Heights

Table 2-Table 5 show the average wave heights per day produced by four (4) different hurricanes (Ian, Nicole, Helene, and Milton), gathered from National Data Buoy Center (NDBC) Buoy 42098,

West of Clearwater Beach, near the project area. Waves as high as 8.38 feet and as low as 1.2 feet were recorded. This information provides design perimeters for any future coastal project in the area, as any structure will need to be able to withstand these extreme storm conditions.

Average WVHT Per Day – NDBC Buoy 42098									
2022 Sep.-Oct.	23rd	24th	25th	26th	27th	28th	29th	30th	1st
Meters	0.44	0.54	0.49	0.40	0.65	2.02	2.46	1.18	0.57
Feet	1.33	1.62	1.47	1.20	1.94	6.05	7.39	3.55	1.70

Table 2: Hurricane Ian Wave Heights

Average WVHT Per Day – NDBC Buoy 42098					
2022 November	7th	8th	9th	10th	11th
Meters	0.55	0.83	1.30	2.28	1.47
Feet	1.65	2.48	3.90	6.85	4.40

Table 3: Hurricane Nicole Wave Heights

Average WVHT Per Day – NDBC Buoy 42098						
2024 September	24th	25th	26th	27th	28th	29th
Meters	0.54	0.86	2.79	2.77	1.11	0.73
Feet	1.63	2.59	8.38	8.31	3.33	2.19

Table 4: Hurricane Helene Wave Heights

Average WVHT Per Day – NDBC Buoy 42098					
2024 October	7th	8th	9th	10th	11th
Meters	1.14	0.84	1.79	2.17	0.91
Feet	3.41	2.51	5.38	6.51	2.72

Table 5: Hurricane Milton Wave Heights

1.3 SAV Survey and Water Quality Sampling

A reconnaissance submerged aquatic vegetation (SAV) survey was conducted on January 11th, 2024. The SAV survey mapped the extent and condition of seagrass beds along the shoreline, identifying variations in species density, blade length, and sediment deposition near outfalls (**Figure 30** and **Figure 31**). Seaward from the shore, shallow grass flats transition from sparse *Halodule wrightii* nearshore to a dense mixture of other seagrass types (*Halodule wrightii*, *Syringodium filiforme*, and *Thalassia testudinum)* in deeper areas. The landward edges of the seagrass bed were precisely delineated using a sub-meter GPS, while photographic documentation was used to capture and emphasize the potential impacts of bluff erosion and stormwater runoff.

A baseline water quality initial sampling occurred on January 4th, 2024. Water quality samples were collected from three outfalls (OFs) **(Figure 28, Figure 29, and Figure 31)**:

- OF1, a stormwater conveyance canal between the northern extent of the bluffs in Belleair and the shoreline of the Belleair Country Club Golf Course. As can be seen in **Figure 28,** the evident water quality treatment has been identified to prevent upland pollutants entering and degrading the nearshore waters and ICWW
- OF3, located farther south along the bank of the bluffs in Belleair adjacent to the intersection of Manatee Road and Bayview Drive. The main treatment that this outfall has is the baffle box located just upstream of this outfall.

- OF4, located in the southernmost extent of the study area, adjacent to Harborside Drive at the seawall. This outfall is equipped with pipe grates (i.e., debris bars or trash screens) designed to intercept large debris and trash before reaching the ICWW. While effective for capturing solid waste, this treatment offers minimal protection against micro-particles, nutrients, and bacteria that continue to enter and degrade the nearshore waters and the ICWW.

Figure 28. Outfall 1 – Headwall

Figure 29. Outfall 3 (Left) and Outfall 4 (Right)

Sampling also included a reference station (W3) situated offshore roughly 4,300 feet west of OF1. Results were compared to long-term averages (2003-2023) and regulatory thresholds. High sedimentation rates at OF1, particularly following Hurricane Ian in September 2022, potentially pushed back the extents of submerged aquatic vegetation in the area. Additionally, it was anticipated that an outfall (OF2) existed between OF1 and OF3, but no such outfall was identified during field surveys.

Figure 30: SAV Survey Results

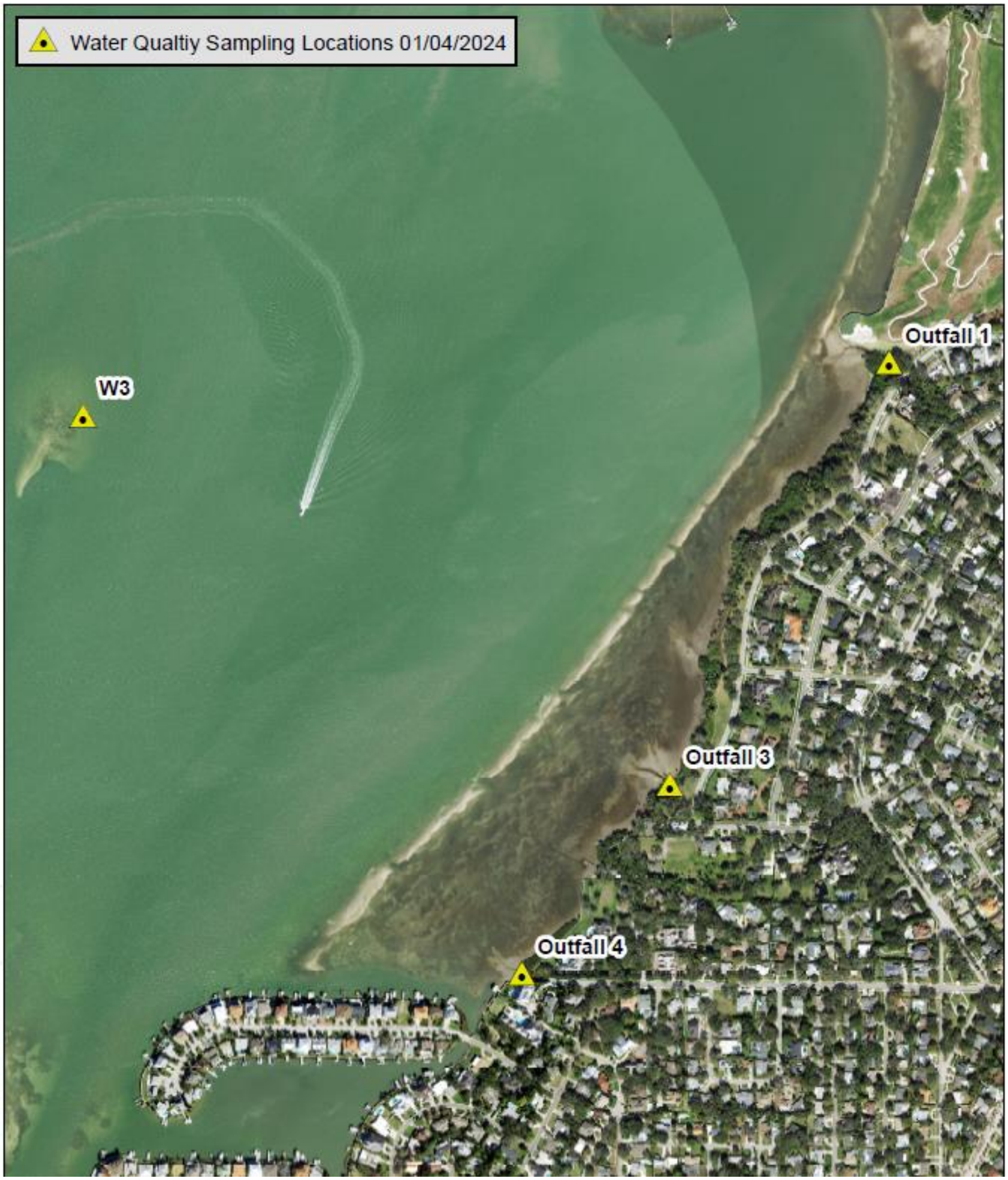

Figure 31: Outfalls and Water Quality Sampling Site

2. DATA COMPILATION AND ANALYSIS

As mentioned in Section 1.1.3, the groundwater monitoring data was collected for monitoring wells MW-1, MW-2, and MW-3. **Table 6** shows the collected measurements. MW-2, between the Belleair Country Club seawall and the intersection of Bayview drive and Ocala Road, consistently recorded the deepest water levels, ranging from 11.30 feet (6/21/2024) to 6.38 feet (8/8/2024). This was most likely due to heavy rainfall or wave impacts given its location near the shoreline. These fluctuations suggest that subsurface water movement in the area could destabilize the bluff by displacing soil and exacerbating erosion. MW-3, situated inland, recorded the shallowest water levels, with a high of 7.28 feet (6/21/2024) and a low of 2.99 feet (10/14/2024). This indicates limited vertical drainage and greater surface water runoff, which may contribute to bluff erosion through waterflow heading west. MW-1, located near OF3 along Bayview Drive, showed moderate water level fluctuations, with a high of 9.79 feet (6/21/2024) and a low of 6.09 feet (10/14/2024). These results are impacted by its location next to OF3, where wave impacts, subsurface drainage, and runoff combine. These observations show how local hydrology impacts erosion and shapes the project area. To improve data accuracy, new groundwater monitoring data was collected on February 20, 2025, and March 7, 2025, replacing previously extrapolated values. Additionally, a final sample was performed on March 28, 2025, to replace the March 29, 2024, sample. These updates have enhanced the dataset's reliability and provided a clearer understanding of site conditions.

Well Reading	Depth to Water (feet)			
	Date	MW-1	MW-2	MW-3
1	2/20/2025	9.46	9.57	5.80
2	3/7/2025	9.52	9.65	5.42
3	3/29/2024	8.75	9.72	5.70
4	4/18/2024	8.60	9.85	5.81
5	5/9/2024	9.48	10.43	6.50
6	5/30/2024	9.68	10.94	6.81
7	6/21/2024	9.79	11.30	7.28
8	7/10/2024	9.12	10.33	6.52
9	8/8/2024	8.01	6.38	3.69
10	9/6/2024	6.21	7.56	3.06
11	10/14/2024	6.09	7.78	2.99
12	11/1/24	8.15	8.29	3.59
13	1/1/25	8.65	9.00	5.01

Note: The initial water level measurements were approximated and based upon saturated soils encountered during installation.

Table 6: Groundwater Monitoring Well Data

The laboratory results of the groundwater samples are shown in **Table 7-Table 9**. These results highlight the impact of nutrient and bacterial loading on bluff erosion mechanisms, as shown in the elevated nitrogen and phosphorus concentrations at outfalls compared to long-term averages and regulatory benchmarks**.** While Total Suspended Solids levels and chlorophyll-a were negligible (2 mg/L at all outfalls), the elevated nutrient loads (NOx and Ortho-P) and bacterial concentrations (E. coli and Enterococci) indicate a problem caused by runoff that can contribute to bluff destabilization and habitat destruction through processes like eutrophication and soil chemistry alteration. The relatively low turbidity levels at the outfalls (1.4 to 2.2 NTU) reflect the clear water conditions observed but do not negate the potential for long-term impacts on soil integrity from cumulative runoff events.

Parameter	OF1	OF3	OF4	W3	LT Avg	LT Max
Chlorophyll-a, corrected (µg/L)	0.25U	0.25U	0.25U	5.5	5.2	82
Ammonia N (mg/l)	0.016I	0.08	0.12	0.65	0.006	0.02
NO_x as N (mg/l)	0.56	0.46	0.21	0.011I	0.01	0.04
TKN (mg/l)	0.68	0.58	0.56	0.82	0.51	1.3
Total Nitrogen (mg/l)	1.24	1.03	0.77	0.83	0.52	1.4
Ortho-Phosphate as P (mg/l)	0.11	0.12	0.21	0.002U	0.01*	0.06*
Total Phosphorus as P (mg/l)	0.10	0.13	0.19	0.015	0.03	0.13
Total Suspended Sediments (mg/l)	2.00I	2.00I	2.00I I	82	14.2	53
E. coli (cfu/100ml)	934	488	617	767	6.25*	20*
Enterococci (cfu/100ml)	638	1,106	1,081	10U	20*	20*

Table 7: Laboratory analyzed parameters at outfalls (OF) and reference area station (W3)

Parameter	OF1	OF3	OF4	W3	LT AVG	FDEP NNC	Mean EMC
Chlorophyll-a, corrected (µg/L)	0.25U	0.25U	0.25U	5.5	5.2	7.6	
Total Nitrogen (mg/l)	1.24	1.03	0.77	0.83	0.52	0.58	2.07
Total Phosphorus as P (mg/l)	0.10	0.13	0.19	0.015	0.03	0.06	0.327
Total Suspended Solids (mg/L)	2.00I	2.00I	2.00I	82	14.2	-	37.5

Table 8: Laboratory analyzed parameters at outfalls (OF), reference site (W3), reference area long-term average, FDEP Numeric Nutrient Criterion (NNC) and Single-Family Residential EMC

Parameter	OF1	OF3	OF4	W 3	LT AVG	LT Min	LT Max
Temperature (°C)	20.7	20.4	18.6	16.6	24.8	11.6	32.7
Specific conductance (µS/cm)	927	783	698	49,992	50,591	1,218	56,860
Salinity (ppt)	0.5	0.4	0.3	33	33	0.6	38
pH	7.4	7.9	8.0	8.1	8.1	6.8	8.5
Dissolved oxygen (DO) (mg/L)	6.1	8.7	8.0	8.4	6.4	0.8	13.3
DO % saturation	67	96	85	105	96	6	188
Turbidity (NTU)	1.4	1.5	2.2	7.7	3.9	0.4	54.0

Table 9: In situ water quality measurements taken at sampling depth

The results of the SAV survey are shown in **Figure 30** showed elevated sand flats at the end of each outfall, which appear to hinder seagrass colonization. This could intensify erosion of the bluff. These sand flats, created by sediment transport and outfall drainage, may destabilize the landward edge of the bluff, as sediment accumulation raises the elevation beyond the reach of seagrass growth. While the presence of emergent plants like the *Spartina* species and short seagrass blades (*Halodule wrightii*) near the outfalls could be seen as positive for bluff stabilization, the location of these emergent seagrasses is within an unstable area with significant sediment movement, hindering their growth. As a result, this could hinder the bluff's stability and contribute to a destructive erosion cycle.

The 2016 as-built drawings for the Bayview Drive Street and Drainage Improvements, acquired from the SWFWMD (**Appendix G: Southwest Florida Management District Cooperative Funding Agreement and Bayview Drive As-Builts**), show significant improvements to the drainage infrastructure from previous condition through added curb inlets, storm manholes, outfalls, and water meters. These elements were placed to manage stormwater efficiently, improve accessibility, and provide necessary utility upgrades. Water meters and curb inlets were added to manage and measure stormwater runoff effectively, ensuring accurate monitoring across the site. Curb inlets channel surface runoff into the drainage system, reducing the risk of pooling and localized flooding during heavy rain. Stormwater manholes facilitate access to underground drainage pipes for maintenance and inspections. These drainage upgrades along the Bayview Drive have assisted with reduced rainfall flooding and improved water quality by preventing debris accumulation. While the outfalls within the bluff are essential to discharge surface runoff from Bayview Drive, time of high discharges are observed to impact the erosion rates around the bluffs. APTIM is assessing the feasibility of erosion mitigation measures around outfalls such as added headwalls, pad riprap, and flex valves. Installing low-flow fixtures, rainwater harvesting systems, and irrigation methods that utilize treated water can substantially decrease runoff volume, reducing nutrient and bacterial contamination, and ultimately the erosive forces.

3. WATERSHED AND WATER QUALITY ASSESSMENT

The Bluff Restoration and Erosion Abatement project along the Hallett Park shorelines aims to maximize natural systems restoration and improve water quality through nutrient reduction Best Management Practices (BMPs). With this end goal in mind, this section builds upon the findings from previous tasks by evaluating potential water quality issues and identifying opportunities to reduce pollutant loading at the project site. Section 3 involved a collaborative effort between APTIM, Environmental Science Associates (ESA), the Town of Belleair, SWFWMD to assess key factors affecting water conservation, storm runoff pathways, and pollutant management strategies. This phase includes a comprehensive analysis of stormwater runoff patterns, potential mitigation strategies, and the implementation of Best Management Practices to reduce the impact of upland pollutants on nearshore waters and the Intracoastal Waterway (ICWW). The following subsections provide a detailed assessment of data collection efforts, evaluation methodologies, and key findings related to watershed health and water quality improvements.

3.1 Water Conservation, Care of Water, and Water Reuse

Water conservation and reuse are integral components of a holistic watershed management approach, particularly in coastal communities like Town of Belleair. These practices reduce the demand on potable water supplies while helping to mitigate water quality issues linked to urban runoff and landscape irrigation. When paired with structural and non-structural BMPs, conservation and reuse strategies can play a significant role in reducing pollutant loading and preserving the health of sensitive nearshore ecosystems like those found along the Hallett Park shoreline and Intracoastal Waterway (ICWW).

Low-impact water use practices—such as installing low-flow plumbing fixtures, smart irrigation systems, and drought-tolerant landscaping—can reduce water waste and lessen the volume of runoff generated during irrigation events. Capturing rainwater through barrels or cisterns provides a non-potable source of water for landscaping, further reducing the use of treated water and limiting runoff. These strategies are particularly relevant in upland areas like Bayview Drive, where residential irrigation contributes to nutrient-laden flows entering stormwater systems.

Water reuse and conservation efforts can be reinforced with **Stormwater BMPs** proposed for pollutant loading reduction. Features such as **vegetated swales, rain gardens, and bio-sorption trenches** promote natural infiltration and evapotranspiration, reducing both runoff volume and pollutant concentrations. These green infrastructure elements can be designed to capture and reuse stormwater for irrigation of native plantings upstream of Hallett Park. Due to potential slope instability issues these water detention features may cause, they are not proposed as part of the conceptual design alternatives within the project site.

Stormwater treatment trains—which combine multiple BMPs such as rain gardens, filter strips, and bio-retention areas—can be strategically placed in the low points of Bayview Drive to maximize pollutant removal efficiency. These systems reduce flow velocities, encourage infiltration, and promote nutrient uptake by vegetation, supporting both erosion control and water quality improvements downstream.

Public outreach and **education** further amplify the benefits of conservation and reuse. By promoting awareness around **irrigation efficiency**, **proper fertilizer use**, and personal pollution prevention, **residents can play an active role in reducing nutrient and bacterial inputs**. The Town of Belleair can leverage existing education programs from Pinellas County or develop site-specific campaigns tailored to watershed goals. Infographics similar to one shown in **Figure 32** can be beneficial for educational purposes during public outreach meetings.

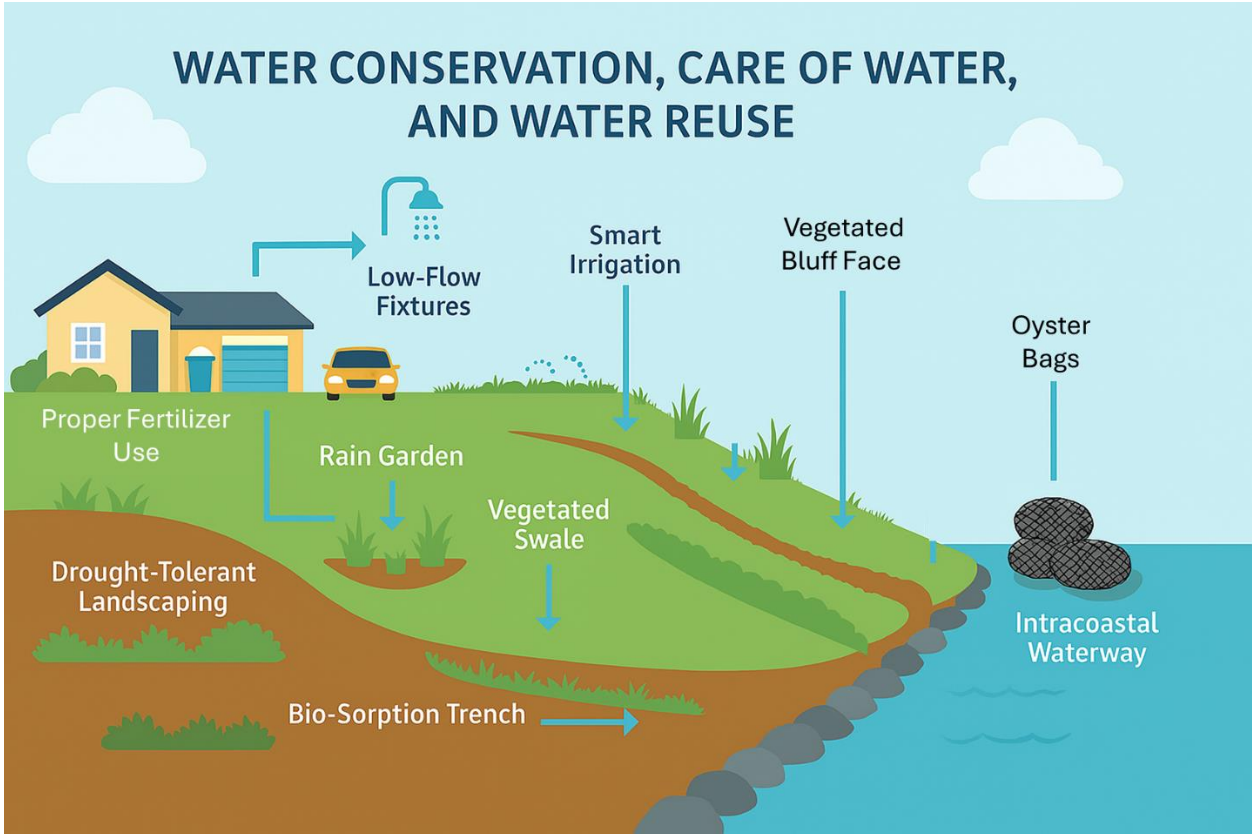

Figure 32. Example water conservation, care, and reuse strategies for the study area

Ultimately, integrating water conservation and reuse with resilient shoreline restoration and stormwater BMPs offers a systems-based solution. These measures not only address water quantity and quality issues but also contribute to climate adaptation, coastal resilience, and long-term environmental health for Belleair's community and ecosystems.

3.2 Water Quality Sampling Efforts

3.2.1 Introduction

As part of Water Quality Assessment efforts, ESA has conducted event-driven stormwater quality sampling at the three stormwater outfalls and long-term Pinellas County ambient surface water monitoring site (W3)**. Figure 33** shows the locations of the outfalls and the water monitoring site. The water quality monitoring efforts served to characterize the stormwater inputs to, as well as the ambient conditions of the receiving water, Clearwater Harbor (also referred to as ICWW throughout this document). After an initial water quality sampling event on January 04, 2024, which was used as a baseline event, five additional events were conducted within 24-hours of a rainfall event to determine concentrations of parameters of interest (e.g., nutrients, suspended solids, and bacteria) (**Table 10 –** Full Lab Reports are provided in **Appendix F: ESA Analytical Test Report**). In addition, a reference area adjacent to the project sites was denoted (Site W3; **Figure 33**), and ambient water quality conditions characterized in tandem with the event-driven sampling effort.

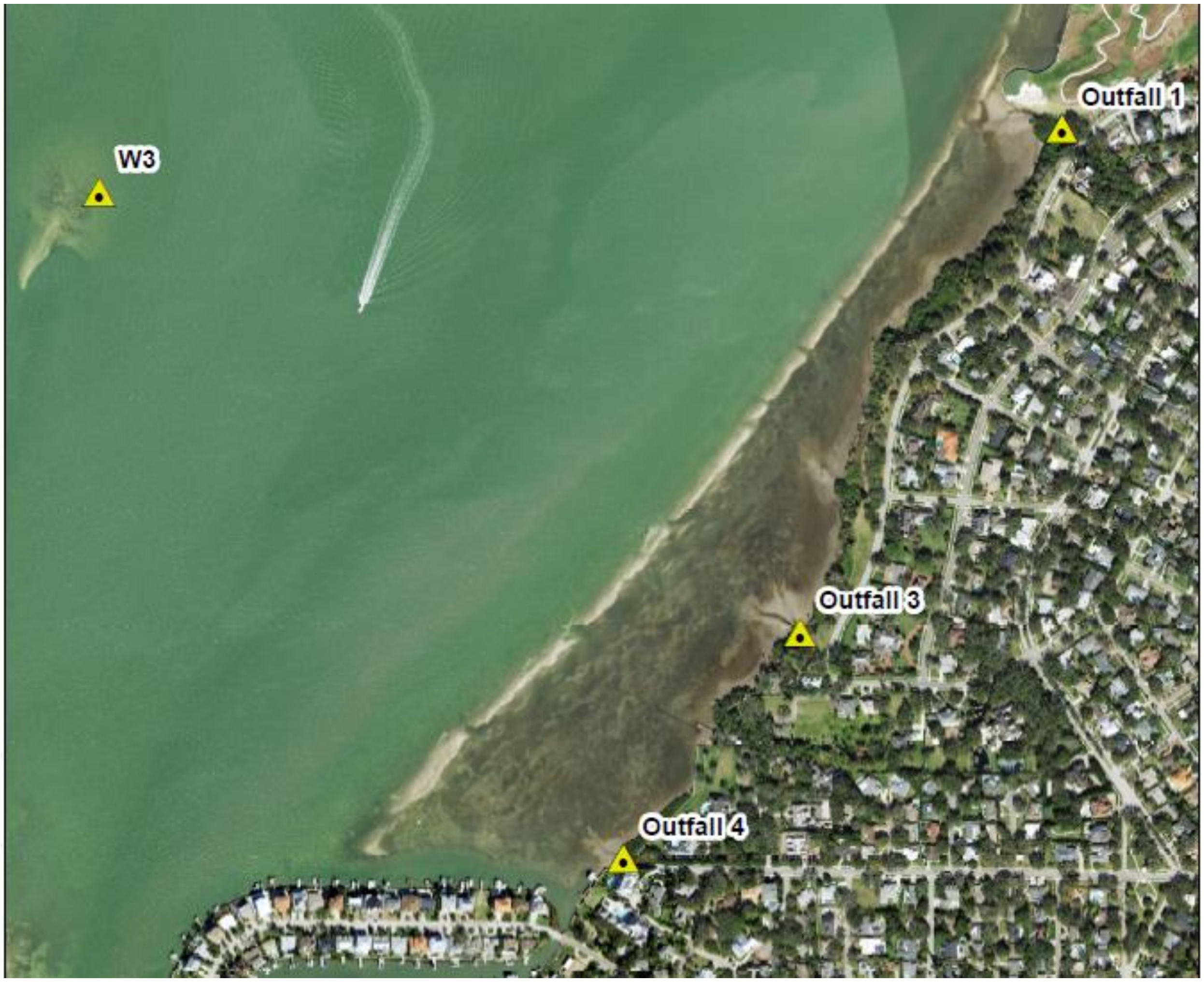

Figure 33. Water Quality Sampling Locations

Table 10. Completed Sampling Event and Associated Previous 24-hr Accumulated Rainfall (in).

Sampling Event	Sampling Date	Rainfall (in)*
Baseline	1/4/2024	0.36
1	11/20/2024	0.42
2	12/11/2024	0.26
3	12/30/2024	0.33
4	2/20/2025	0.68
5	2/24/2025	1.5

*Source: USGS 02309100

Pinellas County implements a randomized stratified sampling effort, therefore; the long-term average of existing, available County Water Quality Data retrieved from the Florida Department of Environmental Protection (FDEP) Impaired Waters Rule database Run 66 were calculated from all monitoring sites located within the reference area. This effort is intended to **support the**

development of conceptual project elements along the bluff to mitigate erosion and address stormwater outfall impacts to the adjacent seagrass beds.

3.2.2 Field Evaluation

Hallett Park is bordered on the northern limits by the Belleair County Club Golf Course (**Figure 33**). Outfall 1 (OF1) is a cascading stormwater conveyance canal which discharges between the northern extent of the park and the hardened shoreline of the golf course. Through review of available aerial imagery from 2007 to 2025 (Google Earth), and post-hurricane imagery from the National Oceanic and Atmospheric Administration (NOAA), it is speculated that high rates of sedimentation occurred during the aftermath of Hurricane Ian in September 2022, Hurricane Helene in September 2024, and Hurricane Milton in October 2024 (**Figure 34**). These events potentially pushed back the extents of submerged aquatic vegetation (SAV) around this outfall. From OF1 south to outfall 3 (OF3), bluffs are characterized as a vegetated, steeply sloped bank, with elevation drops of approximately 10 to 20 feet to the shoreline. It was anticipated that an outfall existed between OF1 and OF3, denoted outfall 2 (OF2), but during sampling, no outfall was found in this area. From OF3 south to outfall 4 (OF4), the shoreline transitions from bank to seawall. Seaward from shore consists of shallow grass flats, comprised initially of sparse *Halodule wrightii* which changes quickly to a dense mixture of *Halodule wrightii*, *Syringodium filiforme*, and *Thalassia testudinum.*

Figure 34. Sand deposition observed from satellite imagery adjacent to OF-1.

3.2.3 Water Quality Characterization

A total of six storm events were captured including the baseline event (**Table 10**)**.** The intent was to capture rain events within both the wet and dry seasons, as wet season stormwater runoff loads are typically higher than those observed in the dry season due to increased rainfall. Many factors can contribute to pollutant concentrations at the outfalls during the wet and dry season, including human activities (i.e. fertilizing) and time between flushing events. Without sampling it is hard to determine what the changes in concentrations would be, but due to increased volume of runoff it is most likely that pollutant loads would be substantially higher in the wet season. However, due to scheduling constraints, all captured events were completed within the dry season (November through May). As such, the presented water quality characterization evaluates only dry season monitoring efforts which may artificially lower the anticipated stormwater runoff contribution associated with nutrients, solids and bacteria. As such, the consultant team reviewed provided monitoring information associated with the Town's NPDES permit as well as readily available data from regionally appropriate adjacent communities to estimate wet season loadings.

Samples were initially planned to be collected at four outfall structures plus the reference station. Since no outfall structure was found at OF2, they were only collected at OF1, OF3, OF4, and W3. Outfalls were sampled before their runoff mixed with the receiving water in ICWW. All samples were placed on ice and transported for analysis by a NELAP-certified laboratory within required hold-times. **Stormwater runoff was observed in the field as being clear in color and devoid of tannins, turbidity, and phytoplankton.**

In **Table 11 and Table 12,** the average and maximum concentrations for laboratory analyzed parameters across six sampling events were compared against the long-term (LT) (2003 to 2024) reference area average (LT Avg) and maximum (LT Max) values. Yellow cells denote results that exceed the long-term reference area average whereas an orange cell means the result exceeds **both** the long-term reference area average and maximum. Graphics depicting the discrete concentrations for each parameter for all sampling events and locations are provided in **Appendix F: ESA Analytical Test Report**. The following conclusions are drawn from the data presented in **Table 11 - Table 13:**

- At all three outfall locations, **inorganic nutrients** (nitrates and nitrites as nitrogen (NOx), and ortho-phosphate as phosphorus (Ortho- P)) **were elevated** compared to the LT average and maximum. Typically, due to longer periods between rainfall events, the nutrient concentrations can be higher in the dry season during these first flush events as organic material has a longer time to break down between events.
- **Chlorophyll-a** values at all outfalls were always below the LT average. Since these values were so low there is no anticipated difference between dry and wet season. It is most likely there is insufficient residence time during or before rain events for phytoplankton production.
- **Total Suspended Solids (TSS)** fluctuated from below the LT average, to occasionally greater at OF1 and OF3.
- It was generally observed in the field that **higher turbidity**, which contributes to TSS, **was prevalent at OF1 and OF3** when sampled less than 1 hour from the rainfall event.
- In regard to **bacteria**, the State of Florida defines the maximum allowable level of bacteria,

E.coli for Class III freshwater and *Enterococci* for Class III marine waterbodies as 126 CFU and 35 CFU, respectfully. **All outfall sites exceeded this level**, as well as the Ten Percent Threshold Value (TPTV) of 410 CFU for freshwater (*E.coli*) and 130 CFU for marine waters (*Enterococci*).

- In situ ambient water quality conditions at sample depth are presented in **Table 13**. All parameters fell within expected values for the outfalls compared to the LT average.

In addition to the average and maximum values provided in below tables, scatter plots were presented in **Appendix F: ESA Analytical Test Report**.

Table 11. Average value of laboratory analyzed parameters at outfalls (OF) and reference area station (W3) across six sampling events, compared to long-term Average and Maximum of the reference area.

Parameter	OF1 Avg	OF3 Avg	OF4 Avg	W3 Avg	LT Avg	LT Max
Chlorophyll-a, corrected (µg/L)	0.9	0.8	0.3	6.4	5.2	82
Ammonia N (mg/l)	0.05	0.08	0.09	0.80	0.006	0.02
NO_x as N (mg/l)	0.42	0.34	0.38	0.01	0.01	0.04
TKN (mg/l)	0.98	1.01	0.80	0.77	0.51	1.3
Total Nitrogen (mg/l)	1.39	1.35	1.18	0.78	0.52	1.4
Ortho-Phosphate as P (mg/l)	0.11	0.15	0.21	0.01	0.01*	0.06*
Total Phosphorus as P (mg/l)	0.14	0.21	0.23	0.03	0.03	0.13
Total Suspended Solids (mg/l)	11.2	14.0	3.9	75.9	14.2	53
E. coli (cfu/100ml)	2106	2534	7968	649	6*	20*
Enterococci (cfu/100ml)	7614	8754	20344	33	20*	20*

*Sample size was less than 20.

Table 12. Maximum Value of laboratory analyzed parameters at outfalls (OF) and reference area station (W3) across six sampling events, compared to the long-term Average and Maximum of the reference area

Parameter	OF1 Max	OF3 Max	OF4 Max	W3 Max	LT Avg	LT Max
Chlorophyll-a, corrected (µg/L)	3.1	3.3	0.5	12.9	5.2	82
Ammonia N (mg/l)	0.14	0.14	0.19	1.12	0.006	0.02
NO_x as N (mg/l)	0.57	0.47	0.71	0.01	0.01	0.04
TKN (mg/l)	2.0	2.0	1.4	1.2	0.5	1.3
Total Nitrogen (mg/l)	2.6	2.3	2.1	1.2	0.5	1.4
Ortho-Phosphate as P (mg/l)	0.23	0.27	0.38	0.03	0.01*	0.06*
Total Phosphorus as P (mg/l)	0.37	0.56	0.44	0.11	0.03	0.13
Total Suspended Solids (mg/l)	46.0	62.0	9.2	92.4	14.2	53
E. coli (cfu/100ml)	7,701	8,664	24,196	1,211	6.3*	20*
Enterococci (cfu/100ml)	24,196	24,196	24,196	146	20*	20*

*Sample size was less than 20.

Table 13. Average In situ water quality measurements at sampling depth.

Parameter	OF1	OF3	OF4	W 3	LT AVG	LT Min	LT Max
Temperature (°C)	22.3	22.2	21.4	19.3	24.8	11.6	32.7
Specific conductance (µS/cm)	608	525	590	50,134	50,591	1,218	56,860
Salinity (ppt)	0.3	0.3	0.3	33.2	33	0.6	38
pH	7.40	7.71	7.80	8.12	8.1	6.8	8.5
Dissolved oxygen (DO) (mg/L)	6.21	8.25	7.70	7.53	6.4	0.8	13.3
DO % saturation	70.9	94.2	86.5	98.7	96	6	188
Turbidity (NTU)	7.7	14.8	3.1	2.5	3.9	0.4	54.0

For additional context, **Table 14** provides the chlorophyll-a, total nitrogen, total phosphorus and/or total suspended solids concentrations from each sampled location compared to the FDEP 62-302.531 peninsular specific Numeric Nutrient Criteria (NNC) for streams and the event mean concentration (EMC) for a single-family residential land-use (Harper and Baker 2007). It is important to note that the NNC is expressed as an annual geometric mean and evaluated based upon the waterbody identification (WBID) extent; therefore, an observed discrete value exceedance does not constitute impairment. All three outfalls reported Total Nitrogen concentrations above the established annual criteria and the expected EMC from single-family residential land use. Similar was observed at OF2 and OF3 for Total Phosphorus.

Table 14. Average and Maximum concentrations for selected laboratory parameters at outfalls (OF), reference site (W3), FDEP Numeric Nutrient Criterion (NNC) and Single-Family Residential EMC.

Parameter	OF1		OF3		OF4		CIII-F	Mean EMC
	Avg.	Max.	Avg.	Max.	Avg.	Max.		
Chlorophyll-a, corrected (µg/L)	0.85	3.1	0.84	3.3	0.31	0.5	20	
Total Nitrogen (mg/l)	1.39	2.6	1.35	2.3	1.18	2.1	1.54	2.07
Total Phosphorus as P (mg/l)	0.14	0.37	0.21	0.56	0.23	0.11	0.12	0.327
Total Suspended Solids (mg/L)	11.2	46.0	14.0	62.0	3.9	-9.2		37.5

Pinellas County implements a monitoring program as part of an Interlocal Agreement with the co-permittees included within the multi-jurisdictional interconnected urban MS4 permit which includes the Town of Belleair. In the absence of direct wet season stormwater monitoring at the above discussed outfall locations, estimated wet and dry season pollutant concentrations were calculated at the Rattlesnake Creek fixed station monitoring site (17-01). Rattlesnake Creek is a tidal tributary north of the project location in which a similar configuration of land uses and stormwater management practices are implemented. The ambient surface water quality data were queried and downloaded from the Pinellas County Water Atlas data portal[1] which contained data for the period of February 2018 through July 2024. The dataset was further refined to identify sampling events completed within 24-hours of a rain event equal to or greater than 0.1" as reported for the USGS McKay Creek (02309110) station. Summary statistics were calculated for those sampling events within either the dry (N=-6) or wet (N=7) season **(Table 15)**.

The average dry season concentrations were higher for Rattlesnake Creek when compared to the TN and TP concentrations calculated for OF1, OF3 and OF4. It is important to note that the Pinellas County monitoring program is implemented to characterize ambient surface water conditions not stormwater alone. Constricting the dataset to incorporate only monitoring efforts associated with rainfall was performed to present a characterization of Rattlesnake Creek under conditions which would most likely represent stormwater as the dominant surface water contribution to the Creek. Variability observed between the outfalls and Rattlesnake Creek could be attributed to factors such as baseflow influences within the Creek, storm characteristics and/or the timing of sampling.

[1] https://pinellas.wateratlas.usf.edu/

Table 15. Dry and Wet season average and maximum concentrations for selected parameters at Station 17-01 in Rattlesnake Creek for monitoring events associated with rainfall.

Parameter	Rattlesnake Creek			
	Wet Season		Dry Season	
	Avg.	Max.	Avg.	Max.
Total Nitrogen (mg/L)	2.09	2.29	2.17	3.27
Total Phosphorus (mg/L)	0.25	0.35	0.28	0.45
Total Suspended Solids (mg/L)	5.0	10.0	7.3	14.0

3.2.3.1 Estimation of Hydrologic and Pollutant Loads

Water quality characterization using concentrations can be a valuable tool to evaluate the status and trends within a waterbody. However, an evaluation of the pollutant load contributed from each outfall allows for a more comprehensive assessment for the potential water quality impact associated with an external contributor. The hydrologic load was estimated for each outfall using standard equations based on the infrastructure configuration. The pollutant load was estimated using the calculated hydrologic load and respective average pollutant concentration for each outfall. Based on this information, the relative contribution of each outfall was assessed to help prioritize the implementation of best management practices for reducing pollutant loads.

The method to calculate hydrologic and pollutant loads is described below. Two of the stormwater outfalls (OF3 and OF4) are reinforced concrete pipe, 72" and 36" diameter, respectively. The **estimated discharge** during each monitoring event was calculated using the water level in the outfall pipe at the time of sampling, an estimated slope of 1% and standard Manning's coefficient for concrete pipe (0.012). Stormwater outfall (OF1) is a weir structure (23 ft) with wing walls (1:1 slope) extending beyond the central straight section with a total length of 53.7 ft. The estimated discharge during each monitoring event at the time of sampling was calculated using a trapezoidal with sloped sides standard equation. The water level above the crest at the time of sampling and an estimated weir coefficient of 3.09 were used to calculate discharge **(Figure 35)**.

Figure 35. Representative site photograph of stormwater outfalls, OF1, (Left), OF3 (Center) and OF4 (Right)

The pollutant loads (total nitrogen, total phosphorus, and total suspended solids) were estimated under low and high discharge conditions calculated using the average concentration **(Table 16).** Due to limited sampling events, these results represent dry season loads only. Further sampling would need to occur to represent loads in the wet season. Stormwater outfalls OF1 and OF3 had similar estimated loads under this high-flow scenario; however, the low-flow scenario was more substantial at OF-1. The relative pollutant loads estimated from OF-4 were minor in comparison to the other outfalls.

Table 16. Estimated dry season pollutant load contribution under low & high discharge scenario

Outfall	Discharge Range	Parameter	Estimated Discharge (m^3/s)	Mean Concentration (mg/L)	Estimated Load (kg/d)
OF-1	Low	Total Nitrogen	0.03	1.39	3.6
	High		0.09	1.39	10.3
	Low	Total Phosphorus	0.03	0.14	0.4
	High		0.09	0.14	1.0
	Low	Total Suspended Solids	0.03	11.2	29.3
	High		0.09	11.2	83.3
OF-3	Low	Total Nitrogen	0.002	1.35	0.23
	High		0.08	1.35	8.8
	Low	Total Phosphorus	0.002	0.21	0.04
	High		0.08	0.21	1.4
	Low	Total Suspended Solids	0.002	14	2.4
	High		0.08	14	91.5
OF-4	Low	Total Nitrogen	0.0003	1.18	0.03
	High		0.001	1.18	0.1
	Low	Total Phosphorus	0.0003	0.23	0.01
	High		0.001	0.23	0.03
	Low	Total Suspended Solids	0.0003	3.9	0.1
	High		0.001	3.9	0.5

3.2.4 Evaluation of Water Quality Issues

The stormwater outfalls discharge into the waterbody identified (WBID) by FDEP as Clearwater Harbor South (WBID 1528), also referred to as ICWW. FDEP designated Clearwater Harbor South impaired for Total Nitrogen due to elevated annual geometric means above the established numeric nutrient criteria. Currently, a total maximum daily load (TMDL) or alternative restoration plan has not been developed to identify the factors attributing to elevated nitrogen nor project identified to reduce nitrogen loads to the Bay. Estuarine systems can be sensitive to nutrient inputs contributing to phytoplankton blooms, expressed as chlorophyll-a. In turn, the increased photosynthetic activity can negatively impact water clarity resulting in stress and/or loss of seagrass within an impacted area.

At times, the nutrient concentrations observed associated with the stormwater runoff from the monitoring outfalls exceeded the Class III freshwater stream criteria. This indicates that increased pollutant loading is attributed at these sites during some rain events. Along with providing shoreline protection, another goal of this project is to **maximize natural systems restoration and improve water quality through nutrient reduction BMPs.** Therefore several best management practices are proposed (see Sections 3.4 & 4) to **reduce nitrogen and**

phosphorus loading to the estuarine system to preserve the integrity of the existing seagrass beds and support overall Bay health.

In addition, sediment deposition areas are evident adjacent to the stormwater outfalls which impact the substrate and bathymetric conditions that currently support seagrass habitats (**Figure 34 and Figure 36**). The potential impact on water clarity, deposition on existing beds and alteration to the existing suitable site conditions are at risk due to increased sediment deposition. The aerial photography shown in **Figure 34** depicts the sediment deposition in 2024 and 2025. While two major "named" storms directly impacted the site conditions represented in the 2025 imagery, there is evidence prior to these storm events that deposition is persistent adjacent to the outfalls.

Figure 36. Drone imagery captured by APTIM at Outfall 3 showing visible sediment deposition and bathymetry impact due to stormwater discharge.

3.3 Evaluation of Storm Runoff Pathways and Potential Mitigation Strategies

Town of Belleair is located within Tampa Bay/Anclote River Watershed, in Coastal Zone 1 Drainage Basin that discharges directly to the Gulf. The Anclote River Watershed is located in the northernmost portion of Pinellas County, extending into Hillsborough and Pasco Counties. Within Pinellas County, it covers approximately 8,750 acres, with 5,421 acres situated in unincorporated areas. The watershed is characterized by a mix of residential, commercial, and recreational open spaces. At a more localized scale for the study area, Indian Rocks Road on the east acts as a drainage divide, and stormwater to the west of it is collected via curb and gutter flow, ultimately discharging to ICWW via outfalls along the bluffs in Belleair (**Figure 37**). The drainage area encompasses approximately 117 acres of residential land characterized by sandy soils with high infiltration rates.

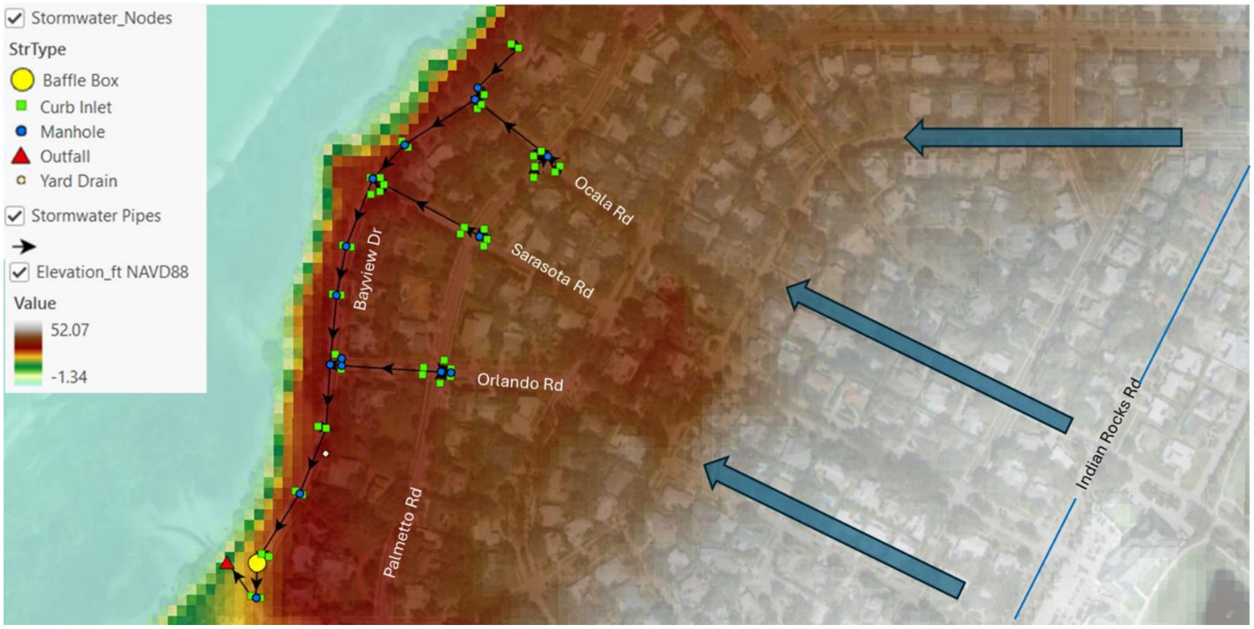

Figure 37. Current drainage network overlaid with Digital Elevation Model indicating flow directions and runoff patterns

Bayview Drive Street and Drainage Improvements project that was completed in 2016 captured and consolidated runoff that was previously discharged through multiple storm outfalls into a single pipe, directing flow to one outfall location (OF3). A stormwater baffle drop box, and an inline sump were installed to dissipate energy and reduce velocities at the outfall. To further reduce the velocity of stormwater discharged into the bay, the inline sump was constructed with the invert elevation of the final outfall pipe slightly above the bottom elevation of the bay. The bluff banks around the new outfall were stabilized with rubble rip-rap.

The existing storm outfalls were removed, abandoned, or capped, eliminating erosion and sedimentation at those locations. These improvements provided benefit to the existing seagrasses and mangroves along the shoreline and helped eliminate localized flooding in upstream areas. Despite the best efforts of this project, erosive runoff patterns and water quality issues persists in the study area. **Figure 38** shows an example of bare patches of grass on bluff bank in the vicinity of Outfall 3. This could be an indication of concentrated surface runoff, groundwater seepage or saturation, or a leaky pipe underground.

Figure 38. Bare patch of grass on bluff bank near outfall 3

Due to the likelihood of large storm events and debris entering the storm system, the existing drainage infrastructure, specifically the baffle box should be routinely maintained, and debris should be vacuumed in preparation of storm events and post-storm. Recommendations from certified APTIM civil engineers suggest that using pipes less than 24" in diameter can lead to an increased chance of water flow being obstructed by sediment or debris. Connecting pipes from curb inlets to manholes are shown as 18" in the as-built surveys, therefore inlet protection via sediment filters can be beneficial. There are three locations with two notable low points where sediment can be collected along the adjacent roadways:

- Intersection of Manatee Road and Bayview Drive
  - Elevation of curb inlet: 22.6 ft-NAVD88
  - Elevation of edge of payment: 22.5 ft-NAVD88
- Intersection of Bayview Drive and Sarasota Road
  - Elevation of curb inlet: 27.9 ft-NAVD88
  - Elevation of edge of payment: 27.9 ft-NAVD88
- Adjacent to the bridge at the north end of Bayview Drive
  - Elevation of curb inlet: 25.3 ft-NAVD88
  - Elevation of edge of payment: 25.2 ft-NAVD88

At the latter intersection, a barrier-free ramp to the park will allow water to flow out towards the ICWW, potentially contributing to erosion, despite representing a relatively small drainage area.

3.4 Best Management Practices

3.4.1 Best Management Practices for Management of Erosion and Upland Pollutants – Nutrient Loading Reduction Estimates

Effective management of bluff erosion and upland pollutants requires a combination of structural and vegetative practices to reduce runoff and improve water quality. Best Management Practices (BMPs) should focus on capturing stormwater and allowing sediments and pollutants to settle before reaching receiving waters. Pinellas County Stormwater Manual groups BMPs in five categories as shown in **Table 17**. A combination of multiple BMPs would yield most optimal results.

Table 17. List of BMPs and their functions (Pinellas County, 2024)

Treatment Process/Function	BMP Options	What is Removed?	How Does It Happen?
Flotation	Skimmers, Oil-Water Separators, and Density Separators	Trash, oil, and other hydrocarbons	Substances lighter than water are removed with units specifically designed for this purpose.
Settling/Sedimentation	Bioretention, wetlands, wet/dry ponds, tree boxes, and cisterns	Suspended solids, metals, particulate phosphorus, and organics	Suspended particles settle by gravity, along with pollutants adhered to them. Forebays must capture and facilitate periodic removal of sediment. Avoid re-suspension of sediment.
Filtration	Sand/gravel filters, natural/amended soil, green roofs, infiltration tanks, and horizontal wells	Suspended solids, metals, phosphorus, and organics	Stormwater passes through a porous material, mechanically removing anything larger than the pore openings.
Sorption	Any BMP employing infiltration through soils or other media, especially organic material or clay	Dissolved nutrients, metals, and bacteria	Contaminants adhere to irregularities in the surface of vegetation, to clay particles in soil, or are attached to other molecules by chemical bonds.
Biological Removal	Bioretention, enhanced ponds, and floating islands	Nitrogen, phosphorus, and organic molecules	Microorganisms and plants take in nutrients needed for their cell growth and break apart large organic molecules.

- **Specific to the bluffs along Hallett Park** (project limits), integration of multiple nature-based BMPs is proposed to address nutrient loading from stormwater outfalls and upland runoff, while providing erosion mitigation benefits. Based upon a review of the watershed including the existing stormwater infrastructure, APTIM proposes several BMPs to provide increased stormwater treatment prior to discharge to the downstream receiving waterbody, Clearwater Harbor-South. The proposed projects include **(Figure 39):**

- **Bioretention cells** at the 3 outfall locations (OF 1, OF3, and OF 4): 15 ft wide, 40ft long, 5.3 ft deep
- **Vegetative buffer/strip**: 15ft wide, 275 ft long
- Existing **baffle box** that currently filters flood waters before they reach OF 3.
- **Shoreline stabilization** using **living shorelines** (Design Alternatives 3A & 3B)**:** 1250 ft long (not modeled in BMP Trains due to not being captured within the software).

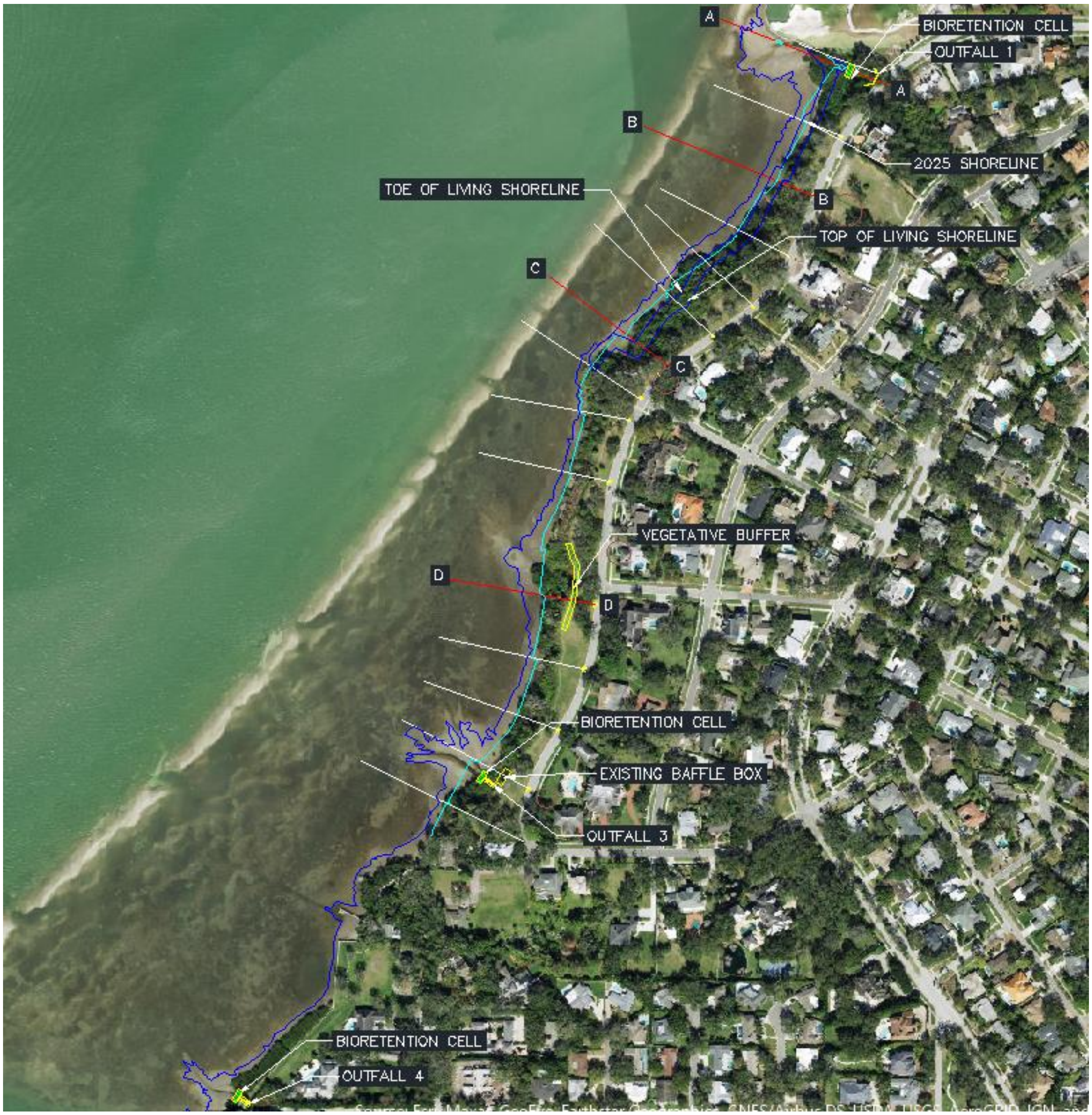

Figure 39. Proposed BMPs in Hallett Park

A **vegetative filter strip** is proposed along a significantly eroded section at the bluff crest to intercept and slow stormwater runoff, particularly during events that exceed the design capacity of the existing drainage system along Bayview Drive. This strip, comprised of species that have high nitrogen uptake, promotes infiltration and sedimentation, helping to reduce nitrogen loads substantially.

Additionally, **bioretention cells** around the three stormwater outfalls are designed to temporarily retain discharge, allowing nutrients to settle before being filtered through engineered media and underdrains—achieving high levels of nitrogen reductions before any overflow reaches the ICWW.

More frequent maintenance of the existing **baffle box**, in accordance with the manufacturer's recommendations, is proposed as another best management practice to enhance its treatment performance.

Lastly, **shoreline stabilization using living shoreline** techniques reduces bluff erosion, thereby limiting the release of nutrient-rich sediments into adjacent waters. By preventing soil-bound nitrogen and phosphorus from entering the ICWW, this approach not only supports long-term slope stability but also contributes to improved nearshore water quality.

3.4.1.1 Nutrient Loading Reduction Estimates via BMP Trains Model

The **BMP Trains 2020 v 4.3.5 model** developed at The Stormwater Academy of the University of Central Florida was used to calculate the respective pollutant load reduction for the proposed BMPs with exception of the shoreline stabilization using living shorelines. BMP Trains is currently being updated accounting for recent changes to Florida’s stormwater management rules. The model allows for user input of the general site information, watershed characteristics, catchment configuration and treatment options. The model calculates the pre- and post- development run-off coefficients (“C value”), the annual runoff volume in ac-ft, and Nitrogen and Phosphorus annual loadings in kg/yr using a combination of user provided site-specific information (e.g., land use and rainfall) and model-generated information (e.g., event mean concentrations). The output is a BMP summary treatment report that provides the following information for Nitrogen and Phosphorus, respectively:

- average annual loading (kg/yr),
- target load reduction (%),
- target discharge load (kg/yr),
- percentage of load reduction (%), and
- provided discharge load and load removed.

Final loads are provided in pounds per year (lb/yr). The “User Manual for the BMP Trains 2020 Model” provides a comprehensive presentation of the model implementation process (Wanielista et al. 2020)[2].

Pollutant load reductions associated with the proposed shoreline stabilization have not been broadly established. Previous projects of similar configuration implemented pre- and post- project monitoring efforts to quantify the nutrient reduction credit (Webb 2019)[3].

The conceptual catchment basins for each outfall (OF-1, OF-3 and OF-4) were delineated using ESRI ArcHydro tools and Digital Elevation Model for the region **(Figure 40)**. Land use was characterized using SWFWMD FLUCCS (2020). Each catchment was comprised of high density residential (FLUCC 1300) which corresponds to the Multi-Family Residential EMC Land Use category within BMP Trains with TN=2.32 mg/L and TP=0.520 mg/L. A negligible portion of the

[2] Wanielista., M., R. Eaglin, R. Magee, H. Harper, E. Livingston, M. Hardin, P. Kuzlo, and I. Gogo-Abite. 2020. User Manual for the BMP Trains 2020 Model. Version 4.2.3. University of Central Florida and the Florida Department of Transportation.

[3] Webb, L. 2019. Proposed Protocol for Shoreline Stabilization TMDL Project Credit- Revision 2 Patrick Air Force Base, Florida. Submitted to FDEP.

OF-1 catchment included golf course (0.1 acres) as a land use category and was removed from the analysis. The mean annual rainfall was estimated as 52 inches. The non-DCIA curve number was estimated as 57 based upon an analysis of DCIA obtained from NOAA satellite imagery. The specifications for each proposed BMP were input as indicated within the design plans (see **Section 4** and **Appendix A-D**). The modeled conceptual nutrient reduction associated with each proposed BMP was calculated using BMP Trains V. 4.2.3 **(Tables 18-22)**. The BMP Trains software report for each modelled scenario is provided in **Appendix K: BMP Trains Output Reports.**

Figure 40. Stormwater Outfall Conceptual Catchment Basin Delineation.

Vegetative Filter Strip

The proposed vegetative filter strip is located at the identified low elevation region within the Bayview Drive stormwater network to capture excess run-off associated with storm exceeding the 25-year design storm **(Figure 39)**. In the absence of a stormwater model to calculate the hydrologic load expected to pass through the vegetative filter strip, pollutant load reductions were estimated assuming a range of scenarios (e.g., 5%, 10%, 25%, 50% and 100%). The 5 percent scenario assumes that the majority (95%) stormwater within the OF-3 catchment area discharge through the outfall within an average year with the remaining 5 percent flowing through vegetative buffer strip. Under all scenarios the vegetative buffer strip is expected to provide 61 and 41 percent removal of TN and TP, respectively for those flows that discharge to the BMP **(Table 18)**.

In the most restrictive scenario (5%), 38 lb TN/year and 6 lb TP/year is estimated to be removed from the system.

Table 18. BMP Analysis of proposed vegetative buffer using BMP Trains v. 4.2.3 for various scenarios

Vegetative Buffer	OF-3 Catchment Load to Vegetative Buffer (Percent)									
	5%`		10%		25%		50%*		100%*	
	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP
Average Annual Loading (kg/yr)	28	6	56	13	140	31	280	63	560	126
Percent Load Reduction (%)	61	41	61	41	61	41	61	41	61	41
Mass Discharged (kg/yr)	11	4	22	7	55	18	110	37	219	74
Load Removed (kg/yr)	17	3	34	5	85	13	170	26	341	52
Load Removed (lb/yr)	38	6	75	11	188	29	376	57	752	114

*Exceeds anticipated hydrologic load to BMP

Bioretention Cells

Bioretention cells are proposed adjacent to each of the identified outfalls (OF-1, OF-3 and OF-4) **(Figure 39).** Each cell is designed to temporarily retain discharge, allowing nutrients to settle before being filtered through engineered media and underdrains. With this design in mind, the bioretention cells were evaluated as two BMPs in sequence **(Figure 41):**

1) Retention area – identified as an area between the outfall and bioretention cell (75'x40x2.76')
2) Rain Garden – as presented in the design plans (15'x40'x5.3')

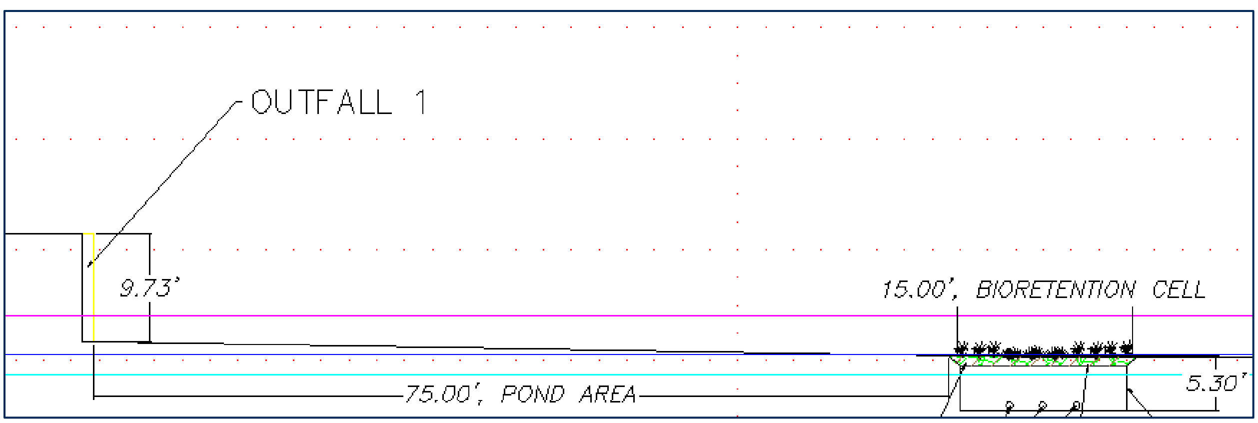

Figure 41: 75' Retention Ponding Area and Bioretention Cell/Rain Garden

The estimated nutrient load reduction at outfalls OF-1 and OF-3 were 6 and 4 percent, respectively **(Table 19)**. A more substantial load reduction (37 percent) was attributed to the OF-4 catchment. Two additional scenarios were evaluated which expanded the bioretention cell an additional 5' and 10' in width respectively, to capitalize on areal extent while still avoiding seagrass impacts. The associated increase in nutrient removals was nominal providing an additional one to four percent removal efficiency dependent on contributing catchment area **(Table 20 & Table 21).**

Table 19. BMP Analysis of proposed bioretention cells at each outfall using BMP Trains v. 4.2.3

Bioretention Cells (Retention then Raingarden)	OF-1		OF-3		OF-4	
	TN	TP	TN	TP	TN	TP
Average Annual Loading (kg/yr)	358	80	560	126	61	14
Percent Load Reduction (%)	6	6	4	4	37	37
Mass Discharged (kg/yr)	335	75	537	120	39	9
Load Removed (kg/yr)	23	5	23	5	23	5
Load Removed (lb/yr)	50	11	50	11	50	11

Table 20. BMP Analysis of proposed expanded (5' increase) bioretention cells at each outfall using BMP Trains v. 4.2.3

Bioretention Cells (Retention then Raingarden)	OF-1		OF-3		OF-4	
	TN	TP	TN	TP	TN	TP
Average Annual Loading (kg/yr)	358	80	560	126	61	14
Percent Load Reduction (%)	7	7	4	4	39	39
Mass Discharged (kg/yr)	334	75	536	120	37	8
Load Removed (kg/yr)	24	5	24	5	24	5
Load Removed (lb/yr)	53	12	53	12	52	12

Table 21. BMP Analysis of proposed expanded (10' increase) bioretention cells at each outfall using BMP Trains v. 4.2.3

Bioretention Cells (Retention then Raingarden)	OF-1		OF-3		OF-4	
	TN	TP	TN	TP	TN	TP
Average Annual Loading (kg/yr)	358	80	560	126	61	14
Percent Load Reduction (%)	7	7	5	5	41	41
Mass Discharged (kg/yr)	333	75	535	120	36	8
Load Removed (kg/yr)	25	6	25	6	25	6
Load Removed (lb/yr)	55	13	55	13	55	13

Baffle Box

The Town of Belleair has an existing baffle box just upstream of Outfall OF-3 **(Figure 39).** Ongoing treatment has occurred but is unquantified and deemed not at optimal level at this time due to the nutrient loading observed during water quality sampling events as illustrated in **Section 3.2**. More frequent maintenance is recommended to obtain complete treatment performance of the baffle box. A user-defined BMP was evaluated within BMP Trains to quantify the potential pollutant load reduction associated with the existing baffle box under improved maintenance schedules. TN (0.5 percent) and TP (2.3 percent) removal efficiencies were identified assuming a first-generation baffle box as documented by FDEP[4]. The calculated load reductions associated with the OF-3 baffle box are **6.2 lbs TN/yr** and **6.4 lbs TP/yr (Table 22)**. These reductions represent the total estimated removal attributable to this BMP.

[4] FDEP. 2021. Statewide Best Management Practice (BMP) Efficiencies for Crediting Projects in Basin Management Action Plans (BMAPs) and Alternative Restoration Plans. Draft. 16p.

Table 22. BMP Analysis of existing Baffle Box at outfall OF-3 using BMP Trains v. 4.2.3

Baffle Box	OF-3	
	TN	TP
Average Annual Loading (kg/yr)	560.0	125.5
Percent Load Reduction (%)	0.5	2.3
Mass Discharged (kg/yr)	557	123
Load Removed (kg/yr)	2.8	2.9
Load Removed (lb/yr)	6.2	6.4

Collectively, proposed BMPs estimated to reduce the nutrient loading by more than **50 lb/yr**.

Living shorelines offer a low-impact, sustainable method for reducing erosion and improving water quality. By blending natural elements like native vegetation, coquina sand fill, toe and armor stone, and biodegradable support structures, living shorelines help trap and filter stormwater runoff before it enters the ICWW. These systems also provide surface area for microbial activity and act as a natural buffer between upland sources of pollutants and sensitive aquatic habitats. These benefits are not captured within the BMP Trains, and the estimate methodology requires post-construction sampling, therefore a definitive reduction estimate may not be able to be provided. However, estimates found in project examples and the FDEP guidance provided in a reference document from 2018[5,6] are deemed comparable to the conditions in this study, therefore the living shorelines are anticipated to provide nutrient load reduction benefits, even if it is minimal.

In areas where bluff slopes exceed 70%, as documented in the March 2025 survey, structural enhancements must accompany living shoreline features to ensure slope stability. Current vegetation, including mature mangrove trees, provides temporary stabilization but is unlikely to remain effective over the long term without intervention. In these areas, targeted structural measures are proposed, such as:

- Installation of a **geotextile cell membrane** at the bluff's edge, filled with gravel and anchored per manufacturer specifications to limit soil movement.
- **Replacement and reinforcement of outfall structures**, many of which are currently destabilizing the bluff and contributing to erosion through splash pool formation.
- **Slope regrading and/or construction of structural supports**, including double-layer revetments, to reduce slope angle and improve long-term slope stability.
- **Additional pad riprap** to reduce flow velocity and minimize erosive energy at points of discharge.

3.4.2 Opportunities to Reduce Pollutant Loading: Upland Measures

In addition to the BMPs identified within the Hallett Park study area discussed in the previous section, APTIM has outlined supplemental recommendations that the Town of Belleair may consider incorporating into future projects. These measures are intended to further reduce upland pollutant loads before they reach the outfalls along the Hallett Park shoreline. Based on a review of the Town of Belleair's NPDES MS4 annual reports, the **Town is in compliance with their NPDES permit requirements**. Continued commitment to these standards is recommended,

[5] Methods for Calculating Project Reductions | Florida Department of Environmental Protection
[6] Proposed Shoreline Stabilization Protocol Tech Memo Rev2 091919 (003).pdf

along with ongoing efforts to identify opportunities for reducing pollutant contributions to the ICWW. It is also suggested that the Town leverage existing public education programs developed by Pinellas County to promote personal pollution reduction within the watershed.

Other opportunities to reduce upland loads include an evaluation of the street sweeping schedule and clean out schedule of the Towns stormwater catchments, pipes, and sediment collection devices (i.e., baffle boxes). During the “fall” season when leaf and pollen tend to accumulate and become sources of nutrient and sediments. Street sweeping should follow periods of extended dry periods when material tends to build up on the roads.

While there is limited space in the study area to utilize stormwater retention systems to manage pollutant loading, there could be such opportunities upstream. **Figure 42** illustrates the Town of Belleair 2018 Official Zoning Map, showing public land (in blue) that could be used as stormwater detention/natural depression. **Desoto Place cul-de-sac** could specifically be of interest as a natural depression area.

Figure 42. Town of Belleair 2018 Official Zoning Map

The Town is also encouraged to ensure the golf courses are adhering to the “Best Management Practices for the enhancement of Environmental Quality of Florida Golf Course.” While compliance with the manual is not mandatory, voluntary implementation of BMPs from the manual could substantially reduce the potential impact from golf courses.

Currently, stormwater in the project area is directed to a **baffle box** located just upstream of Outfall 3. This system includes sediment and trash traps, as well as carbon filters designed to reduce pollutant loads before discharge. However, elevated pollutant concentrations observed in water quality samples suggest that additional maintenance, such as more frequent cleanouts or filter replacement, is required to ensure optimal performance. Furthermore, the existing baffle box may have limited capacity, which could reduce its effectiveness during large storm events. To enhance pollutant removal and better manage upland runoff, the installation of additional treatment units, such as stormceptors, can be considered.

Due to the physical constraints within the watershed, such as limited available space and steep bluff slopes, traditional stormwater BMPs like large retention or detention systems might be limited. Instead, the Town can focus on alternatives that reduce sediment while not restricting stormwater flow. These include additional **baffle boxes, sediment baskets in catch basins, and hydrodynamic separators**. To ensure the effectiveness of these systems, the Town must plan for **routine maintenance and cleanout**, documenting the volume of materials removed to potentially earn pollutant load reduction credits.

Low Impact Development (LID) strategies offer a promising alternative for addressing runoff and pollutant concerns at the source. These systems reduce runoff volume through infiltration and storage, using techniques such as **rain gardens, vegetated swales, and rainwater harvesting (e.g., rain barrels)**. Many of these practices can be integrated into **treatment trains**, where water flows sequentially through multiple BMPs for enhanced treatment. For example, a **rain garden** can overflow into a **vegetated swale** underlain with **biosorption material**, enhancing nitrogen reduction and water infiltration. These systems must be properly engineered to meet local and county stormwater design criteria, such as those outlined in the *Pinellas County Stormwater Manual.*

BMPs like bioswales or treatment swales parallel to roadways, vegetated filter strips, and rain gardens can be implemented without significant earthwork. These measures are particularly appropriate at stormwater low points—such as at Hallett Park—and should be developed in collaboration with a landscape architect to ensure compliance with design guidelines and site-specific effectiveness. However, it should be noted that these solutions may have limited effectiveness in areas where existing infrastructure collects runoff into underground pipes that discharge directly to the bay. Since all water quality testing sites exceeded the maximum allowable level of bacteria, biological removal via bioretention, enhanced ponds, and floating islands may be necessary.

3.4.3 Regional Efforts to Date

Improving water quality in Clearwater Harbor is a regional effort that requires coordination across jurisdictions, agencies, and project boundaries. While this project includes BMPs to reduce upland pollutant loading and improve water quality near the shoreline, Clearwater Harbor is a large and dynamic waterbody influenced by diverse sources of pollution. Addressing these broader water quality challenges demands collaboration with state and regional agencies, including the FDEP, SWFWMD, Pinellas County, City of Clearwater, and Tampa Bay Estuary Program, all of which have undertaken efforts to monitor, manage, and improve the health of the harbor. Several initiatives—ranging from infrastructure improvements to watershed-scale sediment and nutrient management—demonstrate ongoing commitments to restoring and protecting this vital estuarine system, as summarized below.

Northeast Water Reclamation Facility Improvements: In June 2021, the City of Clearwater commenced an $18.4 million project to upgrade the Northeast Water Reclamation Facility. Completed in May 2023, these enhancements improved wastewater treatment efficiency, thereby reducing environmental impacts on Clearwater Harbor. Upgrades included new preliminary and primary treatment systems, sludge handling improvements, and the installation of advanced filtration and grit removal systems (City of Clearwater, 2023).

Stevensons Creek Watershed Project: Initiated in November 2007, this project aimed to improve water quality within the Stevensons Creek Watershed, which drains into Clearwater

Harbor. Efforts focused on widening approximately 700 feet of the Spring Branch Channel and constructing a three-acre stormwater retention pond. These measures addressed water quality, flooding, and erosion concerns by reducing channel erosion and sediment deposition into the harbor. The project was a cooperative effort between the Southwest Florida Water Management District and the City of Clearwater, each contributing $1 million (SWFWMD, 2007).

Water Quality Monitoring Programs: Pinellas County has implemented comprehensive water quality monitoring programs to assess and manage the health of water bodies, including Clearwater Harbor. Since 1991, the county has collected data on various parameters such as pH, dissolved oxygen, nutrients, and contaminants. These programs facilitate the identification of impaired waters and guide restoration efforts to improve water quality (Pinellas County, n.d.).

Sediment Management Plan: A Sediment Management Plan was developed for the watersheds of Clearwater Harbor and St. Joseph Sound. The plan outlines strategies to reduce sediment loads entering these water bodies, thereby improving water quality and aquatic habitats. One component of the plan includes the construction of stormwater detention ponds to treat runoff before it reaches the harbor (Pinellas County, 2012).
These collective efforts demonstrate a commitment to enhancing and preserving the water quality of Clearwater Harbor through infrastructure improvements, watershed management, and continuous monitoring.

4. BASIS OF DESIGN

4.1 Primary Causes of Bluff Erosion

The Belleair project area, encompassing the Hallett Park shoreline along the interior of the Intracoastal Waterway between R-monuments R-60 and R-64, has faced significant erosion due to a combination of natural and artificial factors. **Figure 43** shows an example eroded section of the bluff with vegetation loss.

Figure 43: An example eroded section of the bluff with vegetation loss (Drone imagery credit: APTIM)

Historically, the area was protected by a stable bluff and offshore sandbanks, which helped shield it from wave energy. However, the combination of drainage issues, storm events, and rising water levels have caused degradation along the shoreline. Intense storm events, including Hurricanes Ian, Nicole, Helene, and Milton, have exacerbated the problem, leading to habitat loss and increased vulnerability for both the bluff and nearby infrastructure. Shoreline stabilization and restoration efforts are needed to address these problems.

The metocean analysis of the project area shows how coastal dynamics contribute to these issues. Wave data from NDBC Buoy 42098, west of Clearwater Beach, illustrates the severe impacts of recent storms. Hurricane Ian caused wave heights to exceed 7 feet and Hurricane Helene brought waves up to 8.3 feet, leading to substantial shoreline erosion and sediment displacement. These high-energy events not only increase erosion but also disrupt the sediment budget, preventing natural replenishment of the offshore sandbanks that help stabilize the shoreline.

Challenges in coastal protection for Town of Belleair include addressing the cumulative effects of storm surges, rising sea levels, and water management issues. The analysis of rainfall and runoff patterns provides evidence of how upland drainage can exacerbate erosion. Intense rainfall events that exceed the design storm of the existing drainage network can accelerate runoff, weakening the bluff and transporting pollutants into nearshore waters. To mitigate these impacts and improve water quality, implementing nutrient reduction BMPs is essential. These BMPs, such as vegetative buffers, constructed wetlands, and bio-retention systems, help capture and filter excess nutrients before they enter coastal waters, reducing algal blooms and improving overall ecosystem health. Integrating these practices with erosion control measures will enhance the resilience of Belleair's coastline while promoting long-term water quality improvements.

To mitigate these problems, a holistic approach to shoreline protection is essential. Strategies such as implementing living shorelines, adding additional stone protection, and improving stormwater management could provide solutions to the current issues. Living shorelines, incorporating native vegetation and habitat features, which reduce erosion while being ecologically resilient. Additionally, with the goal of **maximizing natural systems restoration and improve water quality through nutrient reduction BMPs** in mind, several BMPs are proposed both upland and along the Hallet Park shorelines (Section 3.4). Moreover, addressing drainage issues through green infrastructure and runoff controls could stabilize the bluff, reduce future erosion, and filter out pollutants. The following design concepts were created to offer both immediate and long-term solutions, focusing on enhancing coastal resilience, stabilizing the bluff, and restoring natural sediment processes while minimizing future erosion and habitat degradation. The following sections describe the conceptual design alternatives that are aimed to **provide shoreline stabilization and are all improved with the BMPs discussed in Section 3.4.** Integrated with all design alternatives, there are three **bioretention cells**, located at stormwater discharge points (Outfalls 1, 3, and 4), which serve to capture and treat surface runoff before it enters the bay. These cells are engineered basins filled with native plants and filter media that remove suspended solids, nutrients, and pollutants from urban runoff. They also reduce peak discharge rates, minimizing erosion along the shoreline. Adjacent **low points for sediment capture**, identified by specific elevation markers (e.g., 22.5–27.9 ft NAVD88), are used to intercept stormwater at natural collection zones. These points are critical for preventing sediment overload in the coastal system, which can smother marine vegetation and reduce the effectiveness of the living shoreline infrastructure.

Upland from the shoreline, a wide **vegetative buffer** is established to serve as a second line of defense against runoff and erosion. Planted with deep-rooted native species, the buffer slows overland flow, improves infiltration, and stabilizes soils. This layered system not only protects the shoreline from immediate hydrological stress but also promotes long-term environmental health and habitat connectivity. Together, these elements—living shoreline structures, sediment management zones, bioretention cells, improved baffle box performance, and vegetative buffers—form a cohesive, sustainable system tailored for Belleair's coastal dynamics, enhancing resilience against storm impacts while restoring ecological function.

- **All conceptual design drawings are presented in Appendices A-D.** The Following sections describes the engineering methods, design considerations, and technical specifications of the design elements.

4.1.1 Alternative 1A and 1B: Single (1A) and Double (1B) Layer Revetment

The first design alternative proposes a revetment system consisting of a single or double-layer configuration to protect the Belleair coastline from erosion and wave action. The single-layer revetment utilizes a uniform layer of interlocking armor stone to absorb wave energy, while the double-layer revetment incorporates a secondary crest width that increases the elevation for extra protection against extreme storm events. Both alternatives enhance habitat creation by offering surfaces where marine life can thrive. These structures provide a safe place for various species to attach, which in turn attracts fish, crabs, and other marine organisms. Crevices and intertidal zones formed by revetments help create microhabitats that support biodiversity and serve as feeding areas for shorebirds. This approach balances structural resilience with minimized environmental disruption, offering a straightforward and effective solution for shoreline stabilization.

Design specifications of both single- and double-layer revetment alternatives are presented in **Table 23.** The single-layer revetment features a 2:1 slope with crest widths and top elevations varying based on design water levels. The system incorporates an armor layer two stone widths thick, underlain by filter stone, and a toe stone at the base. The armor stone for all design storms weighs 1–3 tons. All designs use filter stone with a diameter range of 9 to 18 inches, with 50% of the stones greater than 14 inches.

The double-layer revetment consists of dual slopes converging at varying top elevations. The first crest elevation for all design storms is 7.4 feet. Both crest widths vary based on the design storm as presented in **Table 23**. The armor stone layer width ranges from 5.2 feet for a 10-year storm to 6.8 feet for a 100-year storm. Armor stone weights remain consistent with the single-layer design, and all configurations use filter stone with a diameter range of 9 to 18 inches, with 50% greater than 14 inches.

An alternative approach included in the design to enhance water quality and ecological benefits is to replace all toe stone with 3 rows of oyster reef balls. Oyster balls are artificial reef structures specifically designed to provide habitat for oysters and other marine life. These structures feature holes that offer shelter, facilitate water flow and nutrient circulation, and rough surfaces that encourage oyster attachment. Measuring approximately 1 foot in height and 1.5 feet in base diameter, with an average weight of 55 pounds, oyster balls are compact yet effective at supporting marine ecosystems. By fostering the growth of oyster populations, they enhance natural water filtration, removing excess nutrients, bacteria, and suspended particles, significantly improving water clarity. Additionally, oyster balls contribute to shoreline stabilization by dampening wave energy to the bluff. Beyond ecological benefits, these structures support recreational fishing and promote biodiversity, making them an innovative tool for improving coastal resilience.

	Water Level	Crest Width (ft)	2nd Crest Width (ft)	Top Elevation (ft)	1st Crest Elevation (ft)	2nd Crest Elevation (ft)	Armor Stone		Filter Stone Size
							Weight (tons)	Layer Width (ft)	
1A	10-yr	23.70	N/A	7.4	7.4	N/A	1–2 tons	5.2	9–18 inches, 50% >14"
	25-yr	26.40		7.4	7.4	N/A	1–2 tons	5.8	9–18 inches, 50% >14"
	50-yr	28.60		8.4	8.4	N/A	2–3 tons	6.4	9–18 inches, 50% >14"
	100-yr	30.70		8.4	8.4	N/A	2–3 tons	6.8	9–18 inches, 50% >14"
1B	10-yr	13.1	18.4	12.4	7.4	12.4	1–2 tons	5.2	9–18 inches, 50% >14"
	25-yr	14.7	20.60	12.8	7.4	12.8	1–2 tons	5.8	9–18 inches, 50% >14"
	50-yr	15.9	22.9	13.4	7.4	13.4	2–3 tons	6.4	9–18 inches, 50% >14"
	100-yr	17	23.9	13.8	7.4	13.8	2–3 tons	6.8	9–18 inches, 50% >14"

Table 23: Design Specifications for Alternatives 1A and 1B

Design calculations were obtained using the storm surge for 10-, 25-, 50-, and 100-year events. These designs ensure stability and functionality across varying storm scenarios. The revetment system offers numerous benefits, including effective shoreline protection, reduced wave overtopping, and minimized maintenance. The single-layer design provides a cost-effective solution for moderate storm conditions, while the double-layer design offers enhanced protection for high-risk areas. Both systems improve coastal resilience, helping to safeguard adjacent infrastructure and natural habitats from erosion and storm damage.

It is a viable option to proceed with the double-layer revetment for locations subject to higher storm intensities, as it provides superior protection and adaptability to extreme conditions. The single-layer design is suitable for less vulnerable areas but may require periodic maintenance to handle increasing storm impacts and sea-level rise. Construction access will require a small regrade of the bluff to allow an excavator to get down. The excavator will then need to create a path adjacent to the bluff face to maneuver for stone placement, ensuring precise and effective construction of the revetment.

4.1.2 Alternative 2: Offshore Breakwater System

The second design alternative features the construction of an offshore breakwater system, designed to shield the Belleair shoreline from wave impacts and reduce erosion. This structure consists of a segmented barrier placed parallel to the coast, dissipating wave energy before it reaches the shore. The breakwater not only protects the existing coastline but also promotes sediment deposition, encouraging natural beach nourishment over time. Similar to revetments, breakwaters can create vital habitats by providing a stable surface for marine organisms to attach. They also offer shelter and create feeding grounds for local marine life. Calm waters behind breakwaters foster the development of seagrass beds and other coastal ecosystems, contributing to increased biodiversity. The terminal groin also promotes habitat creation by trapping sand and building up shoreline, which in turn creates more space for vegetation and animals to thrive. Groins help stabilize the shoreline and form more stable, ecologically diverse environments for marine life to flourish. These elements of the design can be modified to minimize ecological impacts while providing effective coastal protection.

Design specifications of the offshore breakwater system are presented in **Table 24**. The offshore breakwater system consists of seven segmented structures varying in length: 250 (three segments), 300 feet (one segment), 360 feet (one segment), and 500 feet (one segment). These breakwaters have a crest width that varies based on storm intensity and they are designed with a 2H:1V slope. The armor layer is one stone width thick, underlain by filter stone, with toe stones on both sides.

The breakwater layer widths and corresponding crest widths are listed in **Table 24.** This breakwater system effectively reduces wave energy reaching the shore, stabilizes the beach, and promotes sediment deposition, thereby mitigating erosion. The segmented design allows for targeted protection of high-risk areas and minimizes environmental disruption during construction. Additionally, the breakwaters act as a natural habitat for local species.

Replacing all toe stone with oyster reef balls offers numerous ecological benefits, making it a highly effective solution for improving water quality and enhancing coastal ecosystems. Reef Balls are designed to mimic natural reef structures and provide crucial habitat for marine life such as oysters and local fish species. Reef balls have a height of 3 feet 5 inches, a base diameter of 6 feet, and a weight of approximately 3000 pounds. Reef Balls are compact yet effective tools for habitat restoration. Their rough, porous surfaces allow marine organisms to easily attach, while holes throughout the structure promote water flow and circulation, fostering nutrient exchange and oxygenation. Replacing toe stone with these bio-enhancing structures improves water filtration, supports biodiversity, and stabilizes shorelines by reducing wave energy and preventing erosion. Reef balls are used instead of oyster balls due to the larger and more frequent wave action breakwaters face compared to revetments and groins.

Water Level	Segment Length	Crest Width (ft)	Crest Elevation (ft)	Armor Stone Weight	Filter Stone Size	Breakwater Layer Width (ft)
10-yr	250 ft (3 segments), 300 ft (1 segment), 360 ft (1 segment), 500 ft (1 segment)	12.0	7.4	1–2 tons	9–18 inches, 50% >14"	6
25-yr	250 ft (3 segments), 300 ft (1 segment), 360 ft (1 segment), 500 ft (1 segment)	13.2	7.4	2-3 tons	9–18 inches, 50% >14"	6.6
50-yr	250 ft (3 segments), 300 ft (1 segment), 360 ft (1 segment), 500 ft (1 segment)	14.2	8.4	3-4 tons	9–18 inches, 50% >14"	7
100-yr	250 ft (3 segments), 300 ft (1 segment), 360 ft (1 segment), 500 ft (1 segment)	15.1	8.4	3–4 tons	9–18 inches, 50% >14"	7.6
L-Groin	300	10.5-13.6	7.4 (10-25-50-100 year)	1–2 tons (10-25 years), 2–3 tons (50-100 years)	9–18 inches, 50% >14"	2H:1V

Table 24: Design Specifications for Alternative 2

The offshore breakwater system is a viable option due to its versatility and long-term benefits. Its segmented design enables phased construction and adaptability to site-specific needs, making it a cost-effective and environmentally positive solution. Construction access to the site will require the use of a barge to transport materials and equipment, ensuring efficient and safe delivery to the offshore location. The barge will facilitate the movement of heavy armor stones, filter stones, and construction machinery, allowing for precise placement and assembly of the breakwater segments. This method minimizes the impact on the shoreline and surrounding marine environment, ensuring that the construction process is both effective and environmentally responsible.

4.1.3 Alternative 3A: Integrated Groin System, Breakwater, and Nature-Based Solutions

The third alternative integrates a hybrid system of groins, breakwaters, and a living shoreline to provide comprehensive shoreline protection with ecological restoration. Groins will control sediment transport and mitigate erosion, offshore breakwaters will reduce wave energy, and native material will be repurposed to create a living shoreline, enhancing biodiversity and natural resilience. This holistic approach prioritizes sustainability and long-term adaptability for Belleair's coastal environment.

Design specifications of the Integrated Groin System, Breakwater, and Nature-Based Solutions alternative are presented in **Table 25**. This hybrid solution integrates three breakwater segments (250 feet, 250 feet, and 300 feet), a T-groin (135 feet long with a 170-foot cross-section), three L-groins (150 feet, 150 feet, and 225 feet long), and a living shoreline. The breakwaters and groins are constructed with a 2H:1V slope. For each breakwater, elevations are listed in **Table 25** for each design storm. The armor stone in the shoreline is filter stone ranging from 9 to 18 inches in diameter, with 50% greater than 14 inches. The crest width for both breakwaters and groins can be seen in **Table 25**.

The nature-based solution integrates multiple layers to ensure durability and ecological restoration. Starting with toe stone at the base, a 3H:1V sand fill seeded with native plants is added, followed by native earth fill with a temporary grass cover and another toe stone for support. Geotextile fabric wraps the earth fill and toe stone, extending to the bluff face for erosion control. Armor stone is placed behind the earth fill with a 1.5H:1V slope on both sides, and new topsoil and sod fill in the gap to the bluff. This layered approach blends engineered stability with natural resilience to address erosion and enhance biodiversity.

Alternative 3A can improve coastal resilience by replacing all toe stone with a combination of Reef Balls for breakwaters and groins, and Oyster Balls for the living shoreline. Reef Balls, which measure 3 feet 5 inches in height, 6 feet in base diameter, and weigh 3,000 pounds, are the best size to replace the large toe stones found in breakwaters and groins. These help to create artificial reefs, which offer essential habitat for marine life such as oysters and other local species, with surfaces that allow organisms to attach, and holes throughout the structure that promote water flow. By replacing toe stone with these bio-enhancing Reef Balls, wave energy is reduced, and coastal erosion is mitigated. For the living shoreline, three rows of compact Oyster Balls, measuring approximately 1 foot in height and 1.5 feet in diameter, weighing 55 pounds, are strategically placed to foster oyster populations. These Oyster Balls facilitate water flow and nutrient circulation, significantly improving water quality. Together, the Reef Balls in the breakwaters and groins, along with the Oyster Balls in the living shoreline, offer a sustainable, cost-effective solution for habitat restoration, water quality improvement, and coastal resilience.

Component	Length (ft)	Crest Width (ft)	Elevation (ft NAVD)	Armor Stone Weight	Filter Stone Size	Slope	Additional Features
Breakwater 1	250	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 154 Reef Balls
Breakwater 2	250	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 154 Reef Balls
Breakwater 3	300	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 181 Reef Balls
T-Groin	135 + 170 cross-section	10.5-13.6	7.4 (10-25-50-100 year)	1–2 tons (10-25-50 years), 2–3 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 3 – 164 Reef Balls
L-Groin 1	150	10.5-13.6	7.4 (10-25-50-100 year)	1–2 tons (10-25-50 years), 2–3 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 3 – 82 Reef Balls

Component	Length (ft)	Crest Width (ft)	Elevation (ft NAVD)	Armor Stone Weight	Filter Stone Size	Slope	Additional Features
L-Groin 2	150	10.5-13.6	7.4 (10-25-50-100 year)	1–2 tons (10-25-50 years), 2–3 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 3 – 84 Reef Balls
L-Groin 3	225	10.5-13.6	7.4 (10-25-50-100 year)	1–2 tons (10-25-50 years), 2–3 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 3 – 121 Reef Balls
Living Shoreline	Integrated along breakwaters and groins	N/A			9–18 inches, 50% >14"	3H:1V (sand fill) 1.5H:1V Filter Stone	Native earth fill, Topsoil with Sod, Native seed mix/Seedlings, and Sand Fill. Alterative 1 – 1709 Oyster Balls

Table 25: Design Specifications for Alternative 3A

This system offers comprehensive benefits by combining structural protection with ecological enhancements. Groins stabilize sediment transport, breakwaters reduce wave energy, and the habitat area fosters biodiversity while increasing storm resilience. Together, these elements offer a balanced approach to shoreline protection and environmental resilience. The integrated design is highly recommended due to its multifaceted benefits. By addressing erosion, wave energy, and habitat loss simultaneously, it offers a forward-thinking solution to coastal management.

Construction access for the living shoreline will require a small regrade of the bluff to allow an excavator to get down. Beginning with the T-head groin would minimize the necessary entrance points, as the excavator can first build out the groin before applying an adjacent path for the living shoreline. Additionally, a barge will be needed to transport materials and equipment for the breakwater segments offshore. This method minimizes the impact on the shoreline and surrounding marine environment, ensuring that the construction process is both effective and environmentally responsible. For the groins, a similar approach will be needed with a small regrade. The excavator can then build out the groin and use it as a path simultaneously, which erases unnecessary stone use. The positioning of the groins is subject to change based on the bluff's conditions and how it will be affected by the construction access point.

4.1.4 Alternative 3B: Nature-Based Solutions and Breakwater

Alternative 3B integrates the same BMPs as the other alternatives to address nutrient loading from stormwater outfalls and upland runoff, while providing erosion mitigation benefits via nature-based elements. This design is provided as a lower-cost alternative to conceptual design Alternative 3A and has similar but less engineered solutions to reduce the total cost, while still providing shoreline stability where needed.

The living shoreline is constructed with native materials and vegetation to dissipate wave energy while supporting aquatic habitat. This approach allows for adaptive placement of restoration elements, reducing the risk of shoreline retreat and reinforcing long-term resilience. The installation of reef-like structures offshore further promotes sediment stabilization and biodiversity, forming a soft but durable edge to combat wave-induced erosion.

Component	Length (ft)	Crest Width (ft)	Elevation (ft NAVD)	Armor Stone Weight	Filter Stone Size	Slope	Additional Features
Breakwater 1	250	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 154 Reef Balls
Breakwater 2	250	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 154 Reef Balls
Breakwater 3	300	12.0–15.1	7.4 (10-25 year), 8.4 (50-100 year)	1–2 tons (10-25 years), 2–3 tons (50 years), 3–4 tons (100 years)	9–18 inches, 50% >14"	2H:1V	Alternative 2 – 181 Reef Balls
Living Shoreline	1450	N/A			9–18 inches, 50% >14"	3H:1V (sand fill) 1.5H:1V Filter Stone	Native earth fill, Topsoil with Sod, Native seed mix/Seedlings, and Sand Fill. Alterative 1 – 1709 Oyster Balls

Table 26: Design Specifications for Alternative 3B

4.2 Cost-Benefit Analysis of the Design Alternatives

A cost-benefit analysis (CBA) is essential for evaluating all aspects of a project to determine the most advantageous solution for the specific area. Shoreline stabilization alternatives, including revetment systems (Alternative 1A and 1B), offshore breakwaters (Alternative 2), and an integrated groin-breakwater-living shoreline approach (Alternative 3), were assessed for their economic viability, balancing construction costs with long-term benefits, infrastructure protection, and ecological sustainability. A well-structured CBA enables decision-makers to identify the approach that provides the best return on investment.

The Engineers Opinion of Probable Construction Cost (OPCC) is developed by reviewing the site plans and cross sections to identify all construction elements and their dimensions. From these drawings, quantities of materials—such as fill, armor stone, geotextile fabric, native vegetation, and structural components—are calculated based on the specified lengths, widths, depths, and slopes. Unit prices are then applied to each material based on past projects, producing a total material cost for each segment of the project. This approach ensures that the OPCC reflects the actual physical requirements shown in the design, providing a grounded estimate based solely on measurable, material quantities.

This project has been conservatively designed with a high safety factor, meaning that all structural and ecological components are built to withstand forces greater than the estimated maximum loads. While this adds a layer of reliability and resilience, especially in a dynamic coastal environment like Belleair's, it also results in a slightly overdesigned system that may carry higher initial costs. Coastal modeling would provide more information that could be used to optimize the design in the upcoming phases of the project. This would allow for potential cost reductions through more targeted material use, adjusted structural dimensions, or simplified construction methods, ultimately leading to a more efficient and cost-effective implementation without compromising performance. **Table 27** outlines the OPCCs calculated for each design alternative.

25-Year Design	Original Cost	Reduced Armor Stone Cost
1A	$4,380,171	$4,194,537
1B	$7,210,228	$6,809,662
2	$4,515,799	$4,296,486
3A	$5,970,838	$5,446,803
3A without T-Groin (reduced cost option)	$5,260,395	$4,834,415
3B	$4,037,502	$3,780,307

Table 27. OPCCs for Conceptual Design Alternatives

To support decision-making, the matrix below **(Table 28)** offers a structured comparison of all alternatives across key criteria. In this matrix, a scale of 1, 10, and 100 is used to score the alternatives per key criteria. While 1 indicates a less-desirable outcome such as high cost and low ecological benefit, 100 indicates a more desirable outcome such as high erosion control efficiency and ease of permitting. The extent of each criterion is listed below:

1. Cost: This criterion was chosen to evaluate the financial feasibility of each alternative, ensuring that the project remains within budget while maximizing benefits.
2. Ecological Benefit: Selected to assess the positive impact on the environment, including water quality improvements, which are crucial for sustainable development.
3. Erosion Control Efficiency: Included to measure how effectively each alternative prevents erosion, protecting the shoreline and infrastructure.
4. Regulatory Approvals & Permitting: Chosen to evaluate the ease of obtaining necessary permits and approvals, which can significantly affect project timelines and feasibility.
5. Aesthetic & Recreational Value: This criterion was chosen to assess the visual appeal and recreational opportunities provided by each alternative, enhancing community engagement and satisfaction.

Design	Cost	Ecological Benefit	Erosion Control Efficiency	Regulatory Approvals & Permitting	Aesthetic & Recreational Value	Total
Alternative 1A	100	1	100	100	1	302
Alternative 1B	1	1	100	100	1	203
Alternative 2	100	10	100	10	1	221
Alternative 3A	10	100	100	1	100	311
Alternative 3B	100	100	10	10	100	320

Table 28. Matrix to Support Decision Making

While revetments (Alternative 1A & 1B) provide strong erosion control and are relatively easier to permit, they offer minimal ecological benefits. Offshore breakwaters and the terminal groin (Alternative 2) effectively reduce wave energy and erosion but require more complex regulatory approvals and pose moderate ecological concerns due to potential impacts on seagrass. The integrated approach (Alternative 3A) ranks the second highest overall due to its balanced benefits, offering strong erosion control alongside significant ecological and recreational advantages. Alternative 3B scored the highest with 320 total points, as its ecological benefits are increased through the implementation of BMPs. The design is not bound with the regulatory challenges the Alternative 3A may have, due to the removal of groins impacting the submerged aquatic vegetation in the project area.

5. CONCLUSION

The Town of Belleair Bluff Restoration and Erosion Abatement project has thoroughly evaluated various strategies to address erosion, stormwater management, and ecological restoration. Among the proposed solutions, Alternative 3A and 3B stands out as the most comprehensive and sustainable approach. This hybrid system integrates groins, breakwaters, and a living shoreline, BMPs, effectively stabilizing sediment transport, reducing wave energy, and enhancing biodiversity. By combining structural protection with ecological enhancements, this alternative ensures long-term resilience and adaptability for Belleair's coastal environment.

Effective management of upland pollutants is crucial for improving water quality and reducing runoff. Groundwater monitoring data highlights the impact of subsurface water movement on bluff stability. Elevated nutrient and bacterial concentrations at outfalls indicate the need for improved stormwater management practices. Implementing Best Management Practices such as inlet filtration devices and living shorelines will help capture stormwater, allowing sediments and pollutants to settle before reaching waterways. This approach not only mitigates erosion but also supports water conservation and reuse, contributing to the overall sustainability of the watershed.

In conclusion, Alternative 3A and 3B offer a balanced and forward-thinking solution to coastal management for Belleair Bluff. By integrating structural and ecological measures, this project addresses erosion, wave energy, and habitat loss simultaneously. The careful management of construction access and the implementation of Best Management Practices will minimize environmental impact and enhance the natural landscape. This comprehensive strategy sets a precedent for effective shoreline protection and environmental resilience, ensuring the long-term preservation and enhancement of Belleair's coastal environment.

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