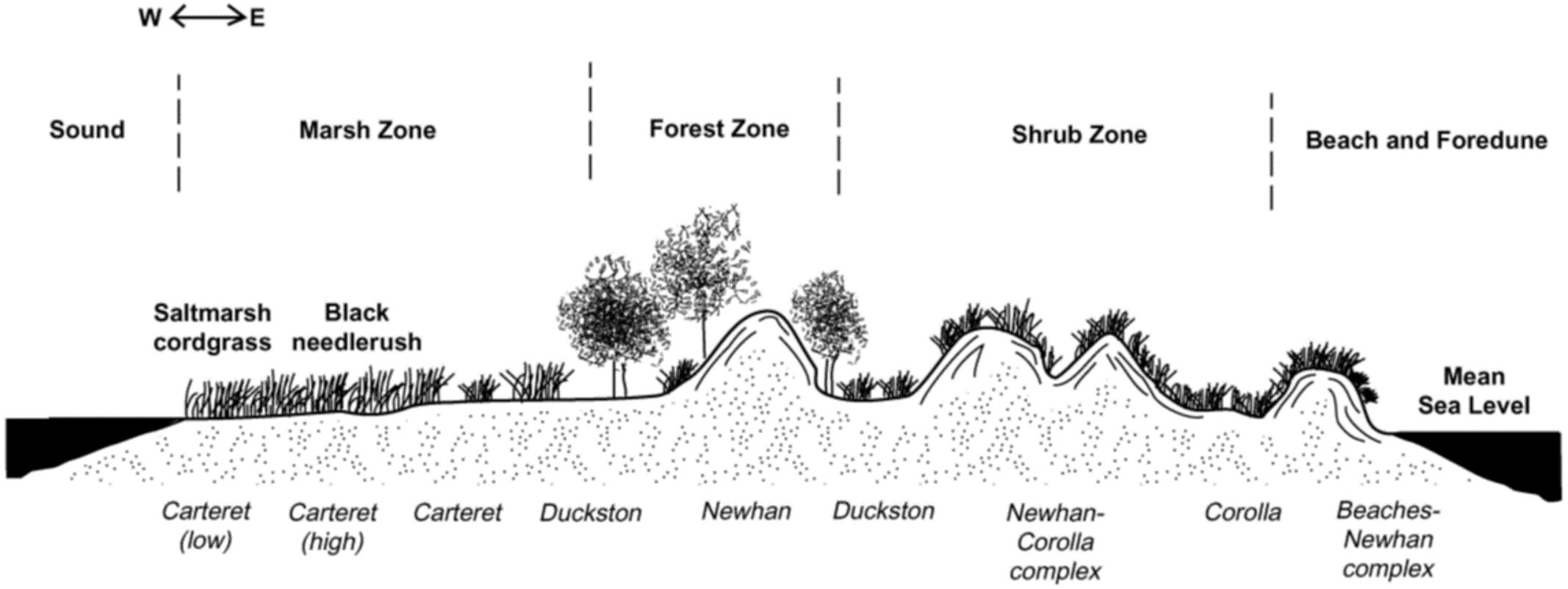
Innovative Stormwater Solutions in Coastal Areas

2023 FSBPA Tech Conference

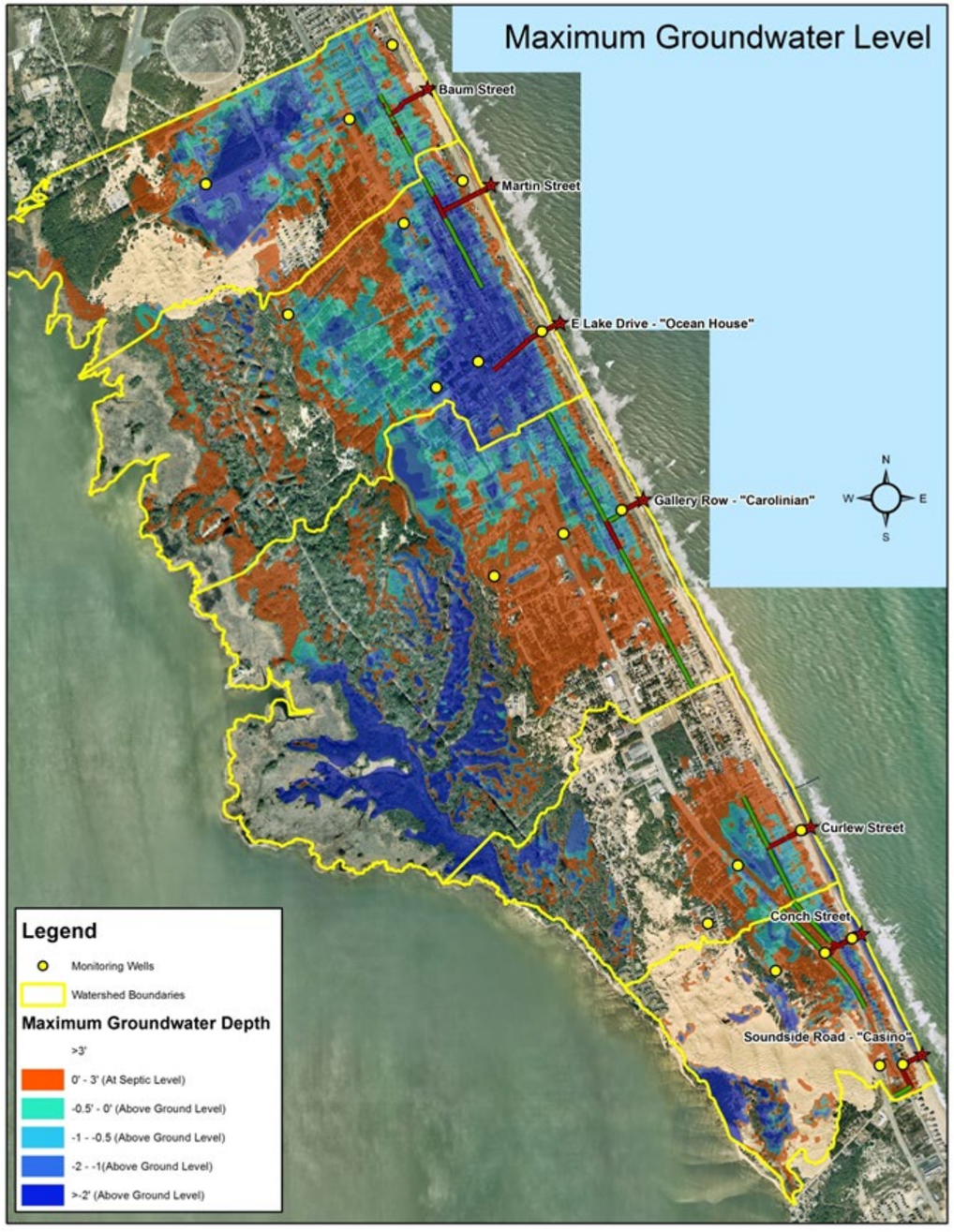
February 2, 2023

moffatt & nichol

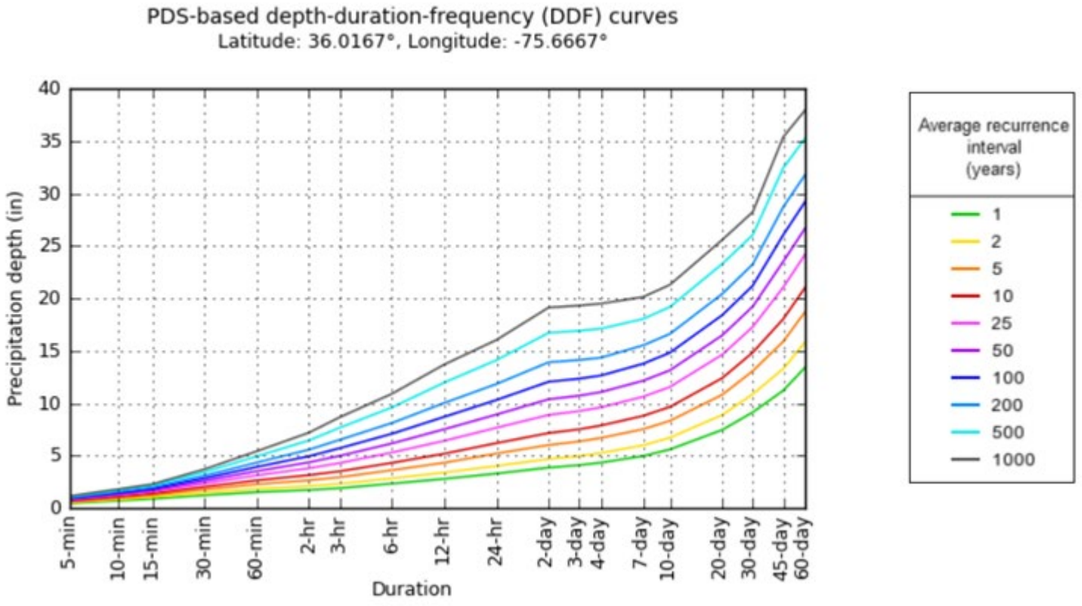
Barrier Island Hydrology



Barrier Island Hydrology



Barrier Island Hydrology



Rainfall Statistics Are Increasing in Many Places

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.452** (0.414–0.497)	**0.534** (0.487–0.583)	**0.622** (0.569–0.679)	**0.697** (0.636–0.760)	**0.789** (0.715–0.856)	**0.860** (0.775–0.934)	**0.931** (0.838–1.01)	**0.999** (0.894–1.08)	**1.09** (0.966–1.18)	**1.16** (1.03–1.27)
10-min	**0.723** (0.661–0.794)	**0.854** (0.779–0.933)	**0.996** (0.912–1.09)	**1.12** (1.02–1.22)	**1.26** (1.14–1.36)	**1.37** (1.24–1.49)	**1.48** (1.33–1.61)	**1.58** (1.42–1.72)	**1.72** (1.53–1.87)	**1.83** (1.62–1.99)
15-min	**0.903** (0.826–0.992)	**1.07** (0.980–1.17)	**1.26** (1.15–1.38)	**1.41** (1.29–1.54)	**1.59** (1.44–1.73)	**1.74** (1.56–1.88)	**1.87** (1.68–2.03)	**2.00** (1.79–2.17)	**2.17** (1.92–2.36)	**2.30** (2.03–2.50)
30-min	**1.24** (1.13–1.36)	**1.48** (1.35–1.62)	**1.79** (1.64–1.96)	**2.04** (1.86–2.23)	**2.36** (2.14–2.56)	**2.61** (2.35–2.84)	**2.86** (2.58–3.11)	**3.11** (2.78–3.37)	**3.45** (3.06–3.75)	**3.73** (3.28–4.05)
60-min	**1.54** (1.41–1.70)	**1.86** (1.70–2.03)	**2.29** (2.10–2.51)	**2.66** (2.43–2.90)	**3.14** (2.85–3.41)	**3.54** (3.19–3.84)	**3.94** (3.55–4.28)	**4.36** (3.90–4.73)	**4.95** (4.39–5.38)	**5.44** (4.79–5.92)
2-hr	**1.75** (1.59–1.92)	**2.12** (1.93–2.33)	**2.67** (2.43–2.93)	**3.17** (2.88–3.46)	**3.82** (3.45–4.16)	**4.38** (3.94–4.76)	**4.96** (4.45–5.39)	**5.59** (4.98–6.07)	**6.47** (5.72–7.03)	**7.21** (6.32–7.84)
3-hr	**1.92** (1.75–2.11)	**2.34** (2.13–2.56)	**2.96** (2.70–3.24)	**3.53** (3.21–3.85)	**4.31** (3.89–4.70)	**4.99** (4.49–5.42)	**5.72** (5.12–6.21)	**6.52** (5.79–7.07)	**7.67** (6.73–8.31)	**8.67** (7.54–9.37)
6-hr	**2.36** (2.16–2.59)	**2.85** (2.60–3.12)	**3.63** (3.31–3.98)	**4.33** (3.93–4.73)	**5.32** (4.79–5.78)	**6.18** (5.55–6.70)	**7.10** (6.33–7.70)	**8.13** (7.17–8.80)	**9.61** (8.38–10.4)	**10.9** (9.42–11.8)
12-hr	**2.81** (2.55–3.12)	**3.41** (3.08–3.78)	**4.34** (3.93–4.81)	**5.20** (4.70–5.75)	**6.43** (5.78–7.07)	**7.53** (6.72–8.24)	**8.71** (7.70–9.53)	**10.0** (8.77–11.0)	**12.0** (10.3–13.1)	**13.7** (11.6–15.0)
24-hr	**3.31** (3.03–3.63)	**4.04** (3.69–4.42)	**5.22** (4.76–5.69)	**6.21** (5.64–6.75)	**7.67** (6.92–8.32)	**8.93** (7.97–9.69)	**10.3** (9.14–11.2)	**11.8** (10.4–12.9)	**14.1** (12.2–15.4)	**16.0** (13.6–17.6)

Site Characteristics

- Topography - Dune And Trough System
- Land Use/Vegetation – Residential & Commercial/ Vegetation Reduced
- Soils – Clean Sands/Organic Pockets and Shallow Confining Layer
- Groundwater Levels – High in Low-lying Areas
- Tides – Can Impede Groundwater Transmission
- Rainfall – Extratropical & Tropical Events
- Water Quality – Fecal Coliform & Enterococcus

Data Collection Efforts

- Geotechnical Information
  - Hydraulic Conductivities (Saturated & Unsaturated)
- Water Quality Testing and Wetland Surveys
  - Fecal counts tied to sample location – surface water samples high – groundwater samples low
  - Wetland surveys needed to estimate potential impacts of solutions

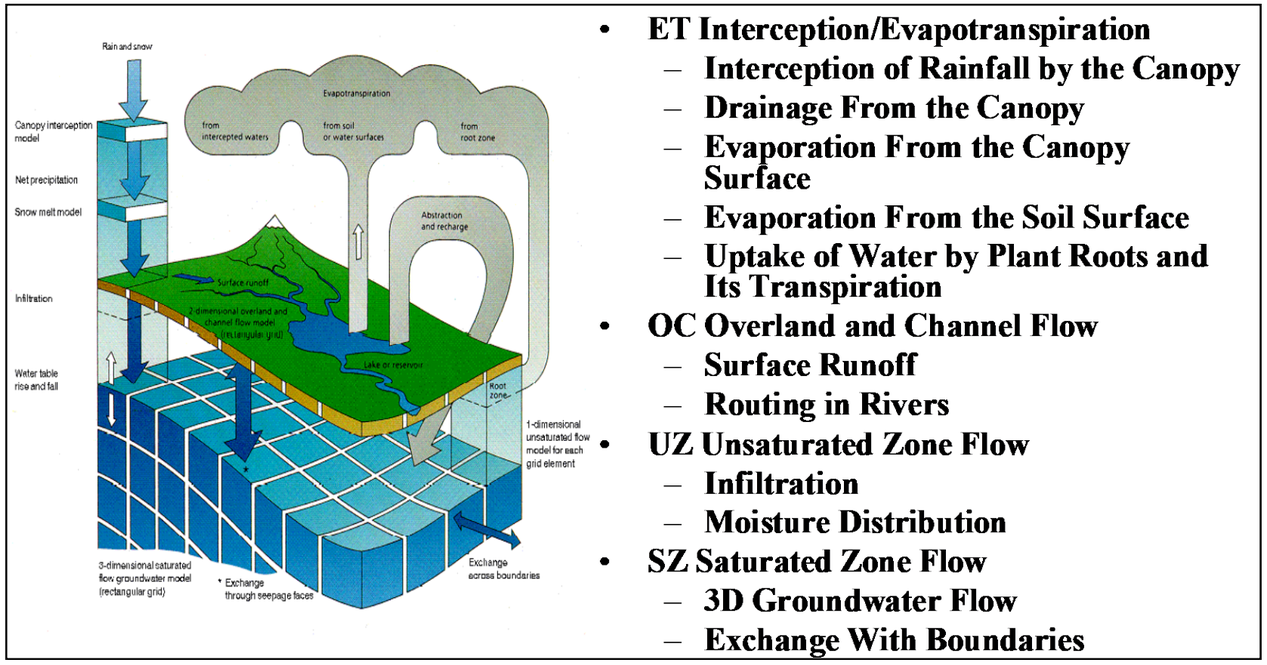
Example Water Quality Sampling Data

Summary of Fecal Coliform Test Results from Sample Sets 1 through 3

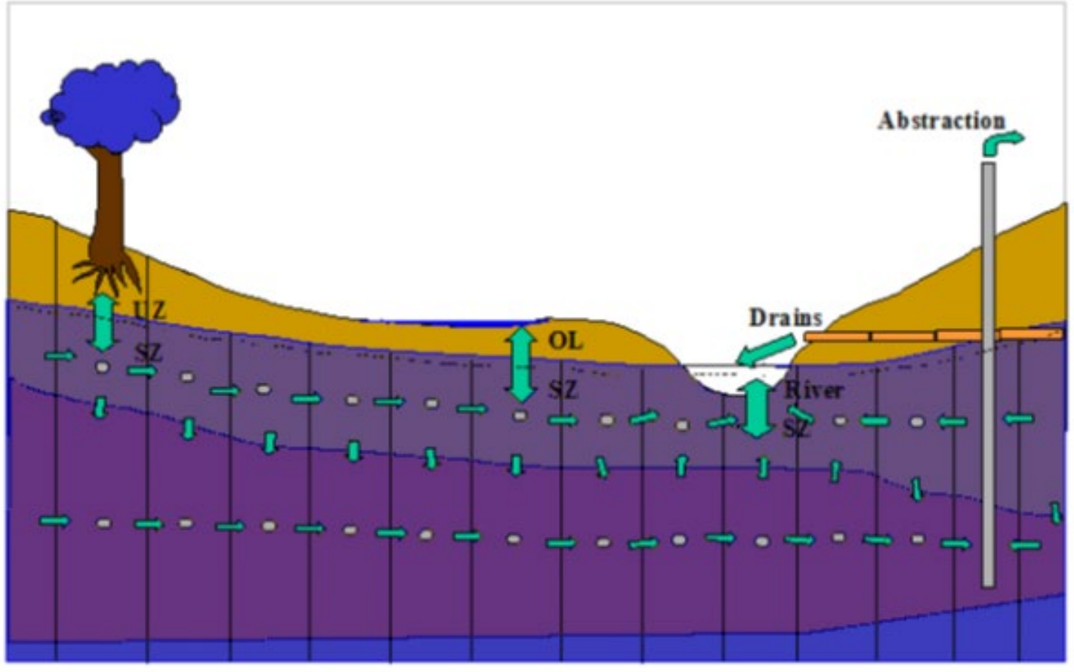
Sample	Fecal Coliform (FC/100 mL)			
	Set 1 (Atlantic Coast Lab)	Set 2 (Craven Co. Health Dept.)	Set 3 (Craven Co. Health Dept.)	Set 3 (CEETL Lab.)
P-1	2,200	< 1	< 1	< 1
P-2	4,000	1	2	< 1
P-3	2,100	< 1	< 1	59
P-4	5,400	< 1	1	< 1
P-5	410	< 1	< 1	< 1
P-6	2,200	< 1	< 1	NE
P-7	2,400	< 1	< 1	< 1
P-8	500	58	< 1	52
S-1	600	2,000	204	145
S-2	46	17	6	20
S-3	23	51	15	< 1
S-4	2,500	1,900	40	41
S-5	182	360	113	91
S-6	2,000	420	290	290
S-7	490	5,700	590	270
S-8	2,800	1,900	234	100
Well 1	-----	< 1	< 1	24
Well 2	-----	< 1	< 2	< 1
Well 3	-----	< 10	16	210
Well 4	-----	< 1	< 1	< 1
Well 5	-----	< 1	1	160
Well 6	-----	< 1	< 1	NE
Well 7	-----	< 1	< 1	< 1
Well 8	-----	< 1	< 1	NE
Well 9	-----	< 1	< 1	< 1

"P" samples collected from wells P-1 through P-8
"S" samples collected from surface water near wells P-1 through P-8
NE – Laboratory was unable to estimate fecal coliform

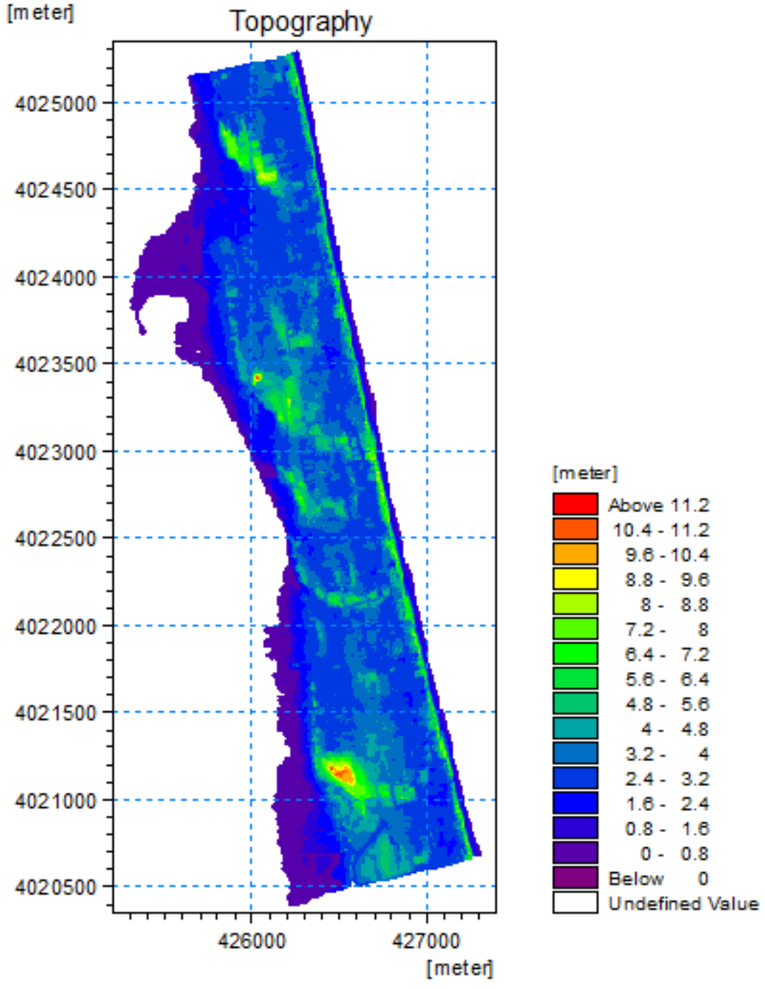
New Modeling Tools

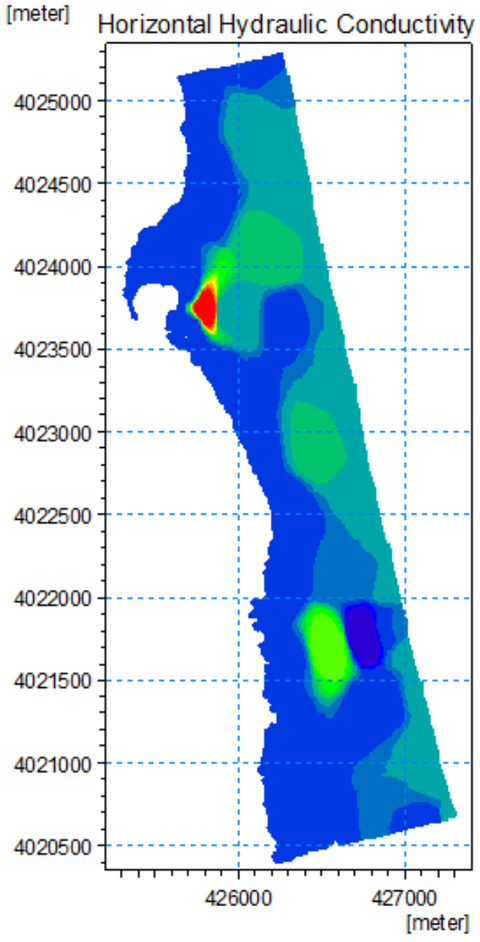


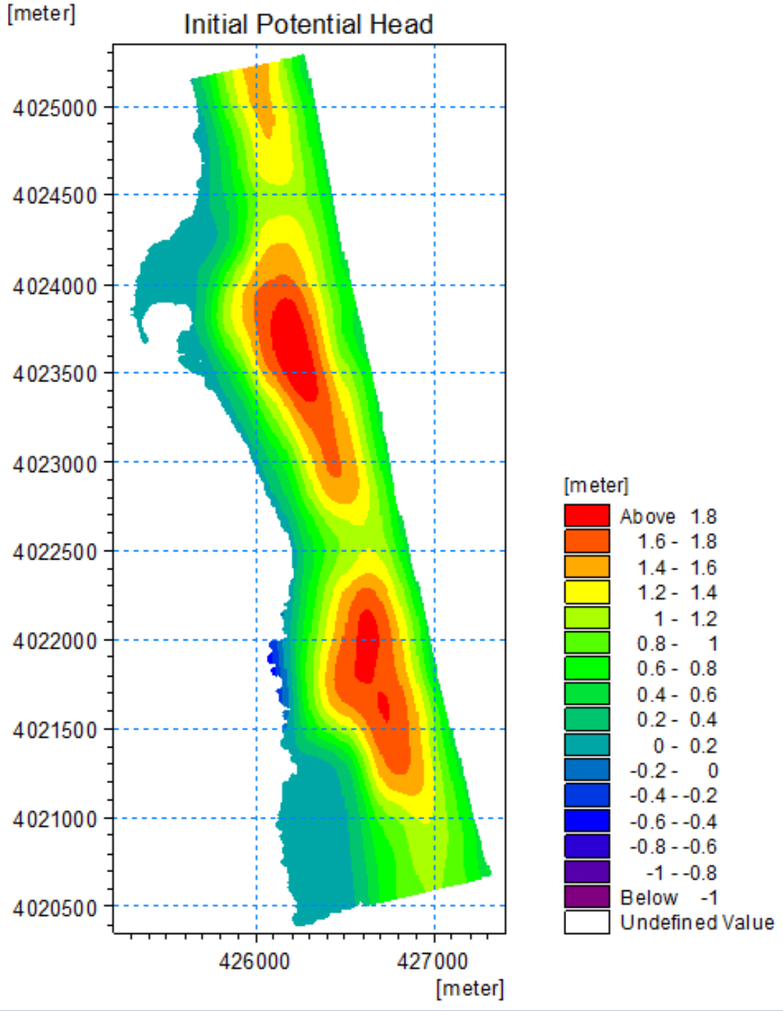
- **ET Interception/Evapotranspiration**
  - Interception of Rainfall by the Canopy
  - Drainage From the Canopy
  - Evaporation From the Canopy Surface
  - Evaporation From the Soil Surface
  - Uptake of Water by Plant Roots and Its Transpiration
- **OC Overland and Channel Flow**
  - Surface Runoff
  - Routing in Rivers
- **UZ Unsaturated Zone Flow**
  - Infiltration
  - Moisture Distribution
- **SZ Saturated Zone Flow**
  - 3D Groundwater Flow
  - Exchange With Boundaries



New Modeling Tools

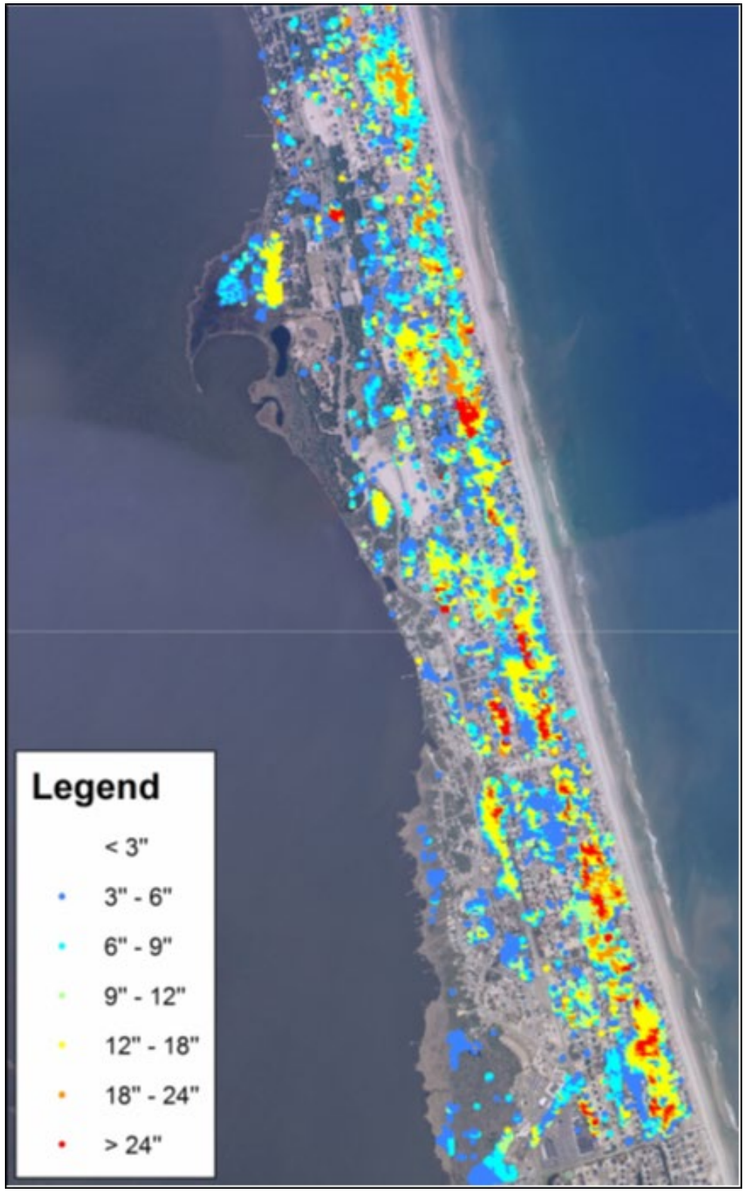






New Modeling Tools

Flooding during an 8” rainfall event



Flooding during a 16” rainfall event

Treatment Options

- In-line Systems Provide Some Treatment
  - Levels are very high
  - Even with treatment, levels above standard
  - Problematic to meet goals
- Groundwater Collection and Pumping More Viable
  - Use in-situ sand to provide treatment
  - Manage groundwater tables to provide additional capacity and limit septic field inundation

Emerald Isle and Currituck County

- Monitoring Data for These Systems Is Promising
  - Pumped groundwater fecal levels are significantly lower than ponded surface samples
  - Agencies have allowed pumping to upland areas and ponds
  - Receiving area needed
  - Force main and pump infrastructure is expensive
  - Generators and SCADA controls also add cost

Emerald Isle and Currituck County

- Monitoring Data for These Systems Is Promising

Water Quality Sampling Results - Discharge

Date	Time	COLIF, FEC col/100ml	TKN (ppm)	NO3+NO2-N (ppm)	TN (ppm)	TP (ppm)	CU/T/ICP (ppm)	ZN/T/ICP (ppm)
2/14/07	12:30 PM	<1	1.390	<0.1	1.390	0.851	<0.002	0.013
2/28/07	12:30 PM	<1	1.960	0.405	2.360	2.040	0.005	0.030
5/16/07	1:45 PM	161	1.300	<0.1	1.300	0.554	0.007	<0.005
7/24/07	12:00 PM	31	0.568	1.170	1.710	0.484	1.380	0.021
11/30/07	2:25 PM	<1	1.900	<.1	1.900	1.950	<.002	0.577
1/29/08	12:00 PM	<1	1.160	<.1	1.160	1.070	0.036	0.055
3/31/08	12:10 PM	2	0.762	<.1	W	0.822	0.103	0.058
5/30/08	11:00 AM	<1	0.948	<.1	0.948	1.280	0.085	0.054
7/31/08	1:00 PM	<1	<.1	<.1	<.1	0.272	0.274	0.080
9/30/08	1:00 PM	No Flow						
2/28/09	8:30 AM	<1	0.621	<.1	0.621	0.744	<.005	0.006

Emerald Isle and Currituck County

Water Quality Sampling Results - Well 3

Date	Time	COLIF, FEC col/100ml	TKN (ppm)	NO3+NO2-N (ppm)	TN (ppm)	TP (ppm)	CU/T/ICP (ppm)	ZN/T/ICP (ppm)
2/14/07	12:30 PM	<1	1.350	<.1	1.350			0.041
2/28/07	12:30 PM	<1	1.350	0.345	2.940	3.170	unreadable	0.017
5/16/07	1:45 PM	<1	1.530	<0.1	1.530	2.270	<.005	<.005
7/24/07	12:00 PM	<1	8.580	1.100	1.960	1.610	0.086	0.038
9/24/07	11:30 AM	<1	6.920	<.1	6.920	2.180	<.003	0.006
11/30/07	2:25 PM	<1	0.745	<.1	0.745	2.520	0.007	0.480
1/29/08	12:00 PM	<1	1.050	<.1	1.050	1.790	0.004	0.021
3/31/08	12:10 PM	<1	0.305	<1	W	0.772	<.003	<.006
5/30/08	11:00 AM	Well Removed						

Water Quality Sampling Results - Well 4

Date	Time	COLIF, FEC col/100ml	TKN (ppm)	NO3+NO2-N (ppm)	TN (ppm)	TP (ppm)	CU/T/ICP (ppm)	ZN/T/ICP (ppm)
2/14/07	12:30 PM	<1	1.350	<0.1	1.350	1.990	<0.002	0.041
2/28/07	12:30 PM	<1	1.350	0.345	2.940	3.170	<0.005	0.017
5/16/07	1:45 PM	<1	1.530	<0.1	1.530	2.270	<0.005	<0.005

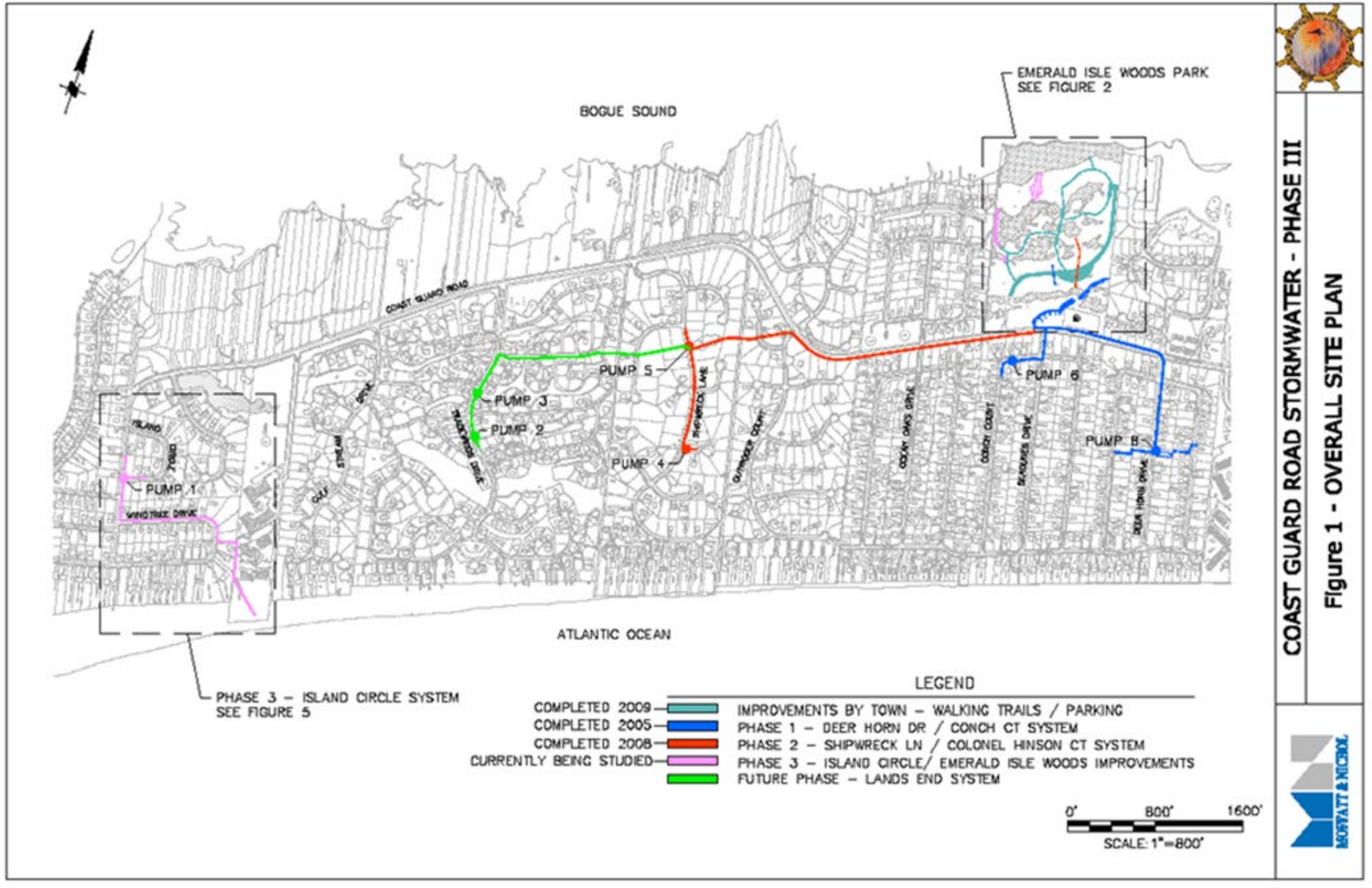
Water Quality Sampling Results - Well 7

Date	Time	COLIF, FEC col/100ml	TKN (ppm)	NO3+NO2-N (ppm)	TN (ppm)	TP (ppm)	CU/T/ICP (ppm)	ZN/T/ICP (ppm)
2/14/07	12:30 PM	20	1.200	<0.1	1.200	0.960	0.242	0.122
2/28/07	12:30 PM	3	1.620	0.210	1.830	0.964	0.552	0.430
5/16/07	1:45 PM	<1	1.420	<0.1	1.420	0.583	0.525	0.213
7/24/07	12:00 PM	25	0.777	1.170	1.950	0.570	0.758	0.036
9/24/07	11:30 AM	dry well						
11/30/07	2:25 PM	83	0.432	<.1	0.432	2.010	0.025	1.110
1/29/08	12:00 PM	dry well						
3/31/08	12:10 PM	dry well						
5/30/08	11:00 AM	Well Damaged						

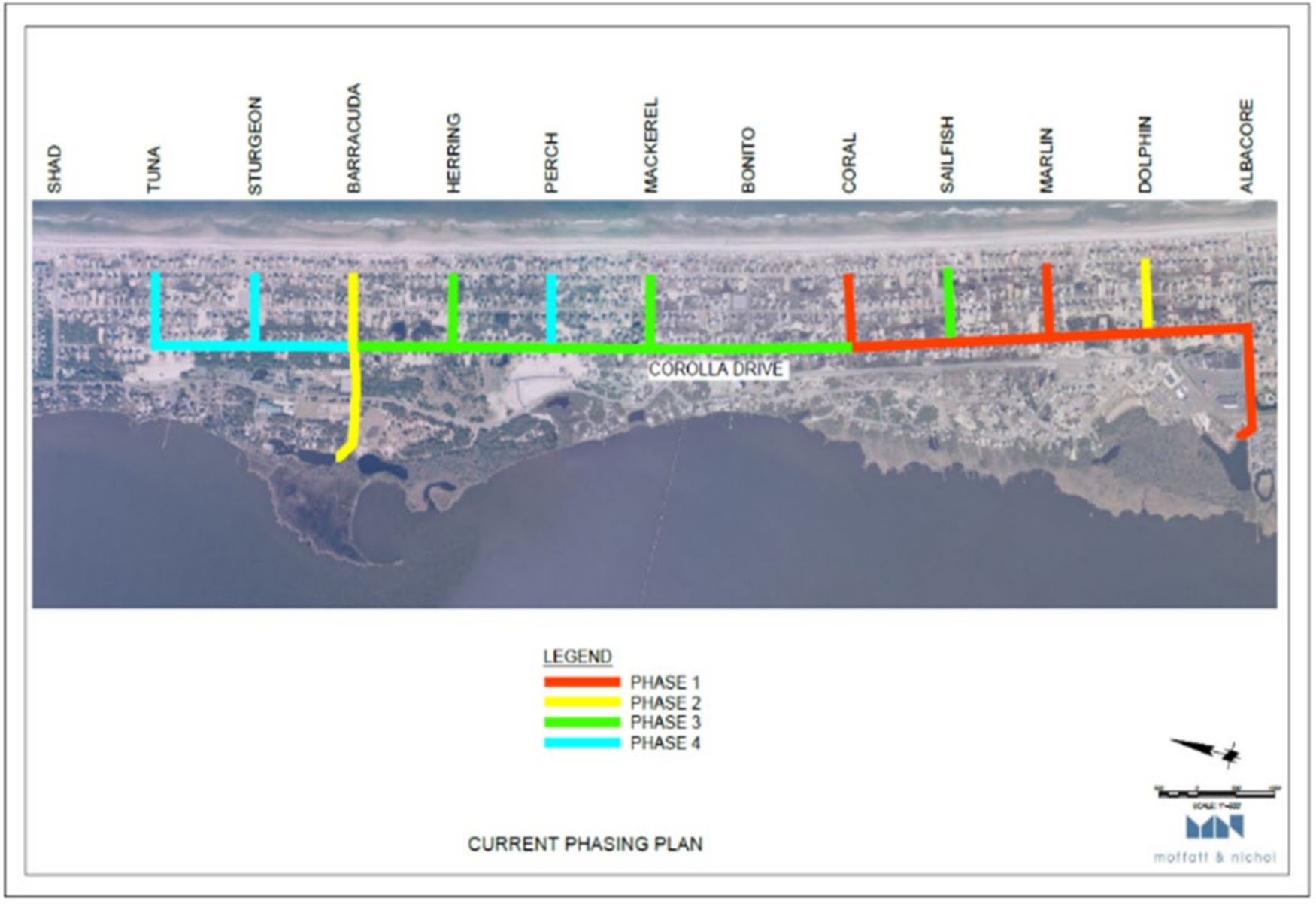
Water Quality Sampling Results - Well 9

Date	Time	COLIF, FEC (col/100ml)
2/14/07	12:30 PM	<1
2/28/07	12:30 PM	<1
5/16/07	1:45 PM	<1
7/24/07	12:00 PM	<1
9/24/07	11:30 AM	<1
11/30/07	2:25 PM	<1
1/29/08	12:00 PM	<1
3/31/08	12:10 PM	<1
5/30/08	11:00 AM	<1
7/31/08	1:00 PM	<1
9/30/08	1:00 PM	<1
2/28/09	8:30 AM	Well Dry

Emerald Isle and Currituck County

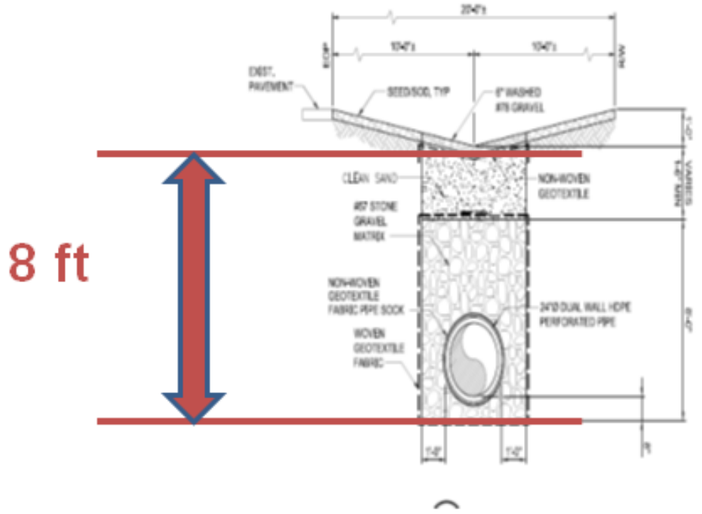


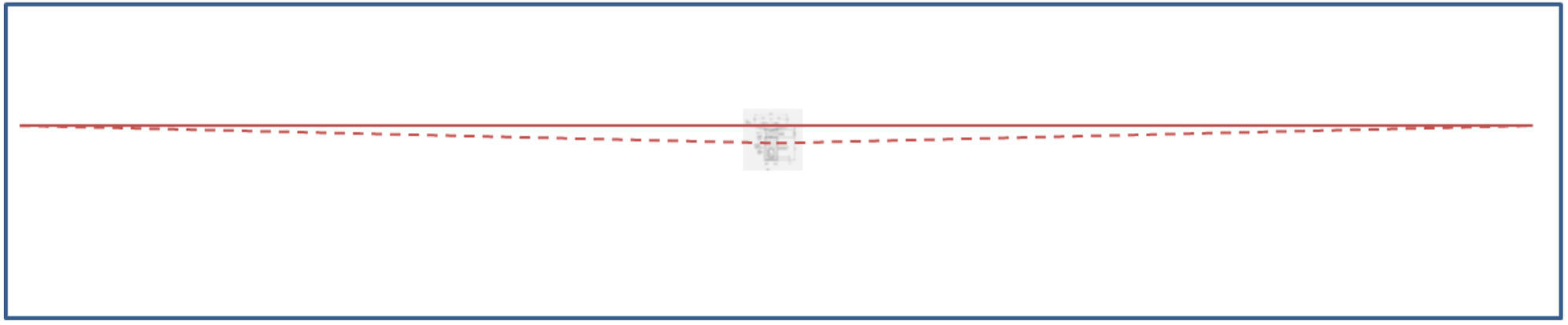
Emerald Isle and Currituck County



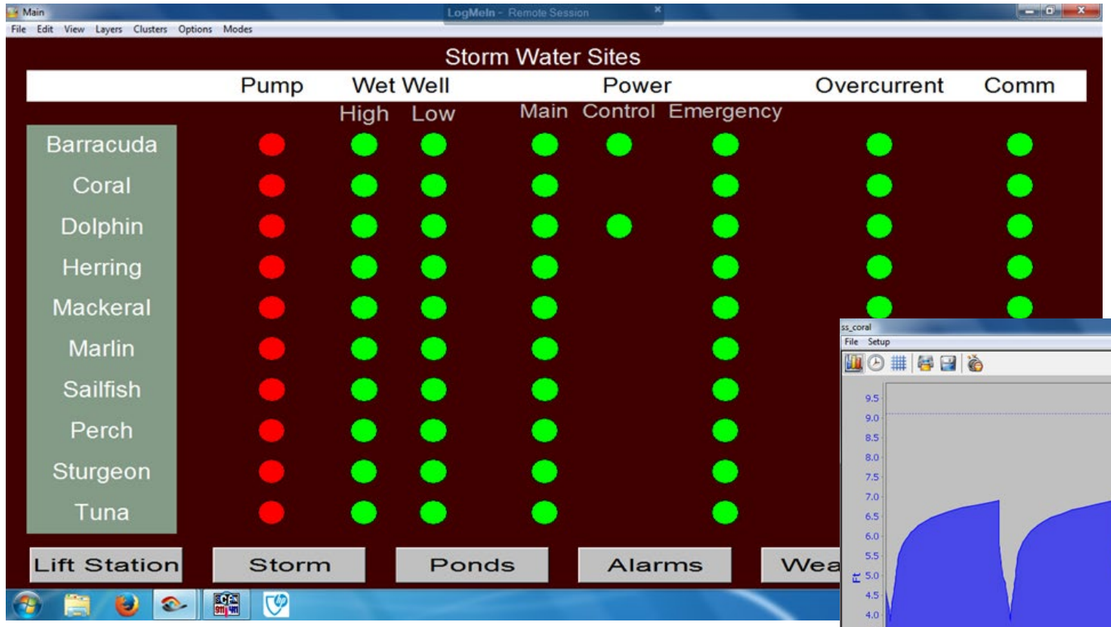
Emerald Isle and Currituck County

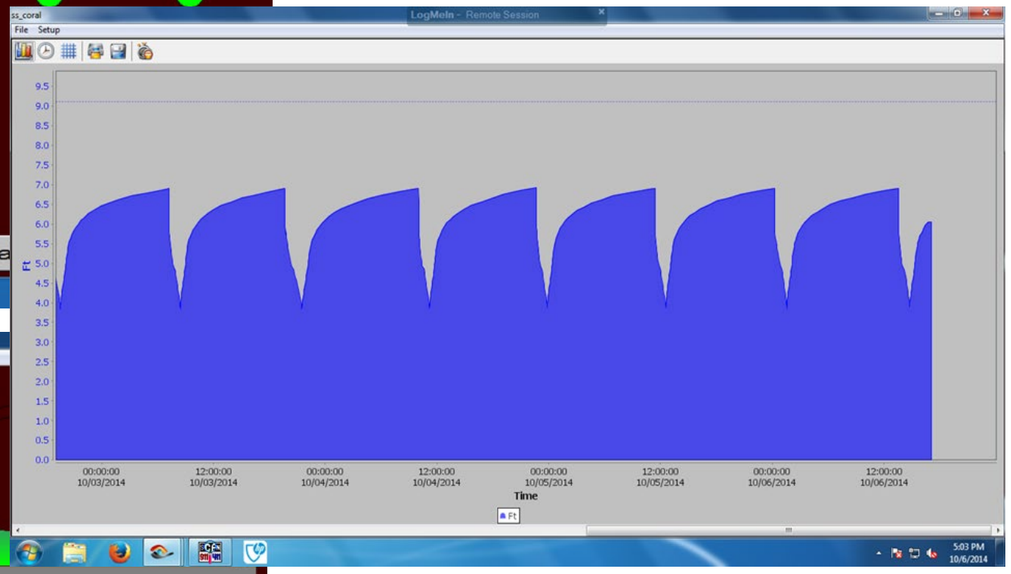
Emerald Isle and Currituck County

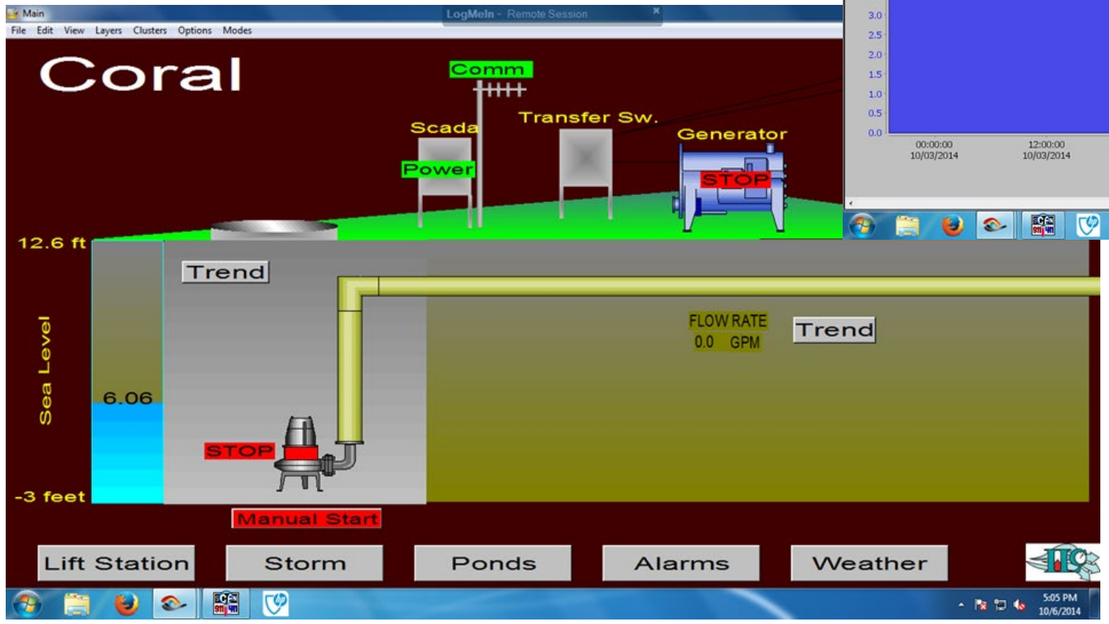




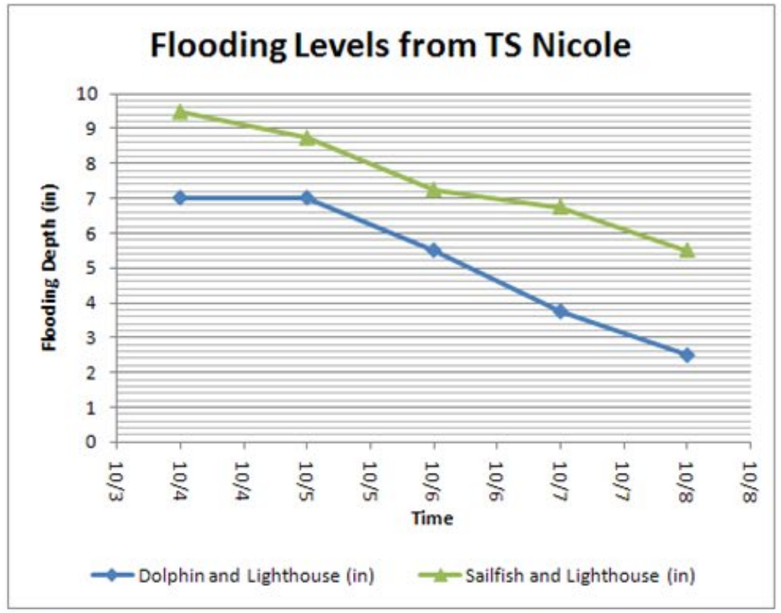
Emerald Isle and Currituck County







Emerald Isle and Currituck County



Emerald Isle and Currituck County

FEMA Stormwater Hazard Mitigation Plan
Client: The Town of Emerald Isle, North Carolina

"The town has enjoyed a productive working relationship with M&N. M&N's staff have been very responsive to the Town's concerns, have shown a willingness to explore all options, and have been successful in presenting highly technical information in a manner in which elected officials, Town staff and the public can understand. M&N staff have been extremely well-prepared for formal meetings with regulatory agencies, and appear to have a cooperative and productive relationship with the regulatory agencies. "

Frank A. Rush, Jr., Town Manager, Town of Emerald Isle

"After receiving approximately 8-10 inches of rain from Hurricane Ophelia, and another 10-12 inches of rain from the remnants of Tropical Storm Tammy a few weeks later, the Town was faced with numerous storm water problems, particularly in the Coast Guard Road area of Town. The Town's new storm water system for the Fawn Drive, Deer Horn Drive, and Conch Court areas worked very well and eliminated storm water problems at these locations in a matter of hours. Water from these locations was pumped to the Emerald Isle Woods Park site."

Emerald Isle and Currituck County

One of the drainage board members, who has worked for the U.S. Army Corps of Engineers for nearly 30 years quoted, **“I’ve never been involved with a project in all my career that has been as satisfying as this one.** I have never seen a municipal agency, A/E firm, and the public work more hand-in-hand to deliver such a great project.”

The system has now performed well during a number of nor’-easters and small hurricanes. The system has also been outfitted with telemetry that allows remote control and monitoring of the system and groundwater levels so that the County can operate the system proactively and draw down groundwater levels if a significant storm is approaching.

Eric Weatherly – Currituck County Engineer

Project Costs & Financing

- Emerald Isle – System Cost = $2.3 M for 1,000 Acre Watershed
  - Project financed with loans paid for by ad-valorem taxes

- Currituck County – System Cost = $8.3 M for 850 Acre Watershed (Aesthetics, Basins, Driveway Relocations, SCADA, Generators) – Project financed with loans paid for by special tax district set up for Whalehead subdivision

Contact Information

Johnny Martin, PE
Senior Coastal/Hydraulic Engineer

Moffatt & Nichol
E-mail: jmartin@moffattnichol.com