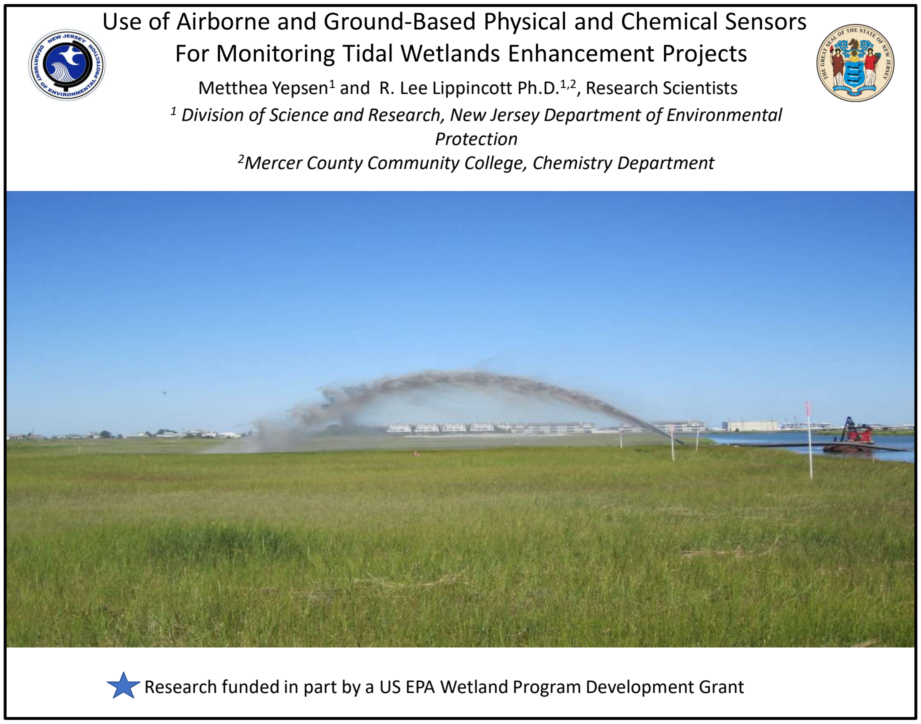


I have the pleasure of working with an diverse team of researchers on this project with a variety of external partners that contribute to our knowledge base when attempting to restore or enhance the state of new jersey's tidal wetlands. The principal research project manager for several ecologically based projects in the division of science and research is Metthea Yepsen. I also am affiliated as an associate professor of chemistry at Mercer County Community College and I use several of the research projects and work that I do for the state as real world examples of how environmental chemistry is improving the water quality and the natural environment in our state.

Pictured here is an example of the deposition process

Marsh Restoration Project Overview

- Project funded by NFWF Hurricane Sandy Coastal Resiliency Competitive Grants Program (2014)
- Continued monitoring funded by EPA Wetland Program Development Grant and NFWF Restoration Grant
- Regional need for marsh enhancement and dredging
- Test dredged material beneficial use concept (ecological & economic benefits)
- Three “experimental” pilot projects in New Jersey – Ring Island, Avalon, & Fortescue

The current project is funded by an EPA Wetland Program Development Grant.
Regional need for marsh enhancement and dredging of the inland waterways
Test dredged material beneficial use concept (ecological & economic benefits)
For example, if you direct the dredge spoils along the inland water way to ecologically stressed area as you proceed,
It is much more economical than constructing the additional pipe required to direct the dredged material to a central mud island
Three “experimental” pilot projects in New Jersey – Ring Island, Avalon, & Fortescue

Airborne Sensor Platforms

- Satellite
- Fixed Wing General Aviation Aircraft and Fixed wing Drone
- Quadcopter Drone

I’ve separated out three categories of high resolution photo gravimetry that were considered and are being utilized in this research.

Satellite
Fixed Wing General Aviation Aircraft and Drone

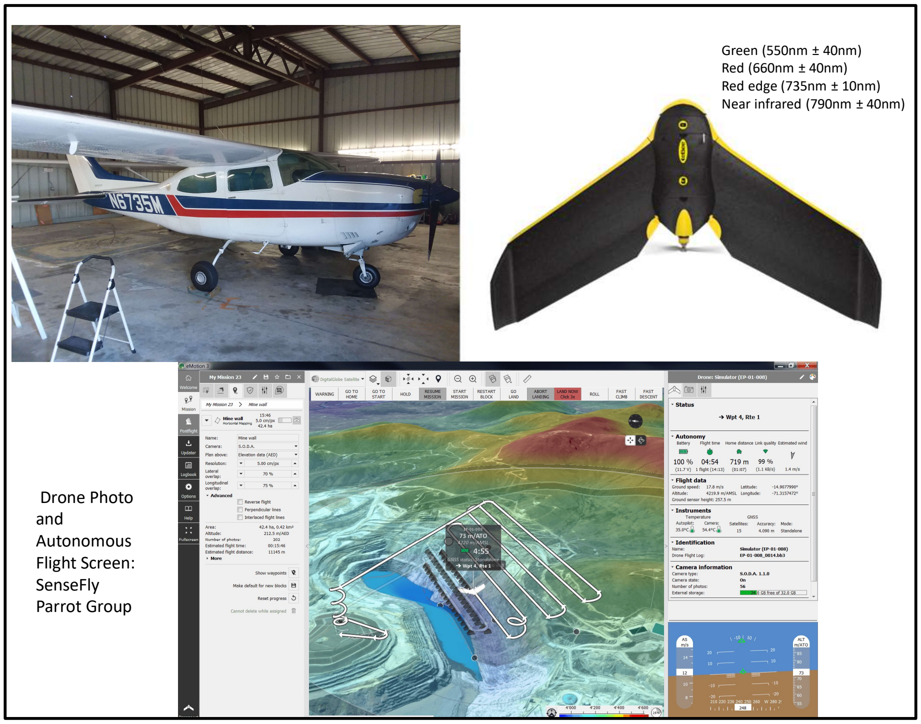
<u>Satellite Data</u>

- Multispectral sensors
- 30 meter pixel resolution

<u>Fixed Wing: General Aviation Aircraft and Drone</u>

- Acquired High Resolution photographs with overflights less than one hour.
- High Wing Cessna 210 with GPS and 28MP resolution camera
- Ebee 12MP visible photography and multispectral camera

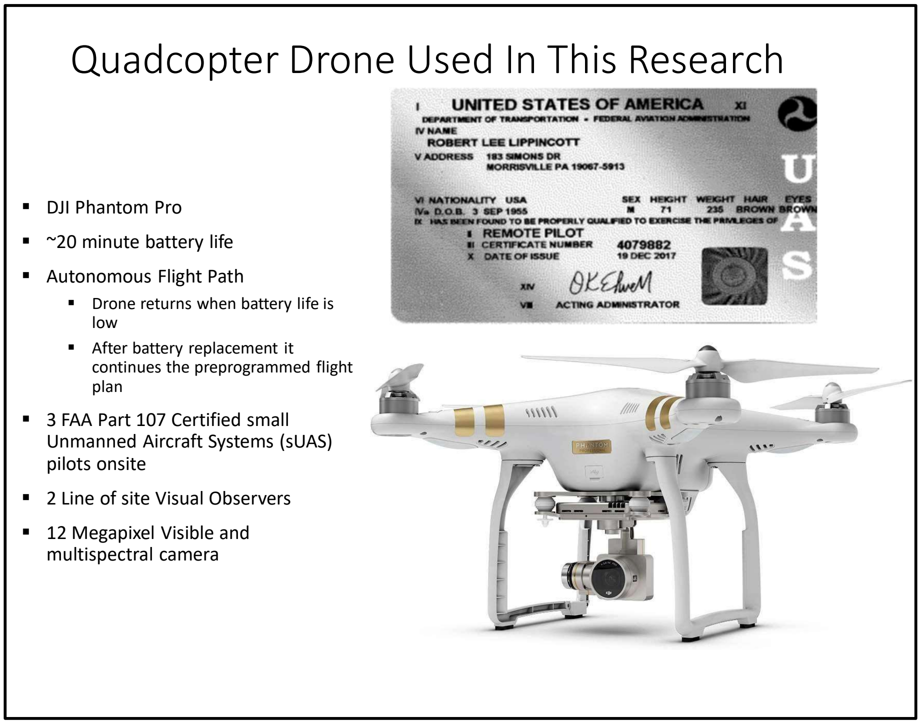
On of the biggest limitations of using the satellite data is the pixel resolution of 30 meters. Although it has been quite useful for assessing chlorophyll concentrations for very large areas like some of the recreational lakes in New Jersey the state is relatively small.



For large area surveillance, we use general aviation aircraft and fixed wing drones. The Cessna Centurion on the upper left with its cantilevered wing and retractable landing gear offers unobstructed view. With this platform we use 28 megapixel cameras with internal GPS to create a photomosaic point cloud of the study areas. The GA aircraft are very efficient in collecting high resolution photography, but the camera angle is not straight down which causes some distortion of the fringe images produced by the post processing software. Flights for both study areas took 20 minutes using this platform.

In addition the DEP Freshwater and Biological monitoring group has a fixed with drone with multispectral capabilities at 12 megapixel resolution for four filter bands. This autonomous drone has programmable flight paths that is illustrated at the bottom of the slide. This makes the data collection more repeatable year after year.   This drone can complete the overflights for the research areas in approximately 20 minutes for each site location.

Images from both platforms are exported into two separate post processing software packages. One is Pix4D and the second is an ESRI product called drone to map. Both software packages can export directly into the state Geographical Information System or GIS.
Multispectral bands for the Ebee are ;
Green (550nm ± 40nm)
Red (660nm ± 40nm)
Red edge (735nm ± 10nm)
Near infrared (790nm ± 40nm)



There are FAA part 107 rule to comply with when flying drones. Waivers must me obtained and permission granted from several federal, state, and local sources before the aerial survey can begin. In this research we take a team of Part 107 Certified pilots in addition to two visual observers to ensure compliance with the flight rules and other requirements to conduct the work. We take multiple batteries to accomplish the entire flight and the drone returns to the starting point automatically when low battery status is indicated. The battery is then changed and the drone returns to its pre programmed point to continue the aerial programmed flight path .

There are three (3) main uses for drone photos in this research:

1. **Annual photos collected at low tide the during peak of growing season are used to track vegetation recovery after the restoration project. This provides more accuracy than randomly selected vegetation plots.**
2. **The photos are also useful for comparison with other types of spatial data – like elevation and flood frequency.**
3. **Assessments can be made for seasonal changes and erosion in the vulnerable study**

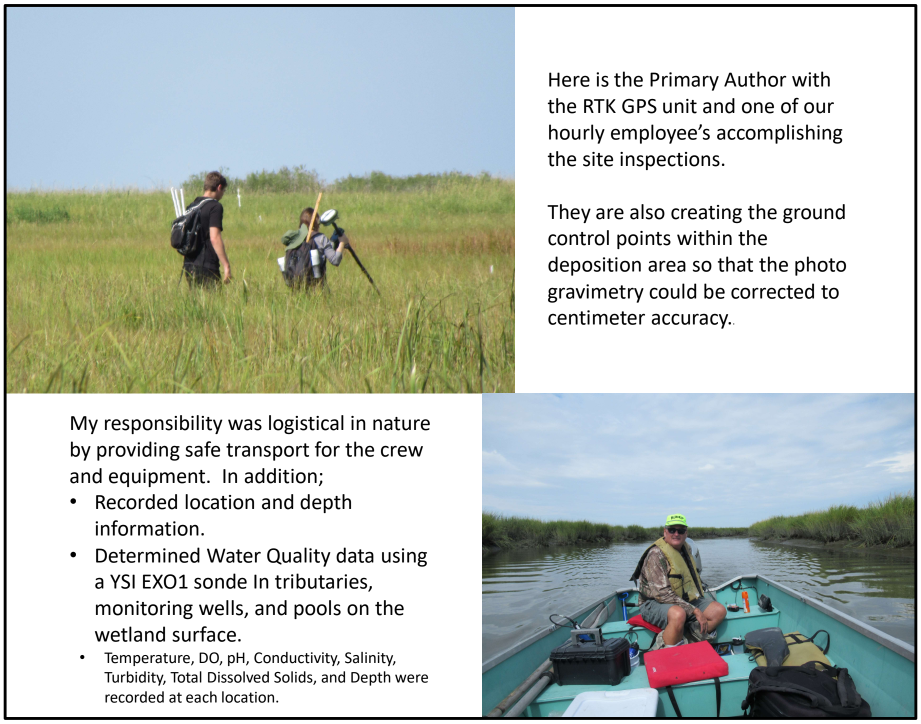
areas.

Here are some pictures of the flight crews on a bright sunny day. Actually the drone pilots prefer overcast days because it provides a more uniform Orthomosaic Raster surface product without periods of sun and clouds.

In the upper right picture you see the drone landing pad, usually the drone can return to the landing pad for battery exchange but if the winds are too strong (in excess of 15 knots) a safe landing may be compromised and damage the drone from collision with the terrain can occur.

The lower right photo shows the quad coptor mavic drone crew at Ring Island. This drone has the infrared camera capability

The left photo shows the pilots in yellow vests with the hardhats and the visual observers that are required to comply with the FAA regulations.



Here is the Primary Author carrying the RTK GPS unit with one of our hourly employee's accomplishing a site inspection.
They are also creating the ground control points within the deposition area so that the photo gravimetry can be corrected to centimeter accuracy..

My responsibility was logistical in nature by providing safe transport for the crew and equipment. In addition;

- I Record location and depth information in the tributaries using the depth recorder and navigation unit pictured to my left.
- I also Determine Water Quality data using a YSI EXO1 sonde In monitoring wells, tributaries, and pools on the wetland surface.
  - The parameter sensors on the EXO1 sonde are; Temperature, DO, pH, Conductivity, Salinity, Turbidity, Total Dissolved Solids,

and Depth were recorded at each location.

Post Processing of Photographic data

<u>Software</u> (Both are compatible with the State Geographical Information System)

- ESRI Drone to Map
- Pix4D

<u>Output Products</u>

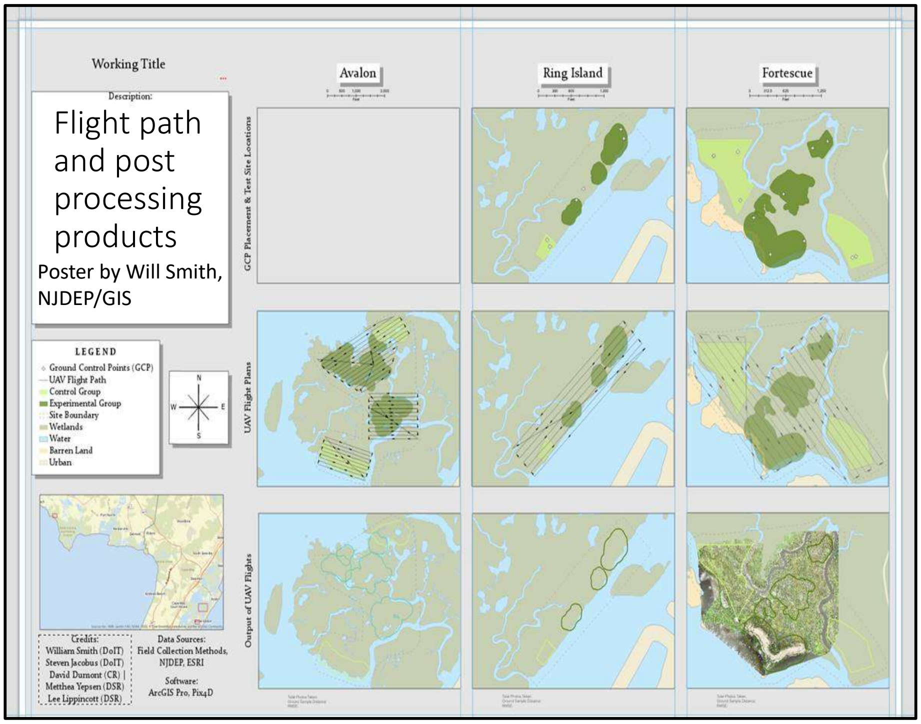
- Orthomosaic Raster
  - Identification of No growth/Regrowth areas and species
- 3D Point Cloud
  - Corrected with RTK GPS to cm precision
  - Seasonal and annual change in vegetation recovery
- Digital Surface Models
  - Encountered problems with pixel recognition over water and elevation projected to the tops of the vegetation
  - Solution RTK surveys

ESRI is the vendor that provides the state's Geographical Information System computing platform. ESRI paid the Pix4D vendor to provide the basic shell programming for Drone to Map initially, then ESRI developed more functionality and compatibility with our GIS system to the point were the Department can utilize the product exclusively.

The three output products from the site overflights are listed here;

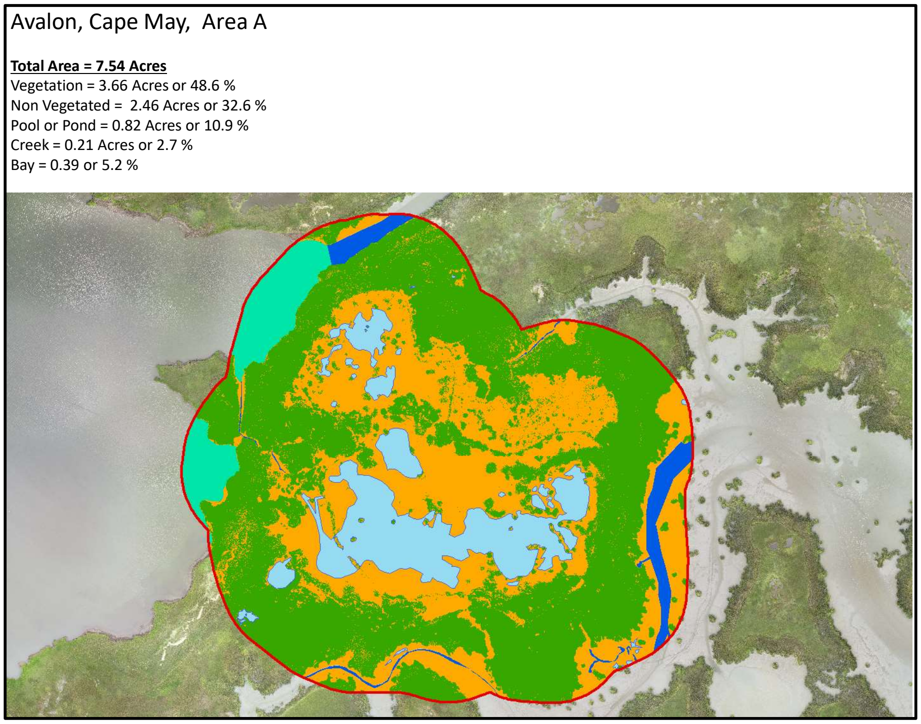
- Orthomosaic Raster
  - Identification of No growth/Regrowth areas and species
- 3D Point Cloud
  - Corrected with RTK GPS to cm precision
  - Seasonal and annual change in vegetation recovery
- Digital Surface Models

<u>We Encountered problems with pixel recognition over water and elevation projected to the tops of the vegetation The program tries to match pixels from adjacent images which is very difficult when over water as there is no unique reference that can be matched. In addition, when the vegetation cover is dense the calculated digital surface uses the tops of the vegetation as the elevation. These two factors have been discovered in the post processing of the pictures The Solution; Ground truthing using RTK Surveys.</u>



Here are the GIS polygons for the Three (3) deposition areas Depicted in our state Geographical Information System. The dots represent the RTK GPSed **ground control points** for each area. This allows the correction of the drone GPS coordinates to a precision level of about 2 cm. The high resolution photography within area inside the polygons is imported as a separate project into the state's GIS system. In the bottom right hand corner you can see the imported project layer from the drone photo mission at the Fortescue location.

Along the lower tributary in Fortescue, the tidal currents are extremely strong causing much undercutting and loss of clods of vegetative material due to erosion within the deposition area. In addition, the left hand side of this illustration is subjected to open Delaware bay erosion from the wind and tide. Hopefully with several seasonal cycles documented in this study, we will be able to predict loss due to erosion in these vulnerable sensitive estuarine systems using the high resolution Orthomosaic output products produced from year to year.

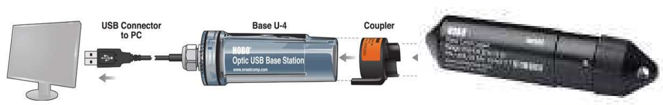


GIS scientists are is developing post processing automated methods for selecting habitat types based on ISO cluster GIS tools. These can be compared year to year to look at vegetation recovery.
Avalon, Cape May, Area A

Total Area = 7.54 Acres

Vegetation = 3.66 Acres or 48.6 %
Non Vegetated = 2.46 Acres or 32.6 %
Pool or Pond = 0.82 Acres or 10.9 %
Creek = 0.21 Acres or 2.7 %
Bay = 0.39 or 5.2 %

https://www.onsetcomp.com/products/data-loggers/u20l-04

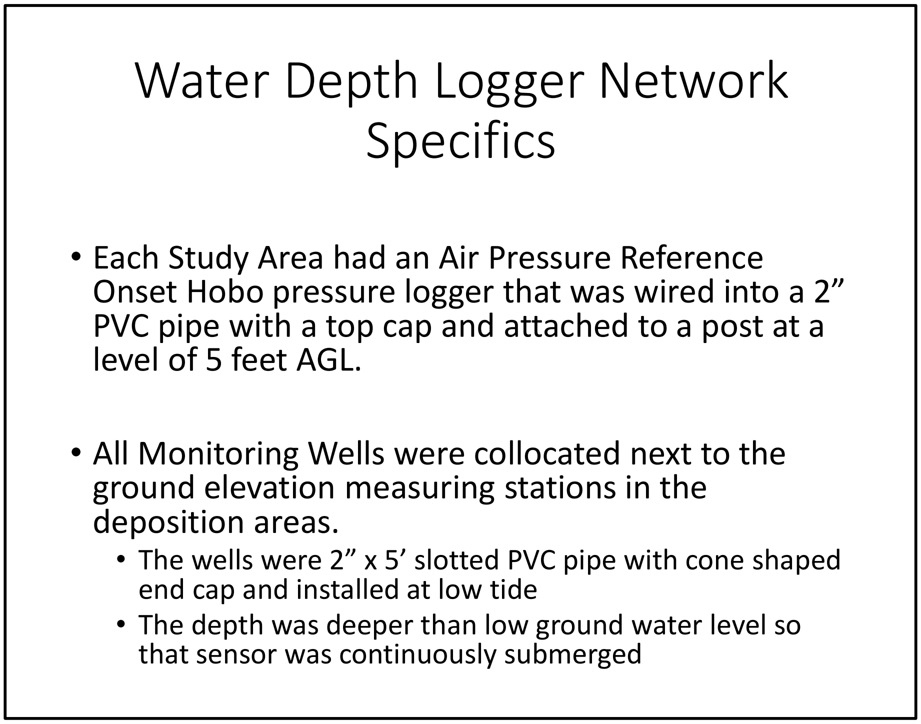


Operation Range	0 to 145 kPa (0 to 21 psia); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level, or 0 to 7 m (0 to 23 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 145 kPa (10 to 21 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.1% FS, 0.4 cm (0.013 ft) water Maximum error: ±0.2% FS, 0.8 cm (0.026 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.43 kPa (0.063 psi) maximum error
Resolution	<0.014 kPa (0.002 psi), 0.14 cm (0.005 ft) water
Pressure Response Time (90%)***	<1 second at a stable temperature; measurement accuracy also depends on temperature response time

Good in salt water and at any temperature – good budget option.

We are well within the operational and factory calibration ranges.

Pressure accuracy is +/- 0.3%



Each Study Area had an Air Pressure Reference Onset Hobo pressure logger that was wired into a 2” PVC pipe with a top cap and attached to a post at a level of 5 feet AGL.

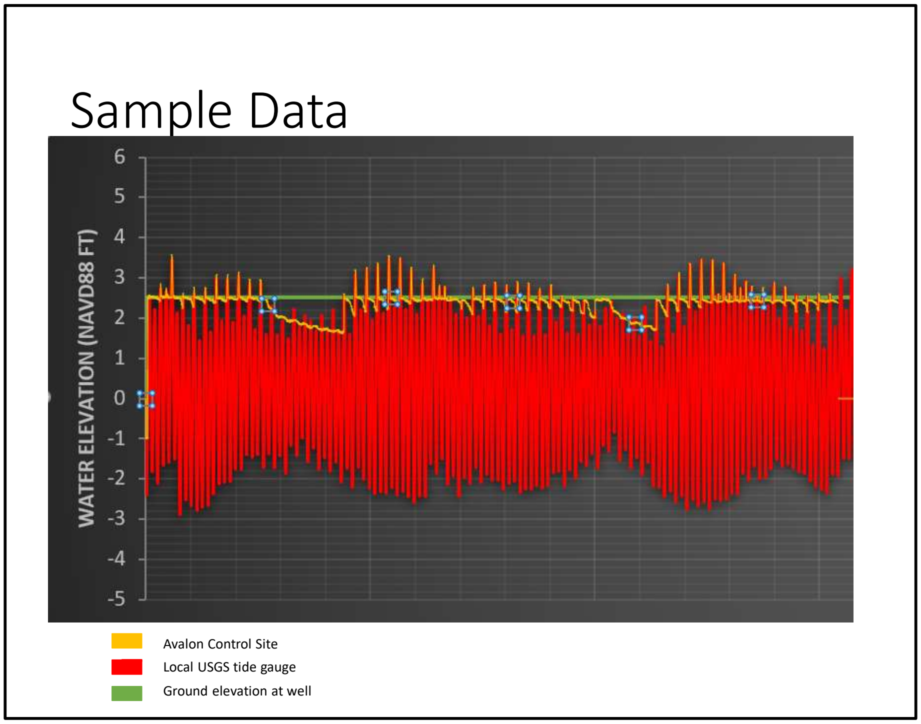
All Monitoring Wells were collocated next to the ground elevation measuring stations in the deposition areas.

The wells were 2” x 5’ slotted PVC pipe with cone shaped end cap and were installed at low tide

The depth was deeper than low ground water level so that sensor was continuously submerged

This slide illustrates the construction housing for the submerged pressure sensors that were deployed in one tributary at each of the three (3) locations. Loggers were suspended horizontally by wire inside a 2” by 1’ PVC pipe with holes drilled along its length for drainage
The PVC pipe containing the logger was secured to a half cinderblock with zip ties and an eyebolt was attached to secure a length of rope and a float.
Water level at deployment and recovery were measured with a ruler along with RTK GPS position for each of the submerged loggers. At one location, the cinderblock also served as a habitat for two juvenile oyster cracker fish that refused to leave the block as we downloaded the data from the logger!

The lower right photograph is a picture of a monitoring well that was installed. The sensors were attached by wire to a hole in the side of the PVC pipe at a depth below the low tide water level.



This chart shows water levels collected by the hobo logger in a well on the marsh platform at a control site in Avalon in YELLOW.
It was compared to the ground elevation at the well in GREEN and the long-term water level data set collected near the site by USGS in RED.

What we can see is that our data tracks very well with the USGS gauge. Anytime that the USGS gauge shows a peak that goes above the green line (ground level), we see an equal peak in the yellow line (the date we collected). This means that we can use the long-term data set from NOAA for our calculations with confidence.

Elevation (NAVD88 FT)	% of time flooded/year	Inundation (Hours /Day)
-1.90	89.91	21.6
-1.43	81.37	19.5
-0.96	72.03	17.3
-0.49	63.02	15.1
-0.02	54.51	13.1
0.46	46.26	11.1
0.93	37.60	9.0
1.40	27.97	6.7
1.87	18.47	4.4
2.34	8.13	1.9
2.82	4.09	1.0
3.29	1.17	0.3
3.76	0.33	0.1
4.23	0.08	0.0
4.71	0.02	0.0
4.72	0.02	0.0

One of the things we can look at with this data is the % of time that a given elevation is flooded, we can overlay this information with our habitat maps, our elevation measurements, and topographic maps to look for correlations between vegetative recovery and tidal flooding.

North American Vertical Datum of 1988 (NAVD 88) The North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-United States leveling observations.

CONCLUSIONS

- Sensors are a great supplement to traditional field based monitoring
- Drone images are high resolution, able to pick out small details, allow for control over the timing of photos, better spatial coverage than ground based plot measurements, and allow for repeatability from year to year.
- Water level loggers allow for continuous, high resolution data collection for months at a time. This data can be compared to long-term datasets.
- Sensor data can be extrapolated and compared to create a 3-dimensional picture of ecological dynamics of the system.

This research shows that sensors can be used to collect high resolution data in complex and challenging environments. We expect that the outcomes of this study will help us to learn from the current pilot projects to better inform the development of future projects. We can also show that the monetary and capacity investments required for sensors is well worth it.

shows balance between need for commercial improvements from USACE

Acknowledgements

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Steve Jacobus and William Smith, NJDEP Geographical Information System (GIS), and David DuMont NJDEP Office of Coastal & Land Use
Nick Procopio Ph.D., DSR

- Planning for the autonomous aircraft and drone survey of the study areas,
- post processing of the aircraft and drone photographic raw data.
- GIS integration, and
- geospatial correction using control points

THANK YOU

QUESTIONS?

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