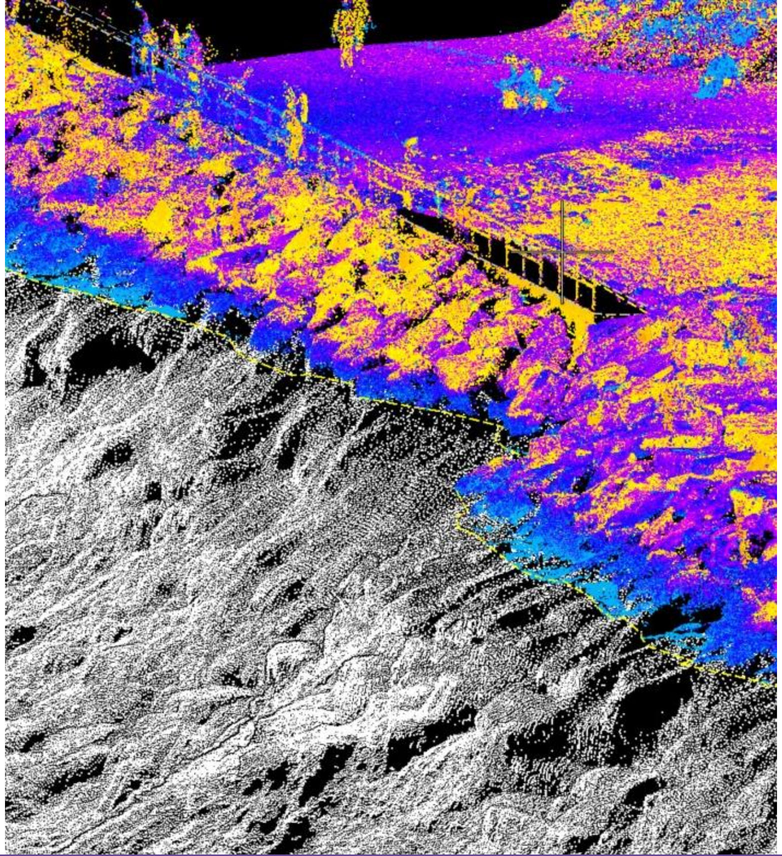



TERRESTRIAL SCANNING OF INLET SHORELINES

(Utilizing Kinematic Workflows with a Scanner Mounted on a Survey Vessel)

McKIM&CREED

OVERVIEW

01. **OVERVIEW OF THE INLET ENVIRONMENT**
A look at the unique environmental and geographical features of working within an inlet.

02. **CHALLENGES OF OVERLAPPING COVERAGE- COLLECTING A 3D SURFACE MODEL**
Acquisition challenges based on currents, tides and timing.

03. **EQUIPMENT OVERVIEW**
Key features and functions of a Riegl VZ400i and Hydrographic Survey Equipment.

04. **PROCEDURES**
Acquisition planning and good methodology help ensure a successful kinematic mission.

05. **DATA INTEGRATION**
Merging of terrestrial Static LiDAR and Hydrographic Surveying data into a seamless 3D surface model.

06. **FINAL DELIVERABLES**
Delivery of Point Clouds, AutoCAD Civil 3D, XYZ files, and Surveyor’s reports.

OVERVIEW OF THE INLET ENVIRONMENT

In June of 2024, McKim & Creed was awarded a project to map an existing inlet and surrounding areas. The project consisted of performing multiple surveys that included multibeam hydrographic surveys of an inlet bottom and all underwater structures, terrestrial LiDAR surveys of all structures above the waterline, singlebeam hydrographic surveys of areas offshore, and conventional beach profiles to develop a complete and comprehensive 3D model of the project area.

The total project area contained approximately 1,700 acres of underwater and uplands mapping. There were varying environments and scenarios to contend with during the data acquisition process, including offshore areas, the inlet, existing jetties, beaches, dunes, parking lots and areas under construction.

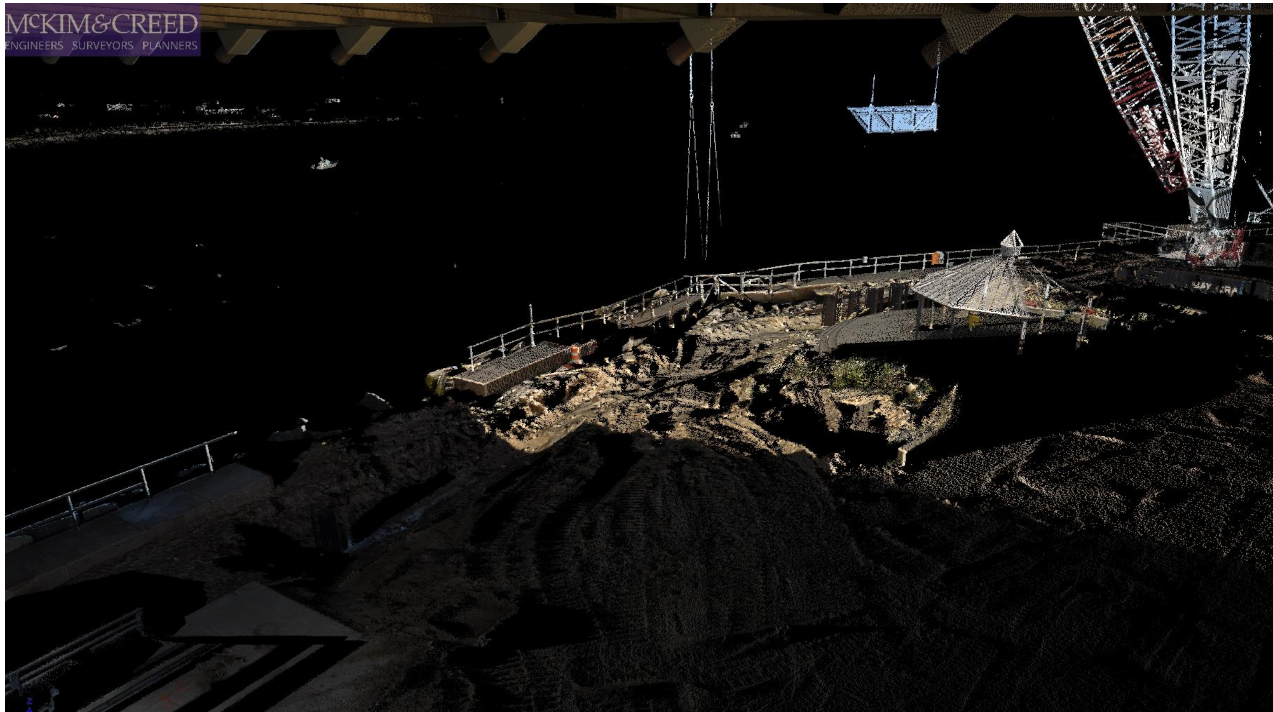
McKim & Creed deployed a Riegl VZ400i terrestrial static scanner, utilizing a kinematic acquisition solution from their Hydrographic Surveying vessel to collect sufficient data on this project.

OVERVIEW OF THE INLET ENVIRONMENT

There were multiple factors pertaining to the existing conditions and environment within the inlet that made it interesting for data acquisition.

Some of the most challenging factors about the environment included:

- ✓ Extreme currents
- ✓ Tidal shifts
- ✓ Heavy public vessel traffic and anchored vessels
- ✓ Winds and gusts
- ✓ Timing of acquisitions to accommodate for tides
- ✓ Active construction with materials entering the Inlet for Jetty repair
- ✓ General public within the project area fishing along the Jetties



CHALLENGES OF OVERLAPPING COVERAGE

COLLECTING A 3D SURFACE MODEL

As previously stated, a comprehensive and complete 3D surface model of the inlet bottom and upland areas was required as a part of this project. This task presented some unique challenges, mainly due to the existing inlet environment as mentioned in the previous slides. However, there were some additional challenges to overcome to obtain overlapping data of the inlet bottom and uplands. Some of the additional challenges included:

- ✓ **Time Limitations:**

  The project required the side slopes of the jetty to be scanned within 2 hours of peak low tide. This allowed a 4-hour time frame to collect data along the jetties.

- ✓ **Inlet Width and Jetty Orientation:**

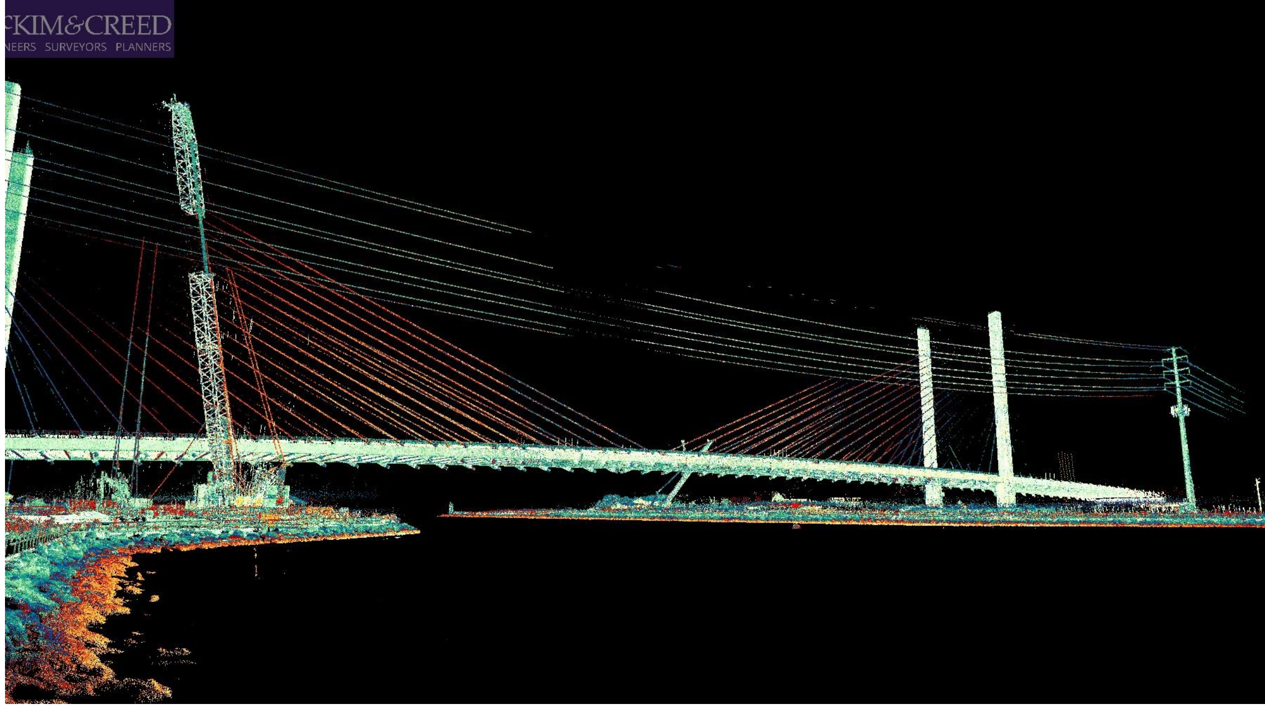
  This Inlet varies in its width throughout the project area. It varies from approximately 500’ at the mouth, to 800’ in the center of the project, and almost 1300’ at the west limit. These distances, coupled with the time restrictions mentioned above made it difficult to obtain sufficient coverage and detail from scanning from the opposing banks alone.

  Additionally, the orientation and direction of the jetties proved to be difficult. As the width of the inlet increased, the jetties cut back, making it hard to obtain an appropriate vantage point to obtain ground-based scans from.

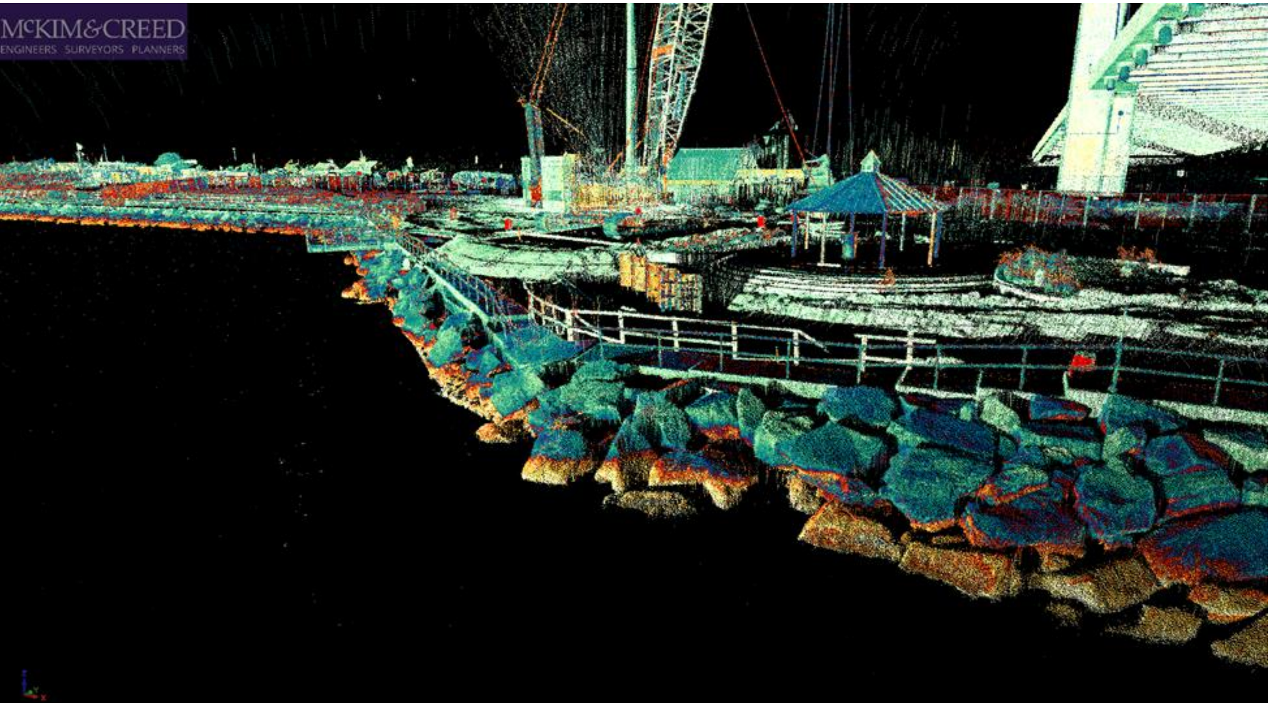
- ✓ **Underwater Topography**

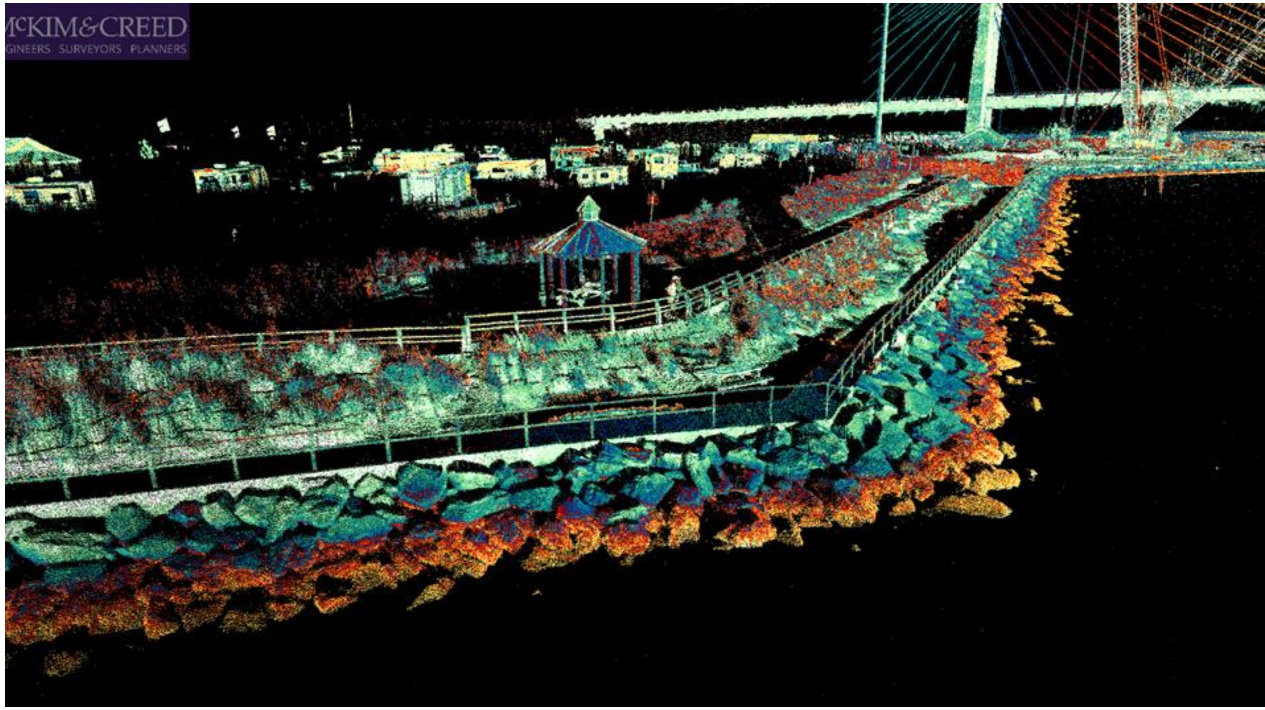
  The existing side slopes under the waterline and other underwater topography features, such as overlapping boulders on the jetty, added to the complexity of obtaining overlapping data between the Hydrographic survey and Terrestrial LiDAR. McKim and Creed tilted the head of the Multibeam Sonar to change the vantage point of the hydrographic sensor to acquire overlapping data below the waterline at high tide.

CHALLENGES OF OVERLAPPING COVERAGE



With the deployment of the Riegl VZ400i and the utilization of a Kinematic scanning mission, McKim and Creed was able to overcome the challenges of overlapping the datasets. Scanning while in motion from the vessel allowed our technicians to collect LiDAR data of the jetties at a closer range. Performing the acquisition at low tide enabled LiDAR data to be captured quickly, and in high resolution at levels well below the Mean high-water mark. Ensuring that we overlapped the datasets with a 95% coverage and confidence level.



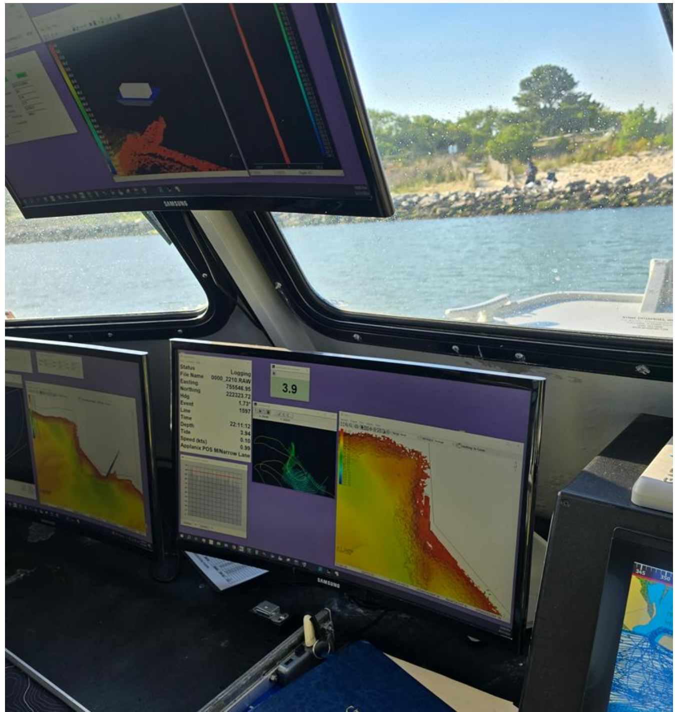


EQUIPMENT OVERVIEW

McKim and Creed utilized cutting-edge Terrestrial LiDAR sensors and Hydrographic sounders to complete the data acquisition on this project.

For the Hydrographic surveys, the following equipment was used:

- A R2 Sonic 2024 multibeam echosounder in the inlet
- The offshore and Ebb shoal data was acquired utilizing an Odom E20 echosounder.



EQUIPMENT OVERVIEW

McKim & Creed deployed a Riegl VZ400i for terrestrial LiDAR collections of above water structures and uplands topographical features.

The Riegl VZ series sensor offers a robust scanning solution with a high range of flexibility by supporting numerous peripherals and accessories.

This sensor also offers:

- High speed data acquisition with up to 500,000 measurements per second.
- An acquisition range of over 400 meters and an accuracy level of 5 millimeters.
- An integrated IMU and compass that tracks the sensors position, orientation, and movements.
- The ability to add an external GNSS receiver to the top of the sensor allowing RTK corrections to be logged directly into the scanner via a cable.
- Built in Wi-Fi communication hardware, which allow you to remotely connect to and operate the scanner via an application from a tablet or smartphone.

PROCEDURES

The process of preforming a kinematic scanning acquisition takes a great deal of mission planning, and a multi-step workflow.

Before arriving to the project site, the following steps were considered for the planning of the kinematic mission:

1. The team had to identify and coordinate an adequate location to launch the mission from.

2. Scanning routes and LiDAR acquisition parameter settings.

3. Weather and sea condition planning.

Following the comprehensive mission planning, arrival to the site, and identifying the collection time to coincide with the best weather conditions and tides, the kinematic acquisition could begin. The kinematic LiDAR acquisition from the survey vessel consisted of a multi-step work-flow for proper collection.

- To start the kinematic LiDAR acquisition, a smartphone was remotely connected to the sensor to run the acquisition operations.

- The connected smartphone also provided a stable internet connection to obtain GNSS RTK corrections.

- Then to begin the acquisition, a traditional tripod-based scan was completed at the vessels launching point.

Following the completion of the start-up tripod-based scan, the sensor was securely mounted to the hydrographic survey vessel. McKim and Creed elected to mount it to the roof of the main cabin, this allowed the scanner to be at an elevated perspective for data acquisition and kept the sensor within an acceptable Wi-Fi range for remote operation.

PROCEDURES

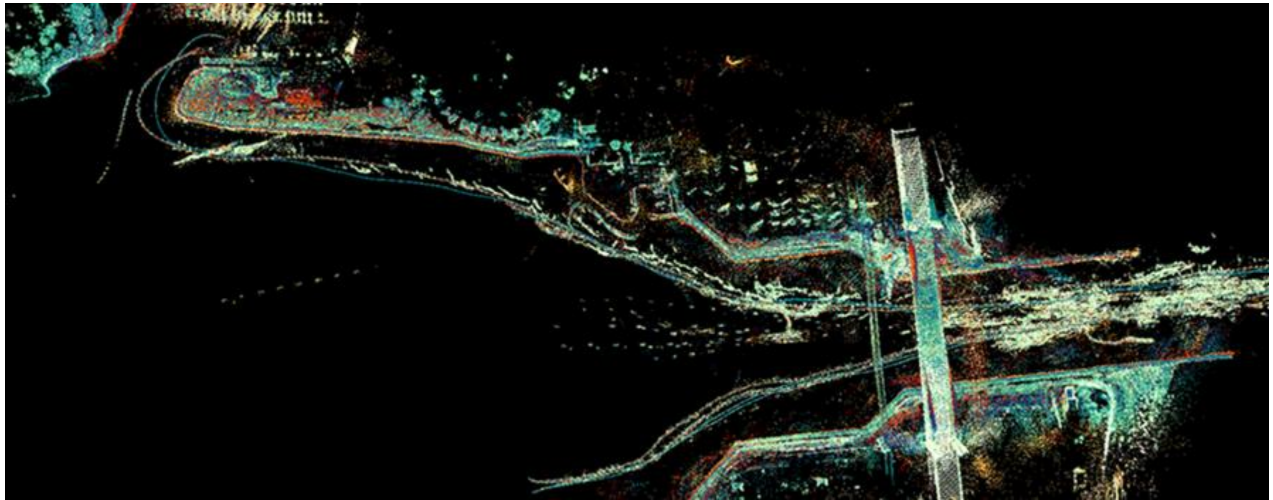
Following all required safety checks, the hydrographic survey vessel left the launch point, and the kinematic portion of the LiDAR acquisition mission began. To complete the Kinematic acquisition mission, McKim & Creed completed a total of 4 passes along the routes of the jetties.

- The first and third passes began at the marina, ran along the north jetty, then crossed over and along the south jetty.
- During the return passes, passes two and four, data was acquired in fixed frame mode (the sensor was locked into a profile view).

After completing the 4th and final pass, the vessel returned to the original launch point.

Once the survey vessel was securely docked, the Riegl VZ series scanner was dismounted from the vessel roof and a final traditional tripod-based scan was completed. This function ended the trajectory and GNSS position logging of the kinematic mission.

The kinematic LiDAR acquisition mission covered a linear distance of 7.4 miles, at an average speed of 5 knots, and lasted a total time of 1 hour and 30 minutes.



PROCEDURES

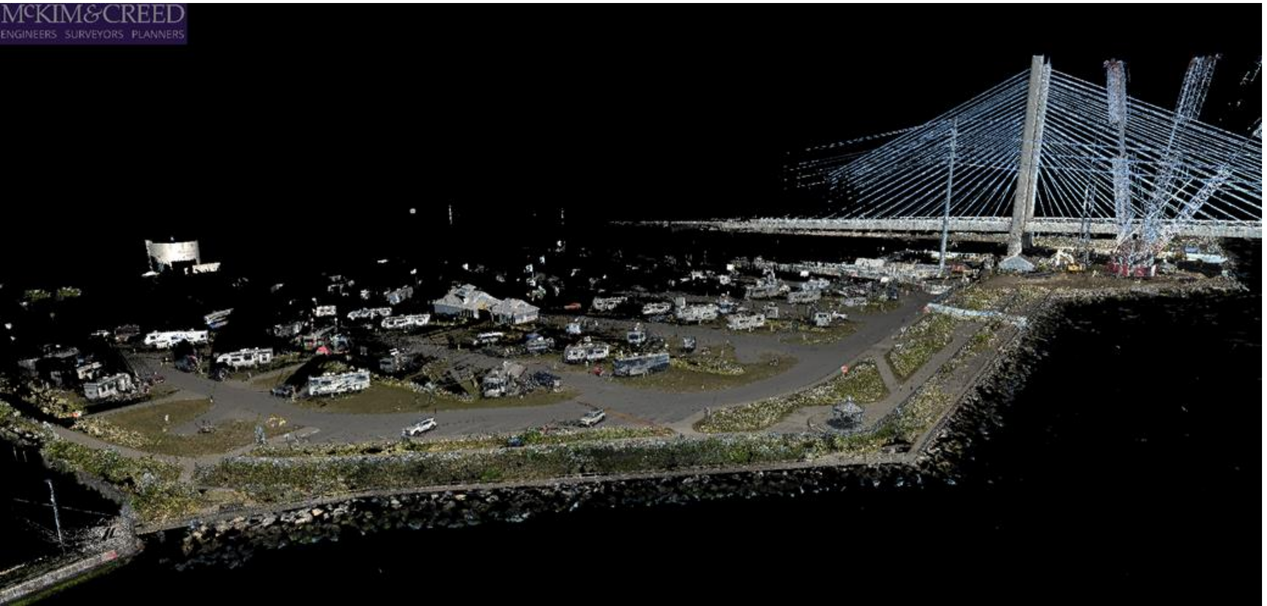
Upon completion of all kinematic LiDAR acquisition tasks, the raw data was imported into Riegl's processing software, RiSCAN Pro.

- All raw laser data, RTK derived GNSS position files, and trajectories from the integrated IMU were processed in RiSCAN Pro.

- The programs robust processing capabilities created geospatially correct point clouds of the kinematic mission.

The final kinematic LAS files were checked and compared to the other Tripod-based scan data that was completed in the upland areas, and the underwater multibeam hydrographic survey data.

- The Kinematic data was found to agree and be within an acceptable tolerance with all other LiDAR and Hydrographic datasets collected during the project by McKim & Creed.



DATA INTEGRATION

McKim & Creed performed various types of surveys on this project and utilized multiple platforms for data acquisition. Additionally, multiple software programs were used to process all the data. Proper survey methods, data integration, data merging, and quality control was key in delivering a quality product.

- Survey control and LiDAR verification points were established along the shores of the project area to constrain and verify the terrestrial static LiDAR.
- Traditional tripod-based terrestrial static scans were acquired along the north and south shores of the project.
- The traditional tripod-based scans were registered utilizing Riegl targets and tied to the previously mentioned survey control.
- Long-range scans were collected during the tripod-based phase to obtain overlapping data from the opposing shores.
- The tripod-based and long-range scan data were merged into a single unified point cloud

This constrained and unified point cloud was checked for any data misalignment or deviation and then verified by the conventional LiDAR Verification points. This data served as the basis and check for the kinematic LiDAR and Hydrographic Survey acquisitions.

Another major contributing factor of the data integration and merging, was the fact that all conventional survey control, LiDAR verification, kinematic LiDAR, and Hydrographic Multibeam acquisition methods utilized the same virtual real-time GNSS network and tied to the same base stations.

- Utilizing the same GNSS base station data increased the accuracy and confidence level for merging data from multiple platforms.

Number	Easting	Northing	Known Z	Laser Z	Dz
11000	756213.577	221977.498	3.725	3.730	+0.005
11001	756226.103	222028.932	8.245	8.240	-0.005
11002	756509.689	222030.828	6.861	6.860	-0.001
11003	756565.720	222094.005	8.768	8.797	+0.029
11004	757168.191	221921.068	5.887	5.960	+0.073
11005	757121.458	222010.530	7.525	7.610	+0.085
11006	756969.780	221314.636	5.896	5.870	-0.026
11007	756957.282	221212.591	5.292	5.240	-0.052
11008	756216.227	221148.452	3.647	3.620	-0.027
11009	756118.199	220987.330	4.263	4.270	+0.007
11010	757530.031	221433.399	5.805	5.765	-0.040
11011	757541.998	221270.025	8.533	8.517	-0.016
11012	757301.979	221279.351	6.880	6.850	-0.030
11013	757273.040	221407.160	5.966	5.953	-0.013

Average dz	-0.008
Minimum dz	-0.052
Maximum dz	+0.085
Root mean square	0.038

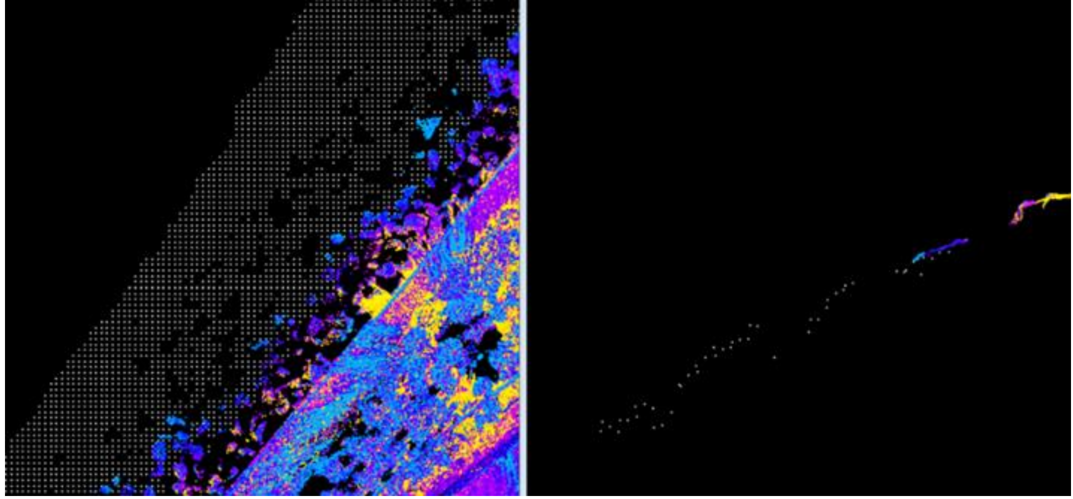
RESIDUAL ERROR (ABS)			
POINT ID	NORTHING	EASTING	ELEVATION
6	0.027	0.037	0.003
7	0.039	0.030	0.014
8	0.039	0.021	0.003
9	0.036	0.027	0.015
RMSe	0.036	0.029	0.010

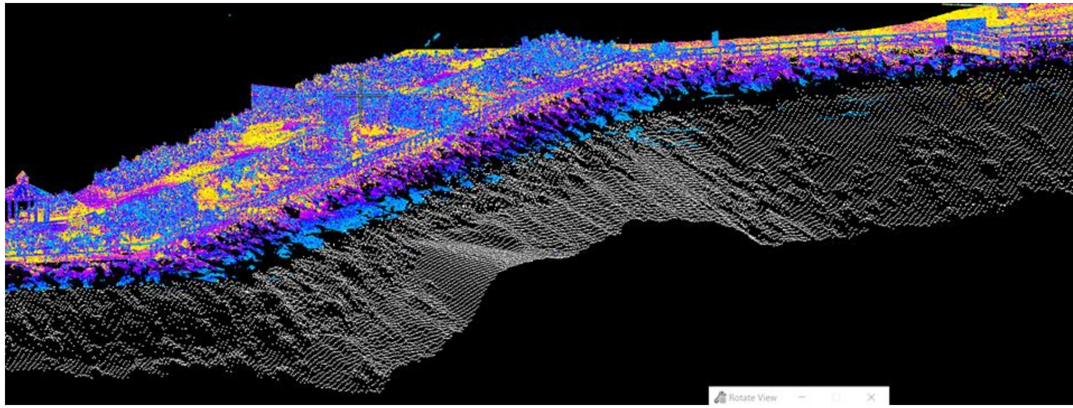
RESIDUAL ERROR (ABS)			
POINT ID	NORTHING	EASTING	ELEVATION
1	0.005	0.030	0.003
2	0.005	0.010	0.008
3	0.018	0.055	0.014
4	0.028	0.021	0.015
5	0.023	0.009	0.005
RMSe	0.018	0.030	0.010

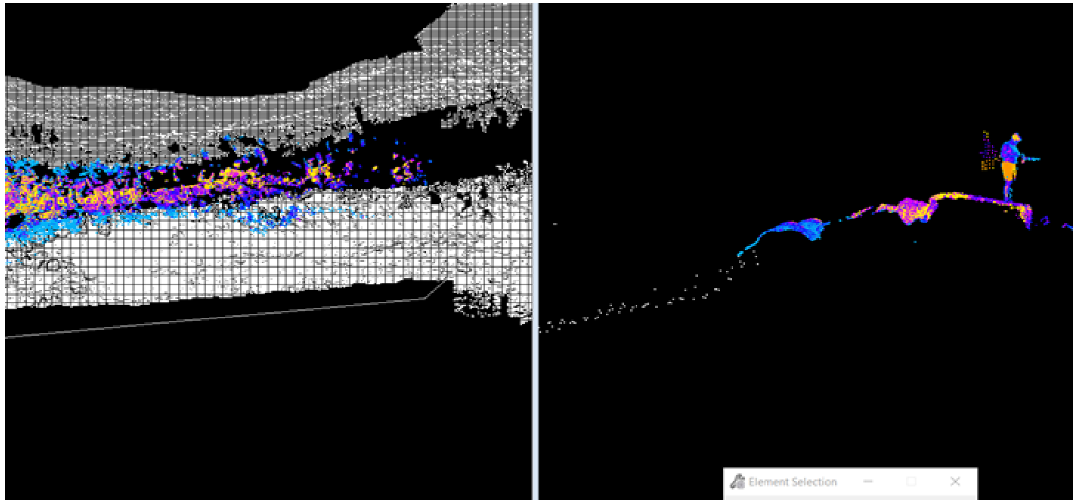
DATA INTEGRATION

Obtaining overlapping data between all acquisition methods was key in for data integration.

- The long-range, tripod-based LiDAR acquisition and vessel-mounted kinematic LiDAR acquisition collected high density and high detail information of the side slopes of the existing jetties during low tide.
- The multibeam sensor was tilted upward and collected side slope data of the jetties up to the high-water mark during high tide
- There was an average of approximately 4 feet of overlapping data of the jetty side slopes between all acquisition methods
- LAS formatted files were created from the final post-processed kinematic LiDAR and Multibeam Hydrographic datasets.
- These LAS files were compared and checked for any alignment and/or deviation against the Tripod-based terrestrial Static LiDAR.
- Common features within all datasets were checked, and cross-sections were cut to determined that all data collected from the multiple platforms agreed and aligned with each other.







DATA INTEGRATION

The final step of the data integration and data merging was the creation of a complete 3D surface model of the inlet bottom and upland areas .

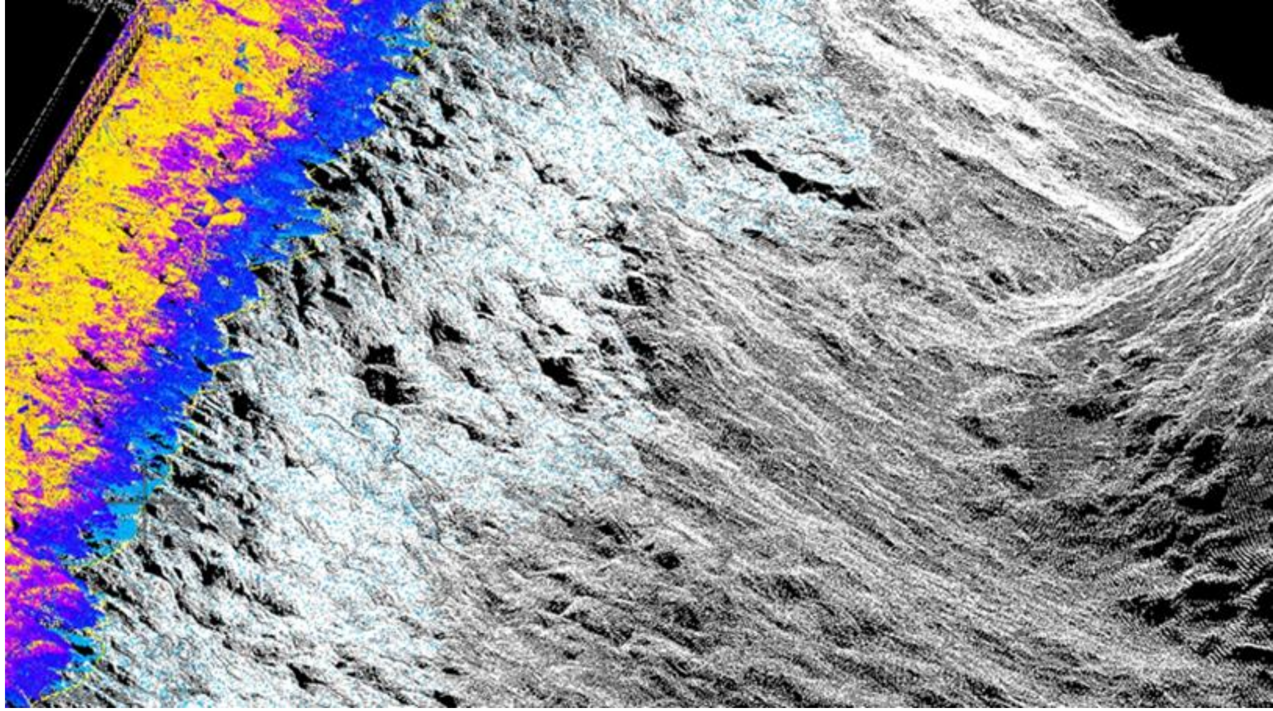
- Topographic features and breaklines of the upland areas were extracted at 20-foot intervals.

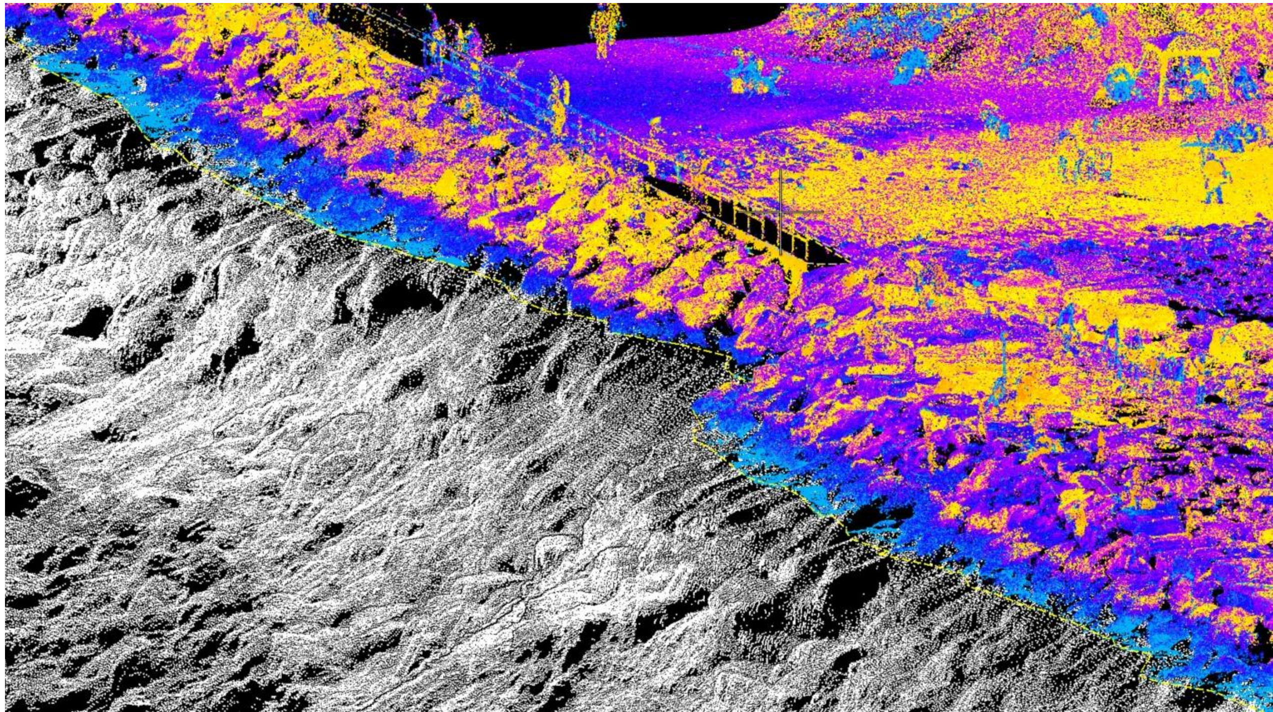
- Ground data of the uplands was extracted on a 25-foot grid.

- Data of complex areas of the uplands, including the existing sand dunes and the jetty tops and side slopes were extracted on a 1-foot grid to match up with the below water, hydrographic data.

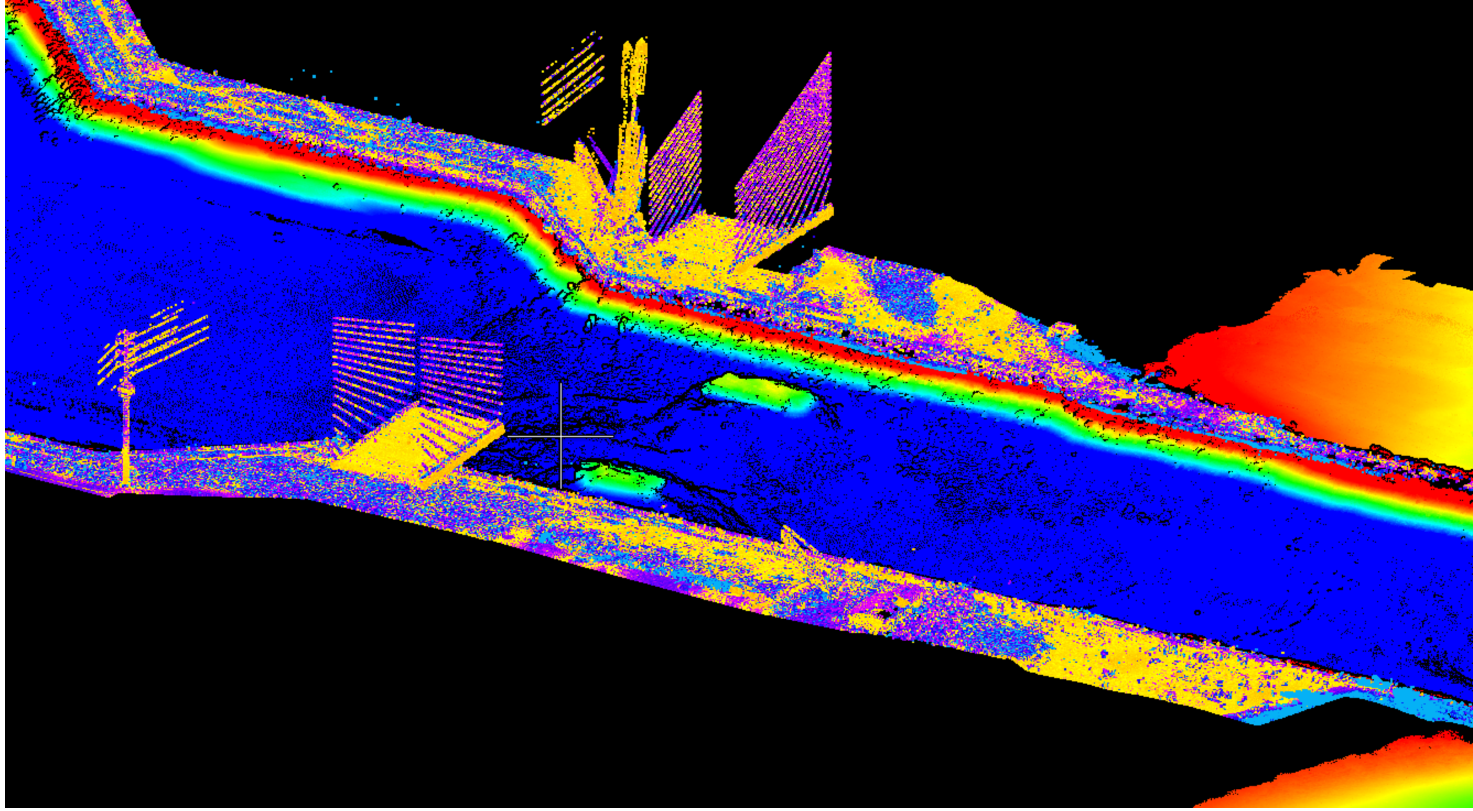
- The final multibeam and single beam hydrographic data was processed out to a 1x1 grid for high detail of the inlet bottom and off-shores areas.

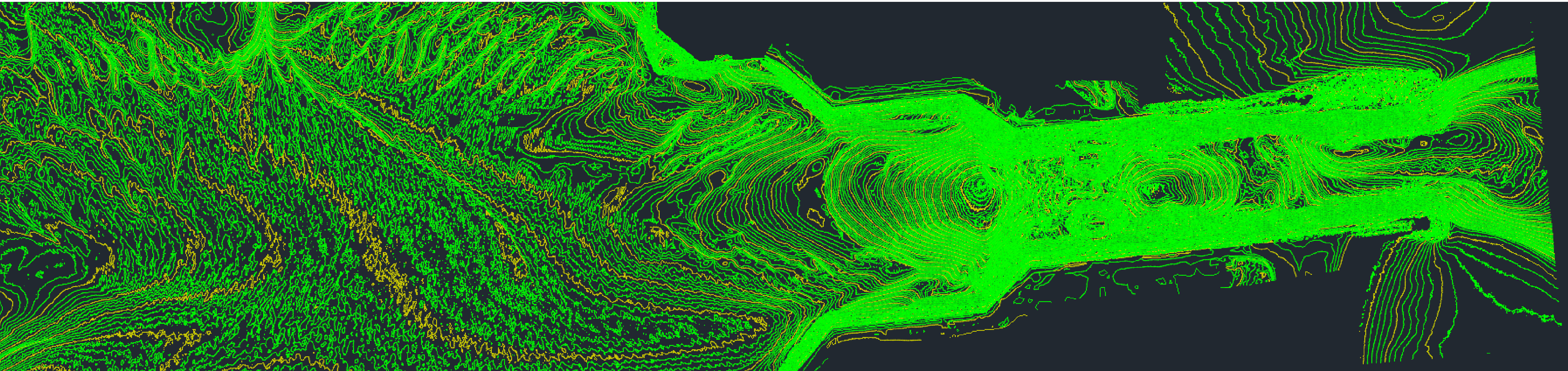
All the finalized data was merged and then entered in AutoCAD Civil 3D for the creation of a complete 3D surface model. The final 3D surface contained a 95% coverage of the entire project area and contained no major spikes and/or deviations.





DATA INTEGRATION





FINAL DELIVERABLES

This project required a variety of final deliverables. Upon completion of all acquisition, processing and data merging tasks, McKim & Creed worked thru the final deliverables. These included:

<u>Raw and Edited Hydrographic Field Files:</u>

- Raw sounding data from the singlebeam and multibeam surveys of the Inlet and offshore area. This also consisted of beach profiles lines which were obtained via conventional survey methods by wading through the surf.
- Field notes created by the hydrographic, terrestrial LiDAR, and conventional crews.
- Positional-POS files

<u>Processed Hydrographic XYZ Files</u>

- Unsorted singlebeam XYZ
- 8'x8' gridded singlebeam xyz
- Full multibeam XYZ
- 1'x1' gridded multibeam XYZ
- 5'x5' gridded multibeam XYZ

<u>Hydrographic Patch Tests Files</u>

- Daily calibration and testing results for the hydrographic sounding units.

File Edit Format View Help

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764015.95,216601.51,-39.50
764015.86,216601.79,-39.49
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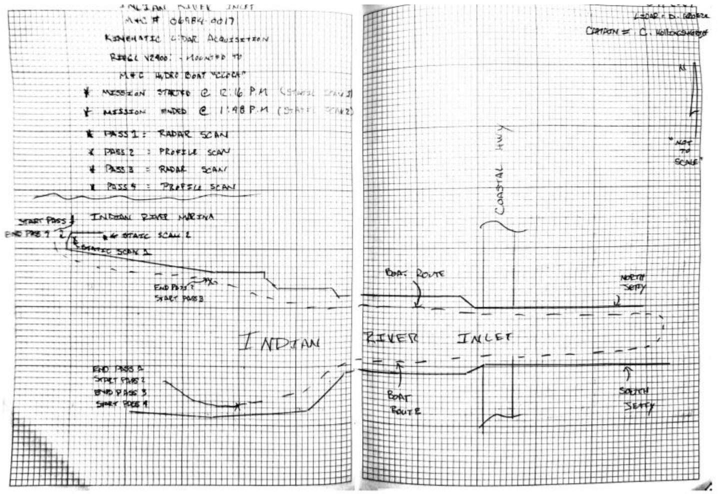


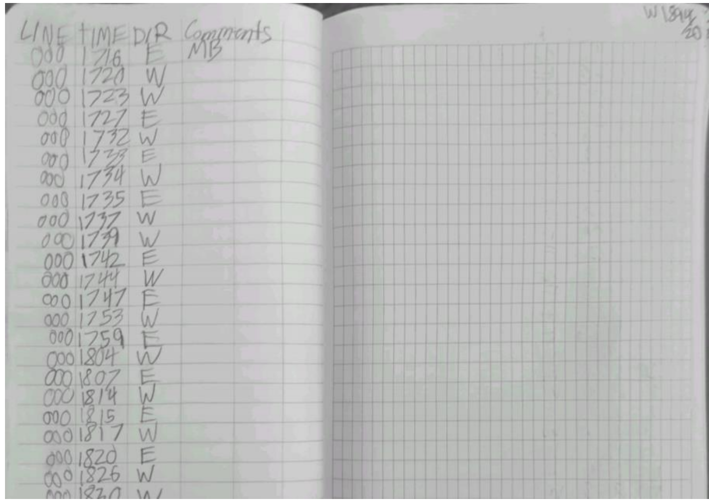


Table 1. Patch Test Results (no tilt).

Test	Results
Latency	0.000 ms
Roll	0.85°
Pitch	2.00°
Yaw	-0.50°

Table 2. Patch Test Results. (30° Tilt)

Test	Results
Latency	0.000 ms
Roll	28.10°
Pitch	2.00°
Yaw	-0.50°

FINAL DELIVERABLES

Raw and Processed Terrestrial LiDAR

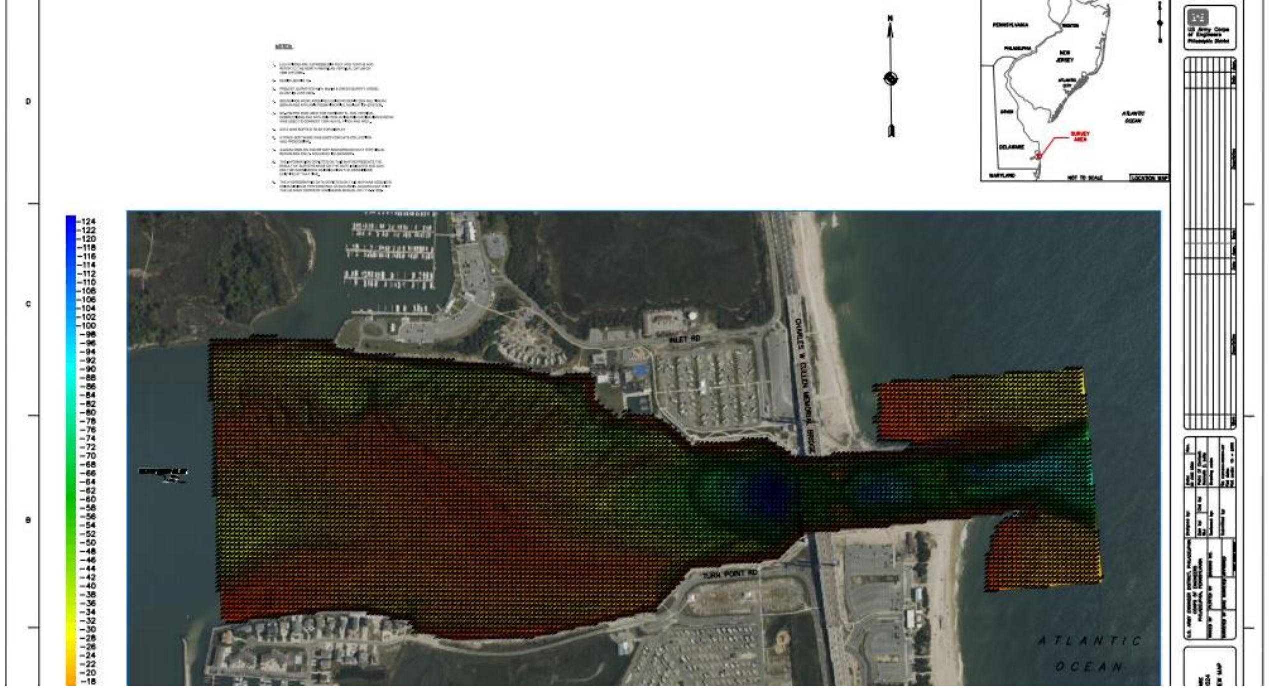
- Raw and processed Kinematic LiDAR files
- Raw and processed Static LiDAR files of Upland areas
- LiDAR Registration reports
- Final point clouds in LAS format of upland area scan and Kinematic mission
- Final combined point cloud of all acquired LiDAR

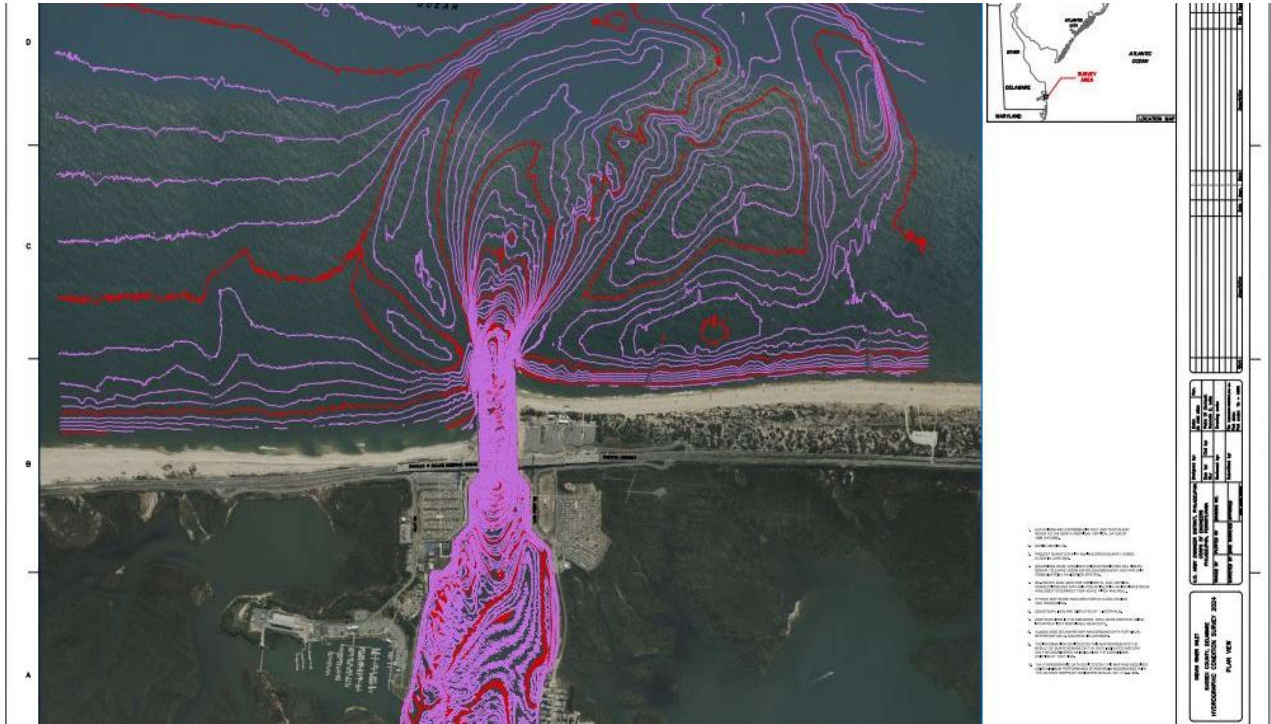
AutoCAD Civil 3D and PDF Surveys

- AutoCAD Civil 3D file and PDF -400' scale contour map of Hydrographic data
- AutoCAD Civil 3D file and PDF -200' scale color filled contour map of Hydrographic data
- AutoCAD Civil 3D file and PDF -20' scale topographic survey of existing jetties and upland areas

DEM (Digital Elevation Model)

- DEM file of Hydrographic data
- DEM File of LiDAR derived Topographic survey
- Combined Dem file of hydrographic and topographic survey data

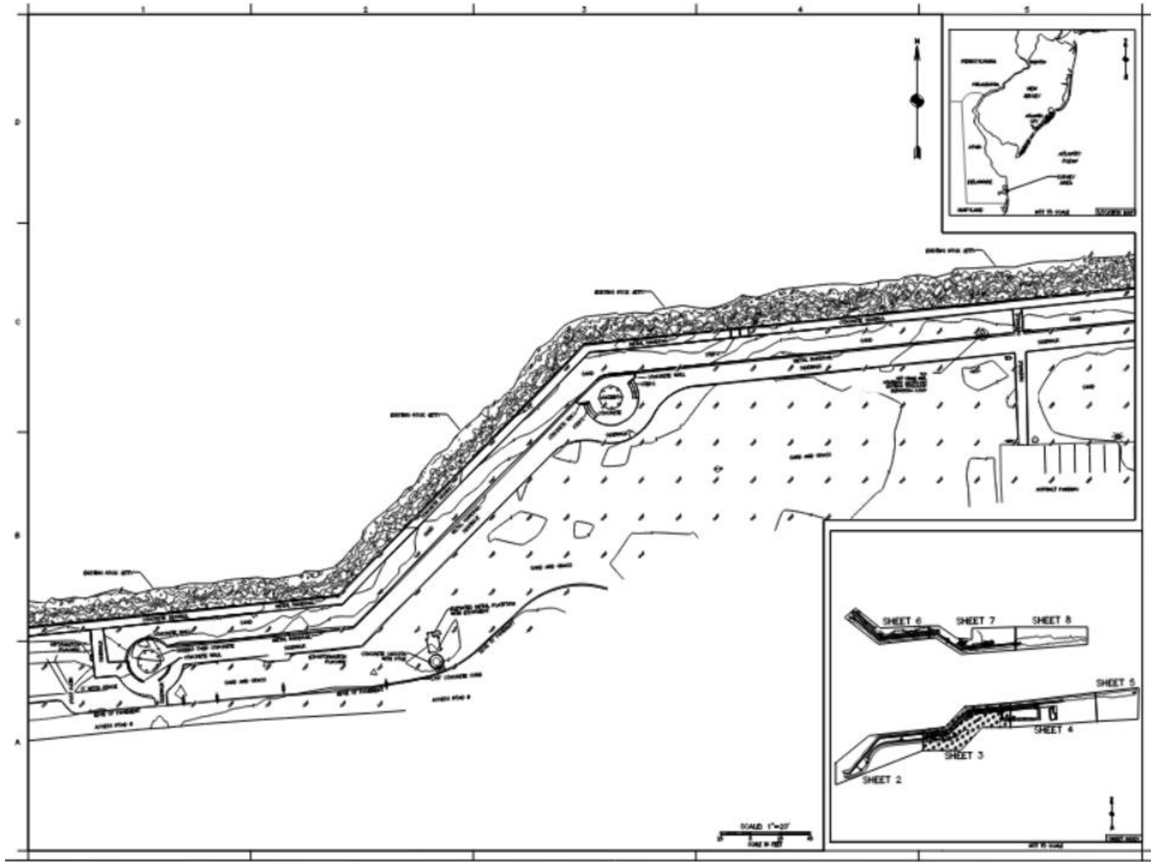


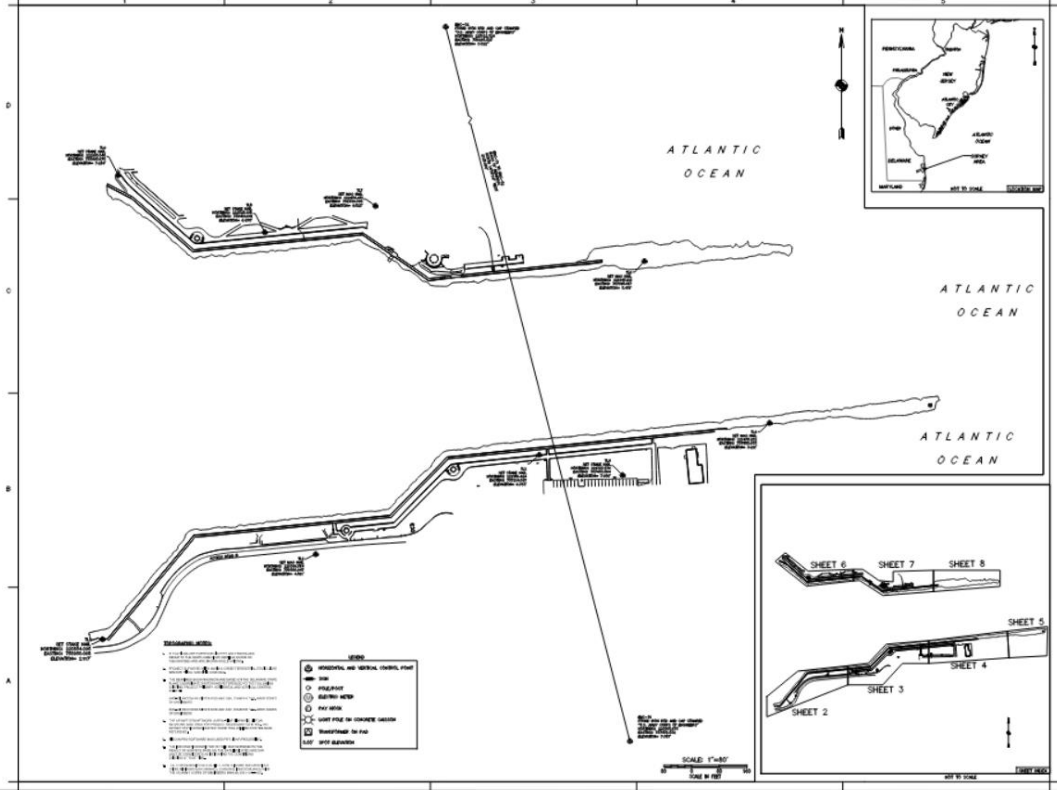


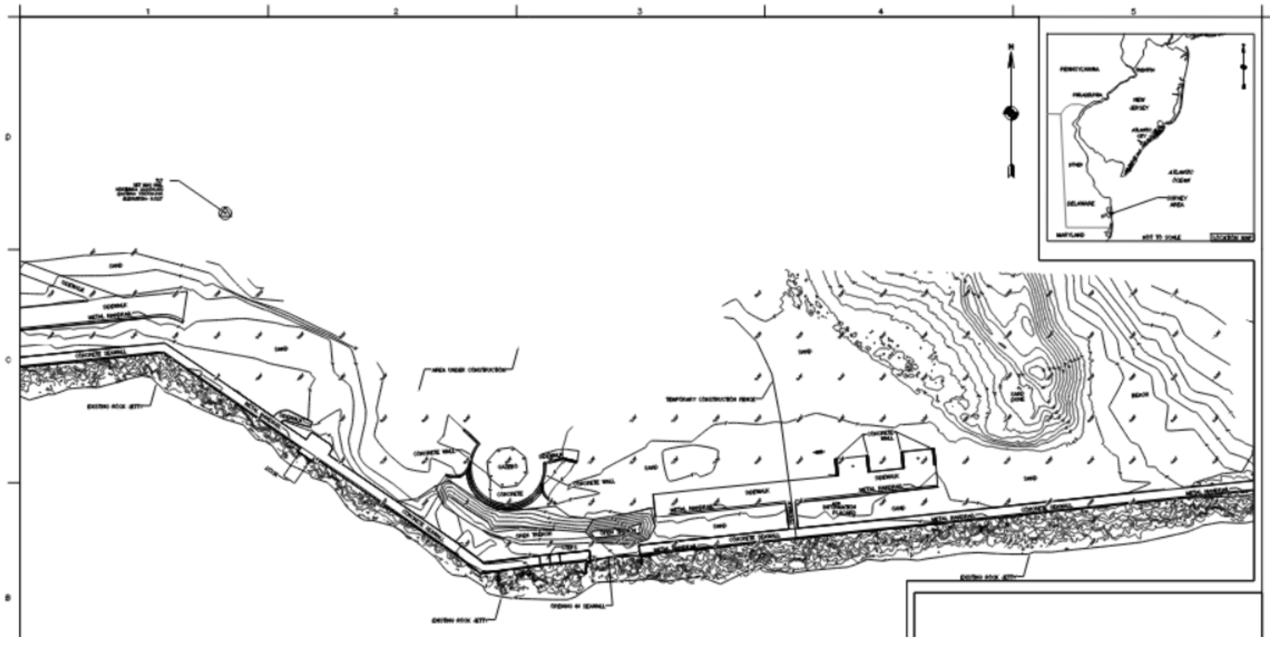
FINAL DELIVERABLES

Reports and Metadata

- Control sheets of verified and established project control
- Control residual reports
- Lidar verification report-blind checks for LiDAR accuracy
- Weather reports for sea conditions during collections
- Survey report outlining methodology, procedures, and results
- Metadata files for GIS application

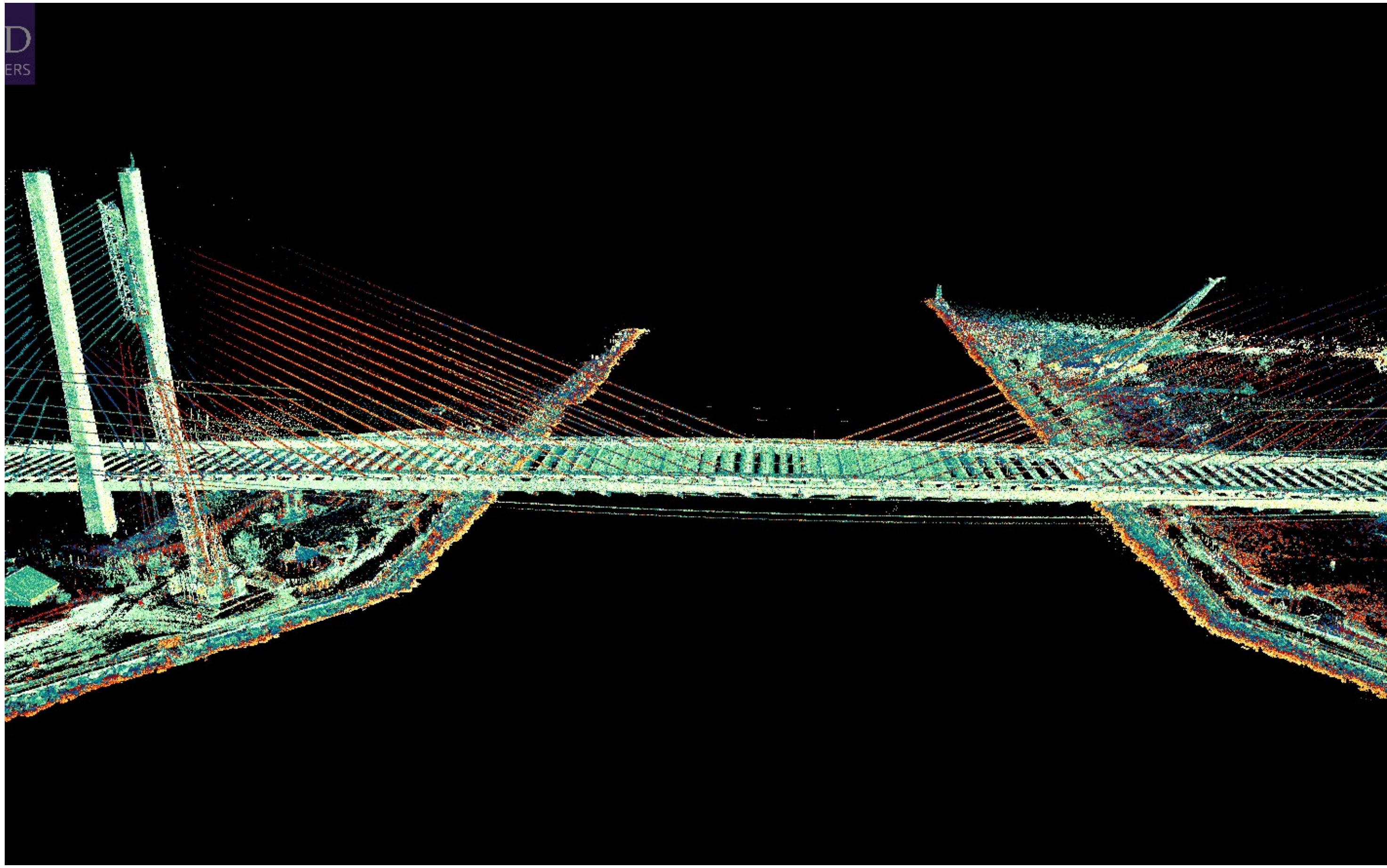






CONCLUSION

The unique existing inlet environment of this site, project requirements and deliverables requested by the client allowed McKim & Creed to produce an innovative acquisition solution. We believe that terrestrial scanning of inlet shorelines utilizing a kinematic workflow from a scanner mounted on a survey vessel could be used as a viable solution on any number of waterway, shoreline, or bridge mapping projects.



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