East Forelands Tidal Energy Power Project

Physical Site Characterization Survey

Cook Inlet, vicinity of Nikiski, Alaska

April 1, 2013
Version 1.1

Prepared by:
Benthic GeoScience Inc.
P.O. Box 556
Sutton, AK 99674
Phone: (907) 715-8144

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF GRAPHICS

1.0 PROJECT SUMMARY

During the summer field season in 2012, Benthic GeoScience Inc. (Benthic) mobilized under contract with Ocean Renewable Energy Company (ORPC) in order to conduct precise geospatial measurements of the seafloor accomplishing a preliminary Site Characterization Study for the ORPC East Forelands Tidal Energy Power Project.

This contract included mobilization to the project site for the recording, processing, analysis, and presentation of remotely sensed data for the purpose of identifying the character of the environment and prospects for harvesting tidal generated current for conversion to electricity. This study included a high-density bathymetric survey, acoustic reflective intensity imagery, and an assessment of the physical character of the ORPC East Forelands Tidal Energy Power Project environment. The Multibeam Echosounder (MBES) survey included a large area surrounding the East Forelands of Cook Inlet in the vicinity of Nikiski, Alaska.

Benthic mobilized to Nikiski on two expeditions in order to complete the acquisition of the contracted study. Benthic mobilized to Nikiski, AK on May 18 2012, however, MBES equipment failure terminated the survey prior to completion. Benthic returned to the project area, after new sonar components were made available, on June 1 2012 in order to complete the necessary work. No measurements recorded during Expedition 1 were used in this report, all data and data products presented in this report are from Expedition 2.

The vessel used during the Expedition 2 for all operations was the 28ft aluminum landing craft *M/V LC*. Benthic developed a survey of the vessel and instrument relationship for use as a survey vessel of opportunity. Benthic contracted *Glacier Craft Boats* and directed the fabrication efforts to ensure stability and pole arm functionality. The geophysical instrumentation deployed during this project included a pole mounted *Kongsberg* 3002 MBES, *Coda* Octopus F-185 Inertial Navigation System (INS), *Trimble* R8 global positioning systems (GPS) Receivers, and *Trimble* Real-Time Kinematic (RTK) radio systems.

This project required an accurate and repeatable acquisition strategy that would establish original baseline bathymetric and acoustic albedo measurements. Benthic established our GPS Base station on a monument established during a geodetic network survey funded by ORPC in 2011. Benthic established no new monuments for this project site. All hydrographic navigation and MBES acquisition was recorded while receiving the distribution of GPS RTK corrections in WGS84 space (horizontal) and corrected to MLLW (vertical) from the primary GPS base station established at EF-2 2011 (N60°44'07.73491", W151°21'05.22713", 62.223 m). A repeater was established on the southern end of the project in order to cover the entire survey area.

The high density MBES survey was designed to establish the foundation for all future charting products. The bathymetric acquisition plan was designed to inform ORPC about the geomorphology of the inlet, facilitate project planning, and to enable modeling efforts. The bathymetry product was intended to be a baseline measurement of the seafloor prior to build out or development as well as help design the position of future project infrastructure. The survey area boundary was contractually established at the -15 m contour (per MLLW datum), with two shoreline approaches for possible cable corridors to the 0 m contour. Benthic was able to survey considerably more shoal area then established per the contract increasing significantly the area of coverage. Benthic accomplished this specifically to collaborate and facilitate future work such as cable corridor selection, marine mammal monitoring moorings placement, current monitoring mooring placement, and future sub-seafloor seismic studies which will require comprehensive understanding of the surface expression. Full ensonification of the seafloor was not a realistic goal for shoal depths due to the constraints of swath width on the shorelines and shoal areas within the project area, so interpolation was necessary for holiday events in order to accomplish a contiguous seafloor surface. Very few holidays exist within this data set, and no holidays exist within the originally contracted survey area.

This report represents the final comprehensive product for the cumulative 2012 efforts. It contains descriptions of the sensor acquisition methodology, data processing path, and quality assurance techniques as exercised by Benthic. It will also generalize specific information regarding data analysis, interpretation, and product dependencies for each dataset during the finalized product development.

The digital deliverables from this effort include:

- Comprehensive Site Characterization Report (Format: PDF, Ver. 1.1, March 2013)
- Comprehensive 3D Fledermaus Presentation (Format: SCENE, Ver. 1.1, March 2013)
- Bathymetric Surface (Format: ASC Ver. 1, March 2013)
- Slope Gradient Surface (Format: ASC Ver. 1, March 2013)
- Comprehensive Acoustic Intensity Image (Format: TIF/TWF Ver. 1, March 2013)
- Geologic Seafloor Interpretation Surface (Format: ASC Ver. 1.0, March 2013)
- Comprehensive Google Earth Presentation (Format: KMZ Ver. 1.1, March 2013)

The final products have been generated to maximize the usefulness with information published by the National Ocean & Atmospheric Administration (NOAA) and other governmental agencies. All final products are relative to UTM, zone 5, meters, as horizontally positioned in reference to the North American Datum (NAD83) and vertically positioned to reference MLLW. Although initially requested in WGS84, the translation to NAD83 will permit use of Benthic products with US Nautical Charts, Electronic Nautical Chart (ENC), and future vessel navigation to utilize US Coast Guard GPS Beacon Correction (DGPS).

The high-density bathymetric surface provides the ability to quantify areas for roughage estimation for future modeling efforts. Boulder sized objects are common through extensive reaches of the seafloor. Texture variations between cobbles, sand wave formation, and fine sand sediments are obvious at appropriate exaggeration levels within the processing software.

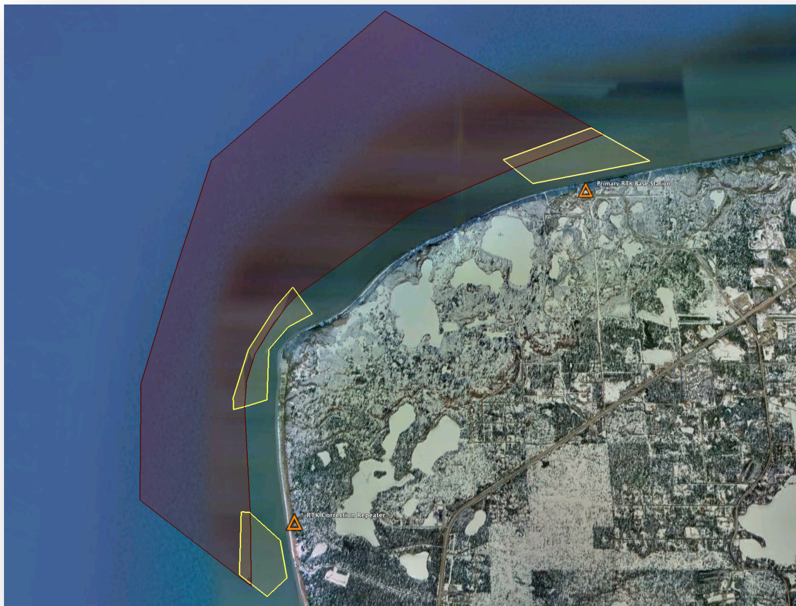
Benthic processed the data to preserve obstruction identification of $1m^3$ for depths <40m. Benthic processed the data to preserve obstruction identification of $2m^3$ for depths >40m (although significantly smaller objects are identifiable below 40m). Although individual obstruction classification and identification was beyond the scope of this report, the project area is far from free of obstructions. A digitized obstruction surface has been generated which delineates areas of significant obstruction density or areas with other observable hazards. Polygon areas which continue through the Danger to Navigation (DtoN) depth contour have been split to segregate Hazard for Construction (HforC) from the DtoN hazards that may impact vessel navigation in a harmful way. Although continuous as geologic or geomorphic aggregate, these have been segregated to help assure notice for vessels entering potentially dangerous waters.

All Cook Inlet environments are dynamic systems, however, the hydrokinetic information reveals areas of high variability on this seafloor with significant sediment transport throughout the shoal area on the north portion of the project. Repeated measurements, over several days while on site, have allowed for a preliminary evaluation of the stability of this sand dune regime. This preliminary evaluation indicates high potential seafloor change and any project development or cable placement will need to account for this dune behavior at this site.

Benthic finds no significant man-made infrastructure, geomorphology, or geologic obstruction that would preclude this site from future development for hydrokinetic power conversion activity. Although obstructions and zones for caution exist within the project boundaries, it is the opinion of Benthic GeoScience that no obstacle was identified that cannot be avoided, remediated, or otherwise overcome through skillful engineering. We recommend this site for further development for the purpose of hydrokinetic power conversion.

This page was intentionally left blank.

2.0 GEODESY & NAVIGATION



Survey Area with GPS Base Station and Repeater locations, vicinity of Nikiski, Alaska

Benthic GeoScience Inc. was contracted to acquire measurements as a baseline environmental condition with the expectation that future measurements would be for future research or study measurements. This required all operations to be conducted in a repeatable methodology.

ORPC contracted a Geodetic Network Survey in 2011 which established several monuments and calculated their relationship to MLLW previous studies for the ORPC East Forelands Tidal Energy Power Project prior to the Benthic's 2012 Site Characterization Study described within this document. Benthic used the positions and relationships described in the *East Forelands-Project Control Report, TerraSond 2011* to establish a GPS Base Station above monument EF-2 2011 at location (N60°44'07.73491", W151°21'05.22713", 62.223 m) broadcasting RTK corrections to the vessel navigation system during all operations. Verification of the reports findings was beyond the scope of this effort, however, for repeatability, Benthic recommends future measurements incorporate ties with monument EF-2 2011.

Benthic used radio-scanning technology to identify the extent of coverage at the monument site and installed a repeating radio broadcast on the southern portion of the survey area in order to establish an acceptable coverage area. The repeater was established in the vicinity of

(N60°42'27", W151°24'27"). All contractually obligated surveyed areas were within the RTK broadcast area.

2.1 Establishing the GPS Base Station and RTK Broadcast Network

Benthic was provided the position for EF-02 2011 that was established to be the foundation of the survey geodetics.

2.1.1 *Monument EF-2 2011*

GPS Base Station with RTK radiobroadcast at Monument EF-2 2011

The primary GPS Base Station was established at monument EF-2 2011 as reported by the Geodetic Control Survey of 2011 by TerraSond LLC. The base station utilized a *Trimble* R8 GPS Receiver and broadcast the RTK position corrections relative to the NAD83 projection with a vertical modifier establishing the vertical datum at MLLW.

East Forelands Control Comparison
8 Nov - 10 Nov, 2011
NAD83 UTMz5Nm GEOID09

POINT		RTK "HERE" Positions		Final - MLLW		DELTA
EF-1 2011	Northing	6,730,593.499		6,730,593.339		-0.160
3 1/4" ALCAP	Easting	587,038.869		587,041.004		2.135
	Elev	26.180		26.084		-0.096
EF-2 2011	Northing	6,734,453.220		6,734,453.051		-0.169
3 1/4" ALCAP	Easting	589,894.977		589,897.102		2.125
RTK Base	Elev	62.137		62.223		0.086
EF-3 2011	Northing	6,728,981.725		6,728,981.580		-0.145
PK Nail	Easting	588,164.189		588,166.308		2.119
	Elev	36.698		36.698		0.000
TBM-1	Northing	6,735,155.058		6,735,154.845		-0.213
40d Nail	Easting	592,443.581		592,444.701		1.120
	Elev	25.121		25.372		0.251

Monument findings from East Forelands-Project Control Report, TerraSond 2011

Due to the near proximity of EF-2 2011 to a helicopter pad and consistent traffic through the area, Benthic secured all tripod structures down to the ground with bailing wire to ensure low risk of movement.

2.1.2 *Southern RTK Repeater*

An additional repeater was established in the southern portion of the project to maximize the coverage area of the RTK broadcast. Benthic first executed a reconnaissance of the southern portion of the project area with a VHF Radio scanner in order to identify viable locations for the repeater that would consistently receive the broadcast from the primary GPS base station and repeat the RTK signal into shadow of the shoreline bluff.

Finding an optimal site for the repeater was difficult due to the topography between the base station and the southern portion of the terrestrial shoreline bluff, which interferes with direct radio communication. There are few opportunities for consistent and quality signal along the bluff edge. Eventually a site was selected which continued the coverage throughout all of the survey area specified in the Scope of Work (SoW).

Benthic did identify an area that was outside of the original SoW while surveying the near shore area just south of the East Forelands Point, however, this area was not in the original scope of work and represented a minor portion of the survey. The position of the repeater was established in the vicinity of N60°42'27", W151°24'27", however, many external factors can effect the quality of radio signal at these distances and through this terrain. The function of the repeater is not tied directly to its position, as is the case with GPS receivers, and the position of future repeating RTK radios is not likely to be precisely the same.

Radio repeater established at the cliff edge on the southern portion of the survey area.

Twice animals in the vicinity molested the repeater. The equipment was not specifically damaged nor was equipment taken from the site. The equipment was simply knocked over, and the battery leads were pulled from the battery terminals. Benthic believes that future projects may benefit from bear resistant infrastructure for terrestrial equipment.

2.2 Navigation

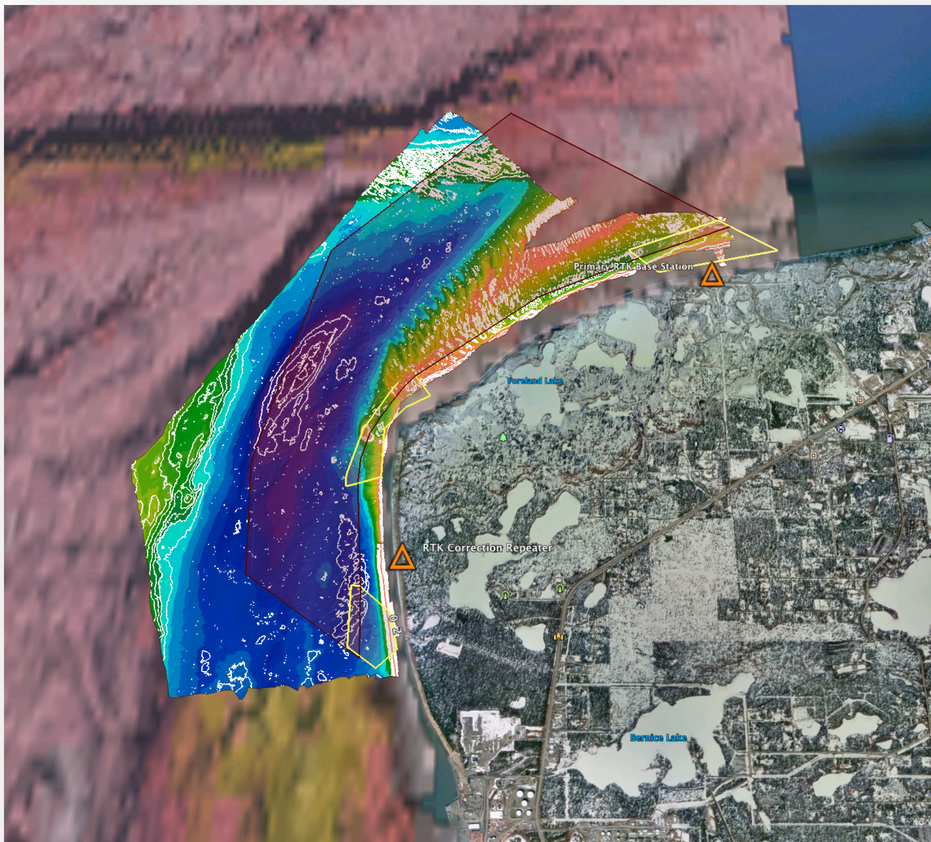
All vessel navigation was processed and distributed by Coda Octopus F-185 (F-185). The F-185 records GPS position, heading, and orientation. It distributes a RTK and orientation corrected processed vessel trajectory in real time to each navigation and acquisition system operating on the vessel.

RTK corrections were used for vessel navigation and recorded as the positioning for all sensors utilized during this survey. This can be a more precise system of measurement than uncorrected GPS and is expected to significantly increase accuracy. This system utilizes the additional information of the carrier signal, and, when properly processed, will include the Carrier-Phase Enhancement in the final position.

RTK relies upon the GPS satellite's carrier wave as its signal, not the messages contained within. The improvement possible using this signal is over a thousand times as fast as a typical GPS receiver. This corresponds to a 1% accuracy of 19 cm wavelength (±1.9 mm) using the L1 signal, and 24 cm wavelength (±2.4 mm) using the lower frequency L2 signal. Due to the difficulty in computing integer ambiguity RTK is generally accepted to have an error estimation of 20 cm, however, when the two signals (L1 & L2) are correctly aligned, the error is very small (~1 cm horizontally and ~2 cm vertically) in optimal conditions. Marine operations are not optimal and additional error must be estimated or measured accounting for inaccuracy in vessel/equipment survey or latency. Marine survey operations in less then 200 m of depth which utilize L1 & L2 carrier wave analyzed RTK are generally accepted to have an error less than 20 cm in both the horizontal and vertical orientation. L1/L2 RTK corrections relative to NAD83 space horizontally and MLLW space vertically were transmitted to the vessel navigation and recorded by the acquisition software during all East Forelands survey activity.

This page was intentionally left blank.

3.0 HYDROGRAPHY



This compilation includes the historic NOAA Data in the background, the survey polygon detailed in SoW, and the actual surveyed area acquired by Benthic GeoScience in 2012.

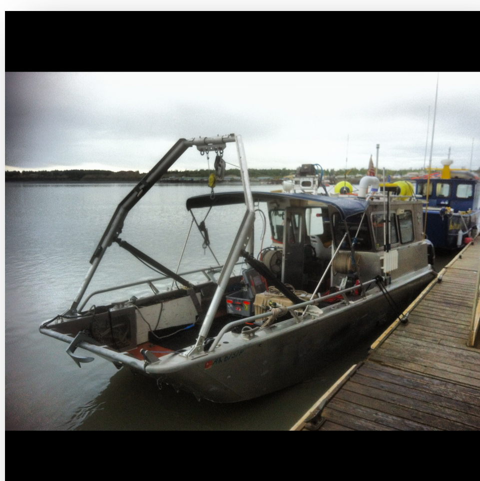
Benthic was contracted to acquire, process, and present remotely sensed geophysical measurements for the ORPC East Forelands Tidal Power Project in the vicinity of Nikiski, AK. Data was gathered to better describe the physical character of the site for the purpose of evaluating aspects of Tidal Hydrokinetic Power Conversion.

A high density MBES survey was designed to establish the foundation for all future charting products. Specifically, this project was designed to inform ORPC about the geomorphology of the inlet, facilitate project planning, and to enable inlet modeling efforts. This product will act as a baseline measurement of the seafloor prior to build out or development as well as help design the position of future project infrastructure. The survey area polygon boundary was established by ORPC to end at the inshore -15m contour (per MLLW datum), with two shoreline approaches for possible cable corridors to the +0 m contour. Full ensonification of the seafloor was not a realistic goal for shoal depths due to the constraints of swath width on the shorelines and shoal areas within the project area, so interpolation was expected to be necessary in order to accomplish a contiguous seafloor surface.

The measurements were designed to be precise and dense enough to allow for obstruction identification of both Dangers to Navigation (DtoN) and for Hazards for Construction (HforC) on the sea floor. The recording of Acoustic Backscatter data was also required to help with future geologic classification and habitat mapping efforts.

The survey area polygon was established based upon very coarse NOAA data. Benthic was able to survey considerably more area than was specified in the provided SoW Polygon. This was accomplished specifically to collaborate and facilitate future work such as cable corridor selection, marine mammal monitoring mooring placement, current monitoring mooring placement, and future sub-seafloor seismic studies which will require comprehensive understanding of the surface expression. Benthic abandoned a portion of the northern polygon once the boundary of the two dune fields (A & B) were identified and delineated. The remaining effort focused upon fully imaging the body of the scour trough and acquiring significantly more inshore data.

Benthic mobilized to Nikiski on two expeditions in order to complete the acquisition of the contracted study. Benthic mobilized to Nikiski, AK on May 18 2012, however, MBES equipment failure terminated the survey prior to completion. Benthic returned to the project area, after new sonar components were made available, on June 1, 2012 in order to complete the necessary work. No measurements recorded during Expedition 1 were used in this report, all data and data products presented in this report are from the Expedition 2.



M/V LC during mobilization at Kenai City Dock

The vessel used during Expedition 2 for all operations was the 29 ft. aluminum landing craft *M/V LC*. Benthic measured the survey vessel and instrument relationship aboard *M/V LC* for use as a survey vessel of opportunity. Benthic contracted *Glacier Craft Boats* and directed the fabrication efforts to ensure stability and pole arm functionality.

Dave McKay about to install the custom pole arm with the mounted and calibrated EM3002

The geophysical instrumentation deployed on *M/V LC* included a pole mounted *Kongsberg* EM3002 MBES and *Coda* Octopus F-185 Inertial Navigation System (INS). The mobilization crew consisted of the project Lead Hydrographer, a Vessel Captain, and a Survey Technologist.

Between June 2 – June 8, 2012 Benthic acquired a precise high-density bathymetric data set that fulfilled the project requirements delineated in the Scope of Work. The acquisition crew acquired both the point bathymetric data and the backscatter data during operations.

M/V LC during survey operations at East Forelands, AK

This was the first step in a series of survey measurements and analytical products needed for the permitting and planning of the ORPC East Forelands Tidal Power Project. This data set will contribute to the project and future operations as a high quality baseline measurement of the sea floor, geomorphologic observations, and evaluation for obstructions avoidance, both for Hazards for Construction (HforC) and Dangers to Navigation (DtoN). It will contribute to future permitting and planning efforts with habitat mapping products and geologic imaging of the sea floor.

3.1 Acquisition of Hydrographic data

3.1.1 *Acquisition of Multibeam data*

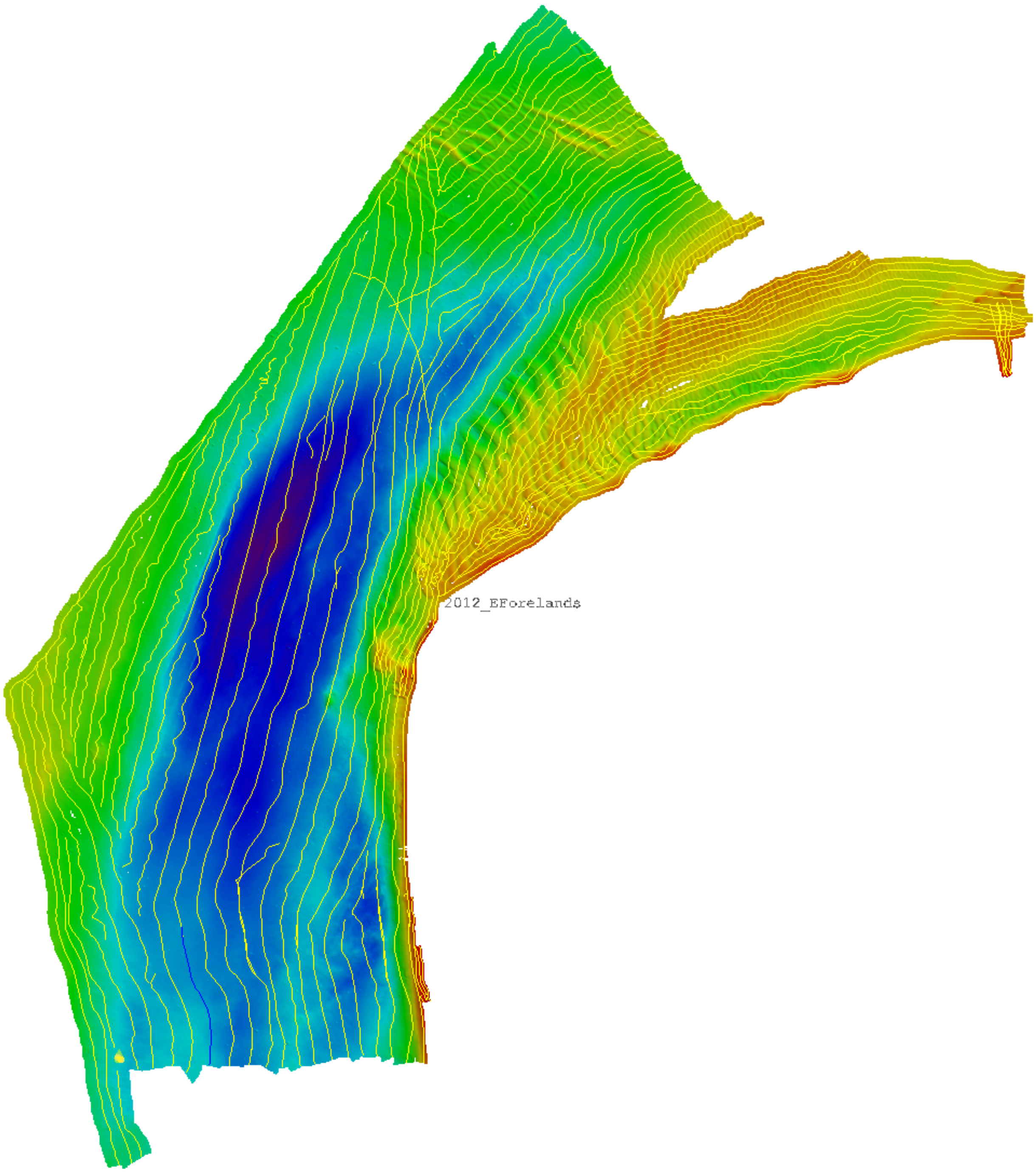
The Multibeam Echosounder (MBES) calibration and acquisition of main scheme MBES data occurred on June 2 – 7, 2012. Benthic acquired bathymetric point data and acoustic backscatter with Kongsberg EM3002 MBES and recorded that information using Kongsberg SIS Integrated Acquisition Software. An AML acoustic velocimeter was used to measure the near field speed of sound at the sonar face. An additional Odom Digibar Pro acoustic velocimeter was used to measure the speed of sound throughout the water column by manual casts performed intermittently throughout the survey effort. During both surveys the water column was measured to be well mixed and of homogenous temperature.

The MBES Calibration test accounts and corrects for electronic timing errors, roll, pitch, and yaw bias. Benthic accomplished the MBES calibration (often called a Patch Test) acquisition according to general industry standards and while using radio corrections broadcast from the EF-2 2011 base stations over a seafloor feature.

The 300 kHz acoustic data was acquired along the topography of the scour trough lines throughout the main scheme survey area with irregular line spacing resulting in 139 main scheme survey lines. This bathymetric project resulted in a full ensonification of the seafloor within the survey area. Significant swath overlap was accomplished for a confident interpretation of the seafloor and to enable confidence during obstruction identification. Sound velocity measurements were accomplished by manual cast and measured to no less than 80% water column during MBES operations.

Non-systematic line acquisition was exercised in the shallow portions of the shoal and inshore areas in an attempt to achieve maximum coverage and reduce holidays as the swath area geometry decreased.

All vessel position and attitude were calculated with a *Coda* Octopus F-185 during the survey. The F-185 consists of two GPS antenna and an inertial motion unit (IMU). The GPS antennas have a primary (L1/L2) antenna and an additional secondary antenna (L1) co-located no less than 1 m apart creating a fine baseline. The F-185 IMU was located on the *M/V LC* near to the Central Reference Point (CRP) of the vessel. The trajectory of the vessel was computed by the F-185 and recorded by the *Kongsberg* SIS acquisition software.



Main scheme Acquisition Lines over preprocessed bathymetry

The RTK corrected GPS navigation was recorded and displayed in SIS during vessel operations. The offsets and lever arms associated with the primary GPS phase center and the IMU were computed within SIS and referenced to the CRP of *M/V LC*.

Offsets from CRP to Sonar Acoustic Center of the MBES were computed in SIS, and a real-time acoustic coverage was computed and displayed for the survey crew.

M/V LC during hydrographic acquisition operations on Cook Inlet, E. Forelands, AK

3.2 Hydrographic data Processing

Benthic exercises a systematic methodology regarding data transfer from the field, processing, editing, and the development of hydrographic products. This rigorous protocol ensures product integrity throughout the processing path.

Prior to processing, the entire field project was uploaded to our server system and included in the regular server backup and replication scheme. The data was distributed and organized by the Processing Department prior to further development.

3.2.1 *Multibeam Echosounder Processing*

The MBES calibration (commonly called a "Patch Test") acquired from June 2, 2012 was processed for the identification of temporal latency and MBES orientation errors. This effort was accomplished using the Caris HIPS and SIPS calibration tool and the correction values were entered into vessel configuration file for CARIS Hydrographic Information Processing System (HIPS) version 7.1. Two MBES calibrations were acquired for the 2012 survey: the first was acquired at the beginning of the survey and another closed the survey. The results from both surveys were in agreement, indicating no changes in the orientation of the sonar during the survey.

On June 8, 2012 the Benthic GeoScience Processing Department in Sutton, AK received the raw MBES data and associated acquisition records for final processing. HIPS version 7.1 was used for all data processing and adjustments necessary to produce final bathymetric products. The Caris HIPS workflow is designed to ensure that all edits and corrections made to the raw data, and all computations performed with the data followed a specific order and were saved separately from the raw data to maintain the integrity of the raw acquisition data. Benthic uses well defined procedures during HIPS processing; all actions are tracked to ensure that no steps are omitted or performed out of sequence.

3.2.2 *Vessel Editor*

The first component of the HIPS processing workflow requires establishment of a framework in which recorded navigation, vessel motion, raw (unprocessed) depths and vessel draft are referenced to a common position. The HIPS Vessel Editor is an application used for viewing and editing the position and calibration of sensors installed on the vessel. This information is stored in the HIPS Vessel File (HVF). The HVF is divided into a number of distinct sections, each describing one type of sensor. The sections are time-tagged and multiple entries can be defined for different time periods. The HVF is based on a three-dimensional coordinate system which locates equipment within an X-Y-Z axis using a reference point on the vessel as the point of origin. The reference point for this survey is co-located with the motion sensor which is installed at the vessel's approximate center of gravity; the point at which the least amount of motion is experienced. The position of the multibeam echosounder transducer as well as the static draft (waterline) of the vessel is recorded in the HVF with respect to the reference point. Static draft values were measured on a daily basis for entry in the HVF to track changes in vessel draft caused by loading and fuel consumption. During data acquisition, RTK GPS positioning was referenced from the X-Y-Z coordinate of the GPS antenna phase center to the motion sensor within the vessel coordinate system. All recorded navigation data is referenced to the R.P. Therefore, the X-Y-Z coordinates of the GPS antenna phase center need not be entered in the HVF.

3.2.3 *Raw Data Conversion*

CARIS HIPS was used to create a folder structure organized by the project, vessel, and Julian day to store data. Raw MBES data was converted from its native Hypack format, *.hsx files, into CARIS HIPS using the CARIS conversion wizard module. The wizard was used to create a directory for each line separating the *.hsx files into sub-files which contain individual sensor information. All data entries were referenced using the time associated with the *.hsx file to relate the navigation, azimuth, heave, pitch, roll, and slant range sensor files.

3.2.4 *Navigation Editor*

Navigation data was reviewed using the CARIS Navigation Editor. The review consists of a visual inspection of plotted fixes noting any navigation gaps in the data. Additionally, vessel speed, distance between navigation fixes, and course made good are examined for anomalies. If any anomalies are detected, the processor may choose to reject or interpolate the affected areas. The data in this project displayed no anomalies with respect to navigation.

3.2.5 *Attitude Editor*

Attitude data was reviewed using the HIPS Attitude Editor. The review consists of a visual inspection of the heave, pitch, roll, and GPS (ellipsoidal) height which are displayed simultaneously in a graphical representation using a common x-axis scaled by time. The Attitude Editor, like the Navigation Editor, is used to identify anomalies and has the ability to interpolate or reject the affected areas. The data in this project displayed no anomalies with respect to attitude.

3.2.6 *Sound Velocity Editor*

Each sound velocity profile, or cast, was examined using the HIPS Sound Velocity Editor for potential outliers prior to its application in HIPS. Erroneous sound velocity changes will cause a concave or convex distribution of soundings. This artifact is caused by the sound velocity correction required for the outer beam forming computation. The data in this project displayed no anomalies with respect to sound velocity.

The sound speed adjustment in HIPS uses slant range data, applies motion correctors to determine launch angles, and adjusts for range and ray-bending resulting in a sound speed-corrected observed-depths file. It is recommended that sound velocity correction be executed before cleaning the data. Cook Inlet is a well mixed water body, and after a sufficient number of full water column casts, Benthic used the surface measurements at the transducer face to determine sound velocity throughout the water column.

3.2.7 *GPS Tide Computation and Merge*

Upon review of navigation, attitude, and sound velocity, the vessel positioning was converted from local datum heights to water level and subsequently to the final space datum. In this case, the tide and GPS tide was the variation of the vessel vertical motion from the position of the base station offset. These processes are referred to as the computation of GPS Tide and Merge. The full formula for GPS Tide is shown below.

GPS Tide = GPS (ellipsoidal) Height - Datum Height - Heave - Waterline Offset

Where:

- **GPS height** = RTK ellipsoidal heights referenced to the vessel RP
- **Heave** = time-tagged measurements of the vessel's vertical motion recorded by the motion sensor and referenced to the vessel RP
- **Waterline offset** = time-tagged waterline levels referenced to the vessel RP and measured daily by the Hydrographer
- **Datum Height:** The distance from the ellipsoid to project datum (USGS Stream Gage Datum).

For this project, the position of the monument, its relationship to the horizontal NAD83 plane, its relationship to the vertical MLLW were known, and the data was acquired in final product space.

3.2.8 *Subset Editor*

Following final processing and quality assurance of draft and GPS tide applications, several area-based editing processes in CARIS HIPS Subset Editor were performed during the office review of survey soundings. During subset editing, the processor was presented with two and three-dimensional views of the soundings and a moveable bounding box to restrict the number of soundings being reviewed. Using the two-dimensional window, soundings were viewed from the south (looking north), from the west (looking east) and in plan view (looking down). These perspectives, as well as controlling the size and position of the bounding box, allowed the operator to compare lines, view features from different angles, measure features, query soundings and change sounding status flags. Soundings were also examined in the three-dimensional window that could be rotated on any plane. Vertical exaggeration was increased as required to amplify trends or features. While HIPS does not allow for the deletion of any sounding, spurious soundings (noise) were flagged as rejected during subset editing. Soundings flagged as rejected are excluded from any final bathymetric product.

3.2.9 *Caris BASE Surfaces*

The CARIS HIPS Bathymetry Associated with Statistical Error (BASE) Surface is a 3D, georeferenced image of a multi-attributed, digital terrain model. To build a BASE surface, HIPS assigns a set of gridded nodes at user-defined spacing and bounding coordinates. Each grid node is assigned a depth value based on nearby sounding values. All BASE Surfaces use range weighting to determine how a sounding is applied to a node. Range weighting is based on distance; soundings close to a node are given greater weight than soundings further away. Additionally, all BASE surfaces created for this project use a weighting scheme based on a beam's intersection with the river bed; soundings formed by the outer beams are weighted less in the algorithm than more reliable nadir beams. BASE surfaces can be used to identify areas requiring further cleaning as well as comprise the final bathymetric product.

Once the sounding dataset was cleaned, and all corrections were applied, a 1 m & 2 m resolution BASE surface was created for use in development of bathymetric products.

Future efforts which focus more specifically upon obstruction identification should process the data specifically for points identified to be the shoal point of an object above the ambient seafloor interpreted to be rocks or other anomalous features which can be designated, exported, and appended to the gridded DEM surface in order to minimize the height attenuation of obstructions common to surface generation. This process was not completed throughout the project area, but it is highly recommended for efforts which require more detailed obstruction analysis.

3.3 Hydrographic Products

Hydrographic products include products exported from Caris HIPS and those exported from Fledermaus Pro. The Hydrographic surfaces produced in Caris HIPS were imported into Fledermaus in order to produce comparison and analysis products.

3.3.1 *Bathymetric DEM gridded dataset and imagery*

The regular gridded Digital Elevation Model (DEM) surface is a critical product. This surface is the foundation for all charting and positioning. It is the reference surface for the Acoustic Intensity deliverables, the slope analysis, roughness for modeling efforts, and most other future study products. This surface was considered in each interpretation and during the generation of all location positions.

The sole origin for this digital DEM is the Multibeam Echosounder point file. Even after processing and editing, the high density data from the MBES is often too large to manage by most software suites. Benthic further reduces the data through the process of surface generation in Caris HIPS software. The final 2012 DEM surface product grid spacing was 1.0 m distance for East Forelands.

There is a small loss of detail that develops as we reduce the data that makes up the surface of the DEM product. This loss is directly related to the node spacing established in the final surface. The exact location of loss is not known nor controlled. During regular gridding, Benthic did not have control of the data that is reduced. We did not confirm that the most shoal depth of an obstruction is the exported grid point nor if it is properly represented in the DEM.

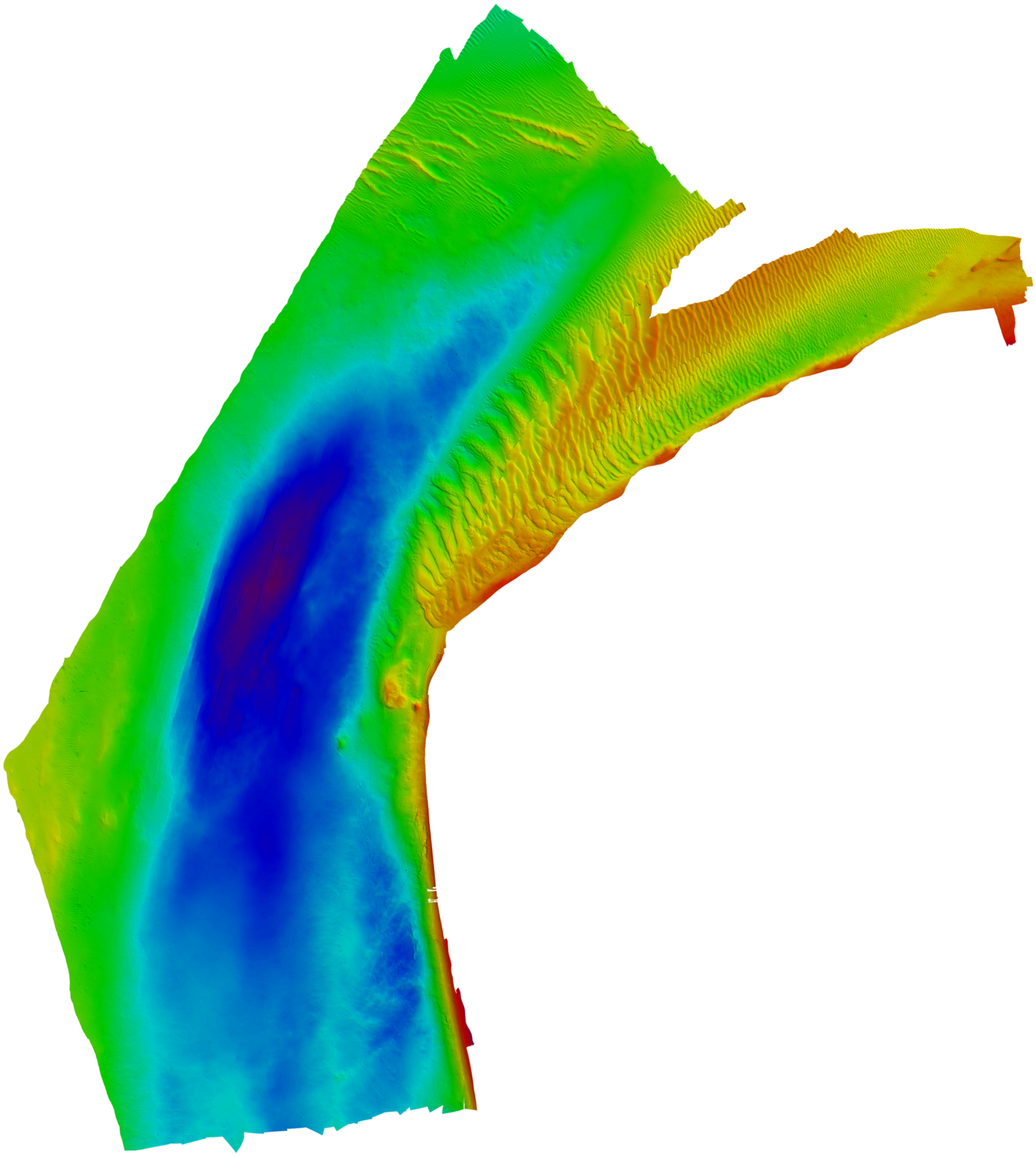
The 2012 surface was acquired and processed in order to maintain the high level of detail necessary for obstruction detection and interpretation. However, several holidays were present in the final surface. Benthic filled the holidays present in the 1.0 m surface grid with information by applying an interpolation function contained in the Caris processing software that allowed for the generation of a contiguous surface. Interpolation to fill holidays was necessary for the 2012 MBES dataset in particular in areas more shoal then the -15m (MLLW) depth which was outside of the scope of work. However, several areas within the SoW polygon also needed filled. The areas that have been interpolated through are likely to be of acceptable accuracy to not effect most products that will depend upon the precision of the DEM.

In contrast, the future obstruction classification may be affected by the lack of data, however, only in the areas missing sufficient point data to meet the criteria for surface grid generation. When the time comes to produce the obstruction evaluation, it is recommended to compare the interpolation polygon with the area to be evaluated for obstructions in order to acknowledge where obstruction data is unavailable.

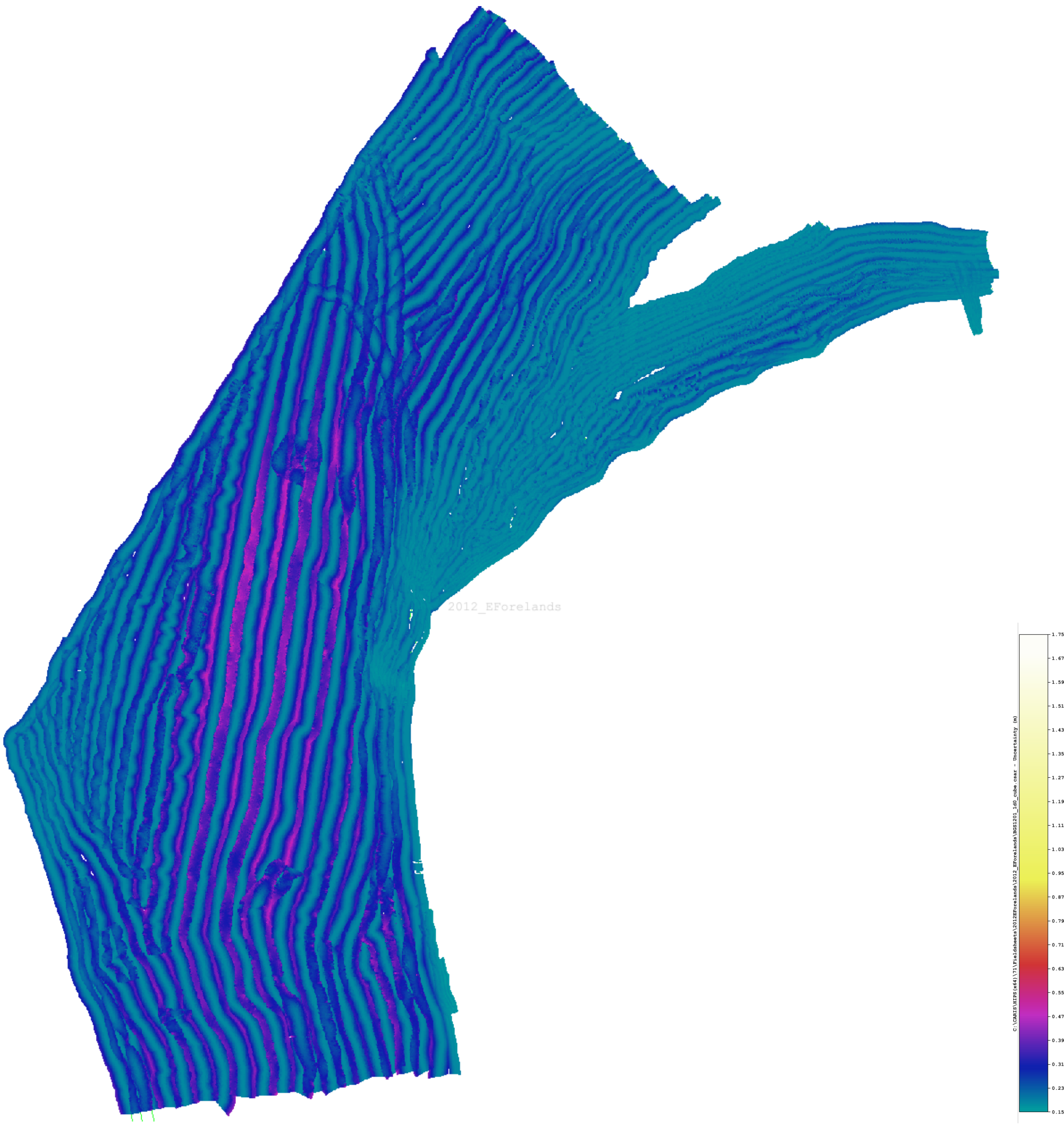
This surface was included in the Fledermaus Digital Product bundle and distributed on both the Benthic FTP site and included in the DVD data distribution that accompanies this report.

Two images with different color scales have been generated from this DEM. Both represent the same surface, however, the color spectrum can help with interpretation of different features.

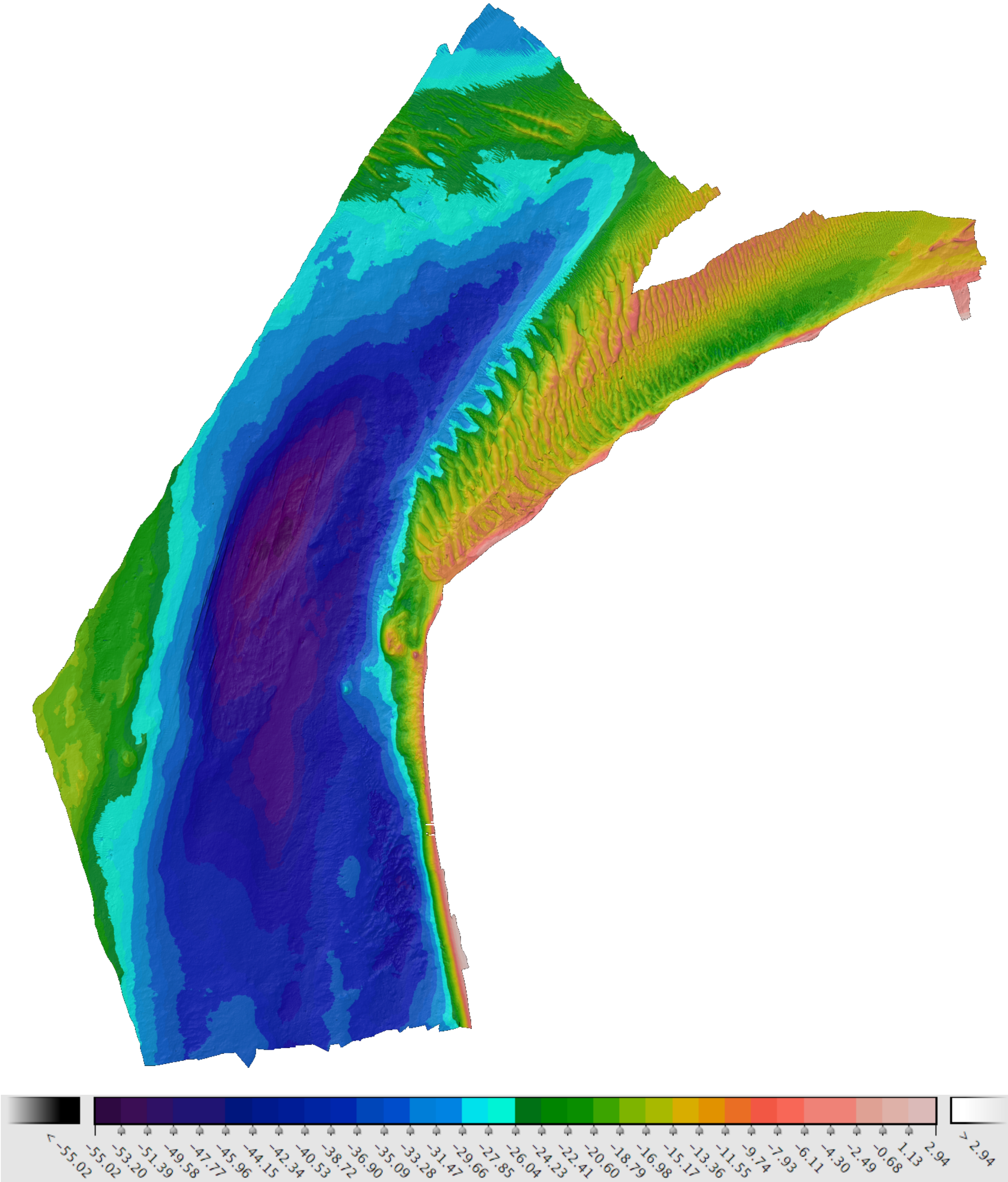
The geodetics for the output file are UTM, zone 5, meters, projected as NAD83. The vertical dimension also has meters as its units and is based upon the local MLLW datum. Caris products will have positive axis down, and Fledermaus products will have positive axis up.



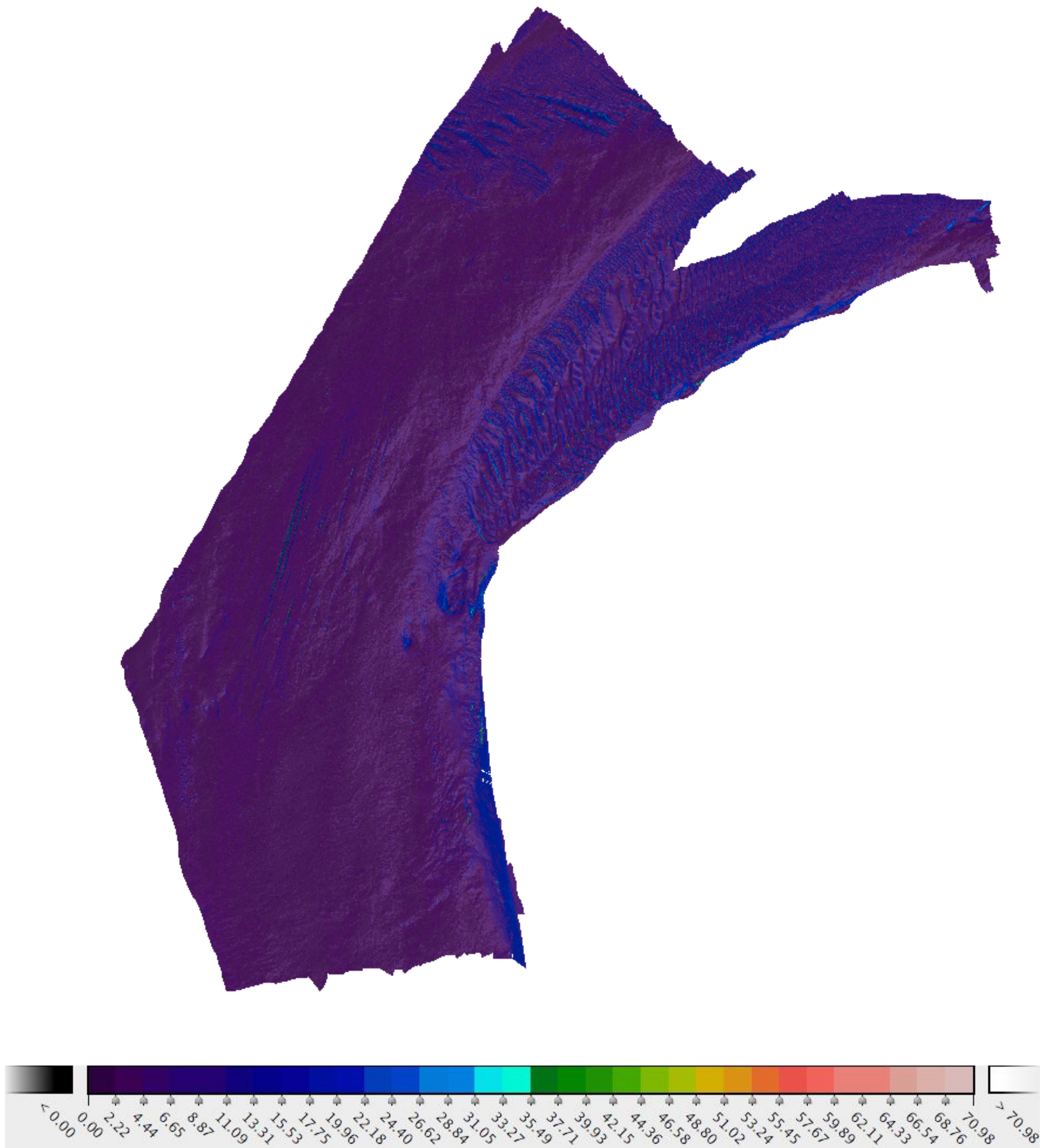
Caris Bathymetry product for ORPC East Forelands Tidal Power Project (scaled by depth)



Caris Uncertainty Surface for ORPC East Forelands Tidal Power Project (scaled by Uncertainty)



Fledermaus Bathymetry product for ORPC East Forelands Tidal Power Project (scaled by depth)



2012 Calculated Surface Slope

3.3.2 *Acoustic Intensity Mosaic*

The Acoustic Intensity Mosaic is a compilation of selected Backscatter files which best visualize the seafloor spatially and through variation in the albedo spectrum. The lines are assembled as a stack of linear swath image files processed with Automatic Gain Control algorithm to best match and normalize the tone with similar geologic material. The compilation was digitally compiled in Caris SIPS, and the seams were digitally muted through software options. Although muted, there are lineation artifacts in the mosaic products which can be attributed to image boundaries and should be recognized as artifacts of the images when viewing this mosaic.

2012 Acoustic Intensity Mosaic for ORPC East Forelands Tidal Power Project

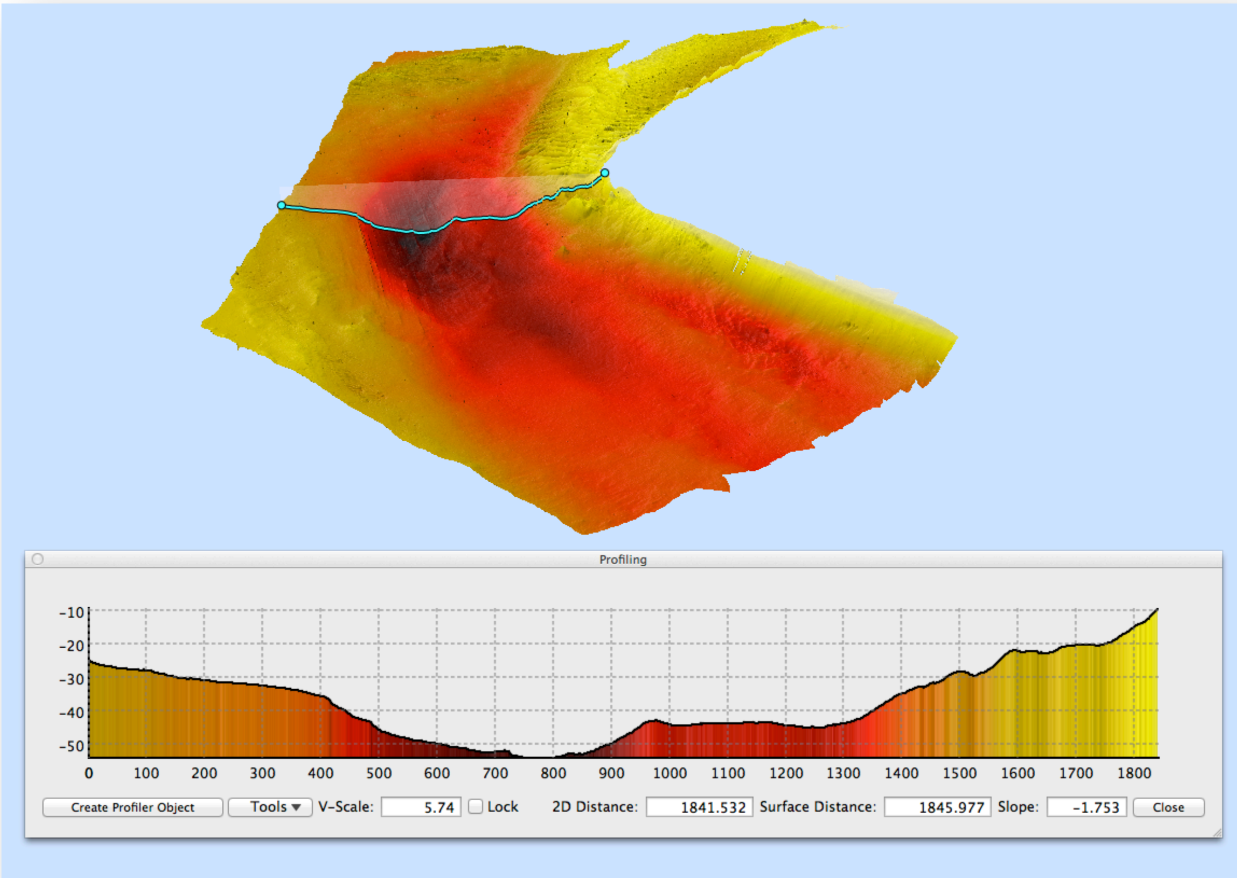
3.4 Important note

Benthic understands that the information gathered for this project is intended to facilitate the planning of marine construction projects and that our data may contribute to safer marine operations. This data is not to be used for navigational purposes. This data should not be used to replace any publication distributed by NOAA, USCG, or the Department of Transportation nor does Benthic assume any responsibility for safe navigation or safe marine operations. The distributions of any obstruction data recorded during June, 2012 may or may not contain valuable information regarding vessel navigation.

For that reason, Benthic recommends avoiding contact locations where navigation may be at risk but does not guarantee that additional unobserved or uninterpreted hazards are within the boundaries of this project. Benthic does not guarantee that interpreted obstructions are persistent or that potential obstructions will be present at a future date. Natural/manmade hazards in this project area are dynamic and are known to be spatially transitory.

The use of products provided by Benthic is only valid for the moment of acquisition and all forecasts, assumptions, or logical conclusions are wholly the responsibility of the user. The use of such products in conjunction with the products of agencies that are responsible for safe navigation (i.e. NOAA, DOT, USACE, USCG, etc.) is highly recommended.

4.0 INTERPRETATION & CONCLUSIONS



Cross section of bathymetric surface, considered during analysis.

Benthic was contracted to provide interpretations and conclusions of the geophysical measurements in order to provide insight defining the physical character for the ORPC East Forelands Tidal Power Project site. Specific conclusions such as Hazards for Construction (HforC), Danger to Navigation (DtoN), Geological Interpretation, and Turbine Site selection were outside the scope of work for this phase in the project and this effort has been postponed until more information is available. However, the acquired MBES dataset was required to be of a quality level with enough detail to facilitate those efforts when the needed.

The conclusion and recommendations found in this portion of the report are primarily a preliminary interpretation from the single data set available to the geophysical interpreter. They are limited by the amount of data available, however, every effort has been exercised to understand the East Forelands area and the behavior of the environment. Particular attention has been placed on classifying the geomorphology and understanding the behavior of the distinct zones so that a common language can be developed for future planning and research efforts. Attempts to identify any zones for caution & behaviors hazardous to vessel operations, cables, or instrumentation are discussed in this section. By no means does Benthic believe that they can produce a comprehensive inventory of potential hazards from this little data, however, if we identify areas for concern, we do highlight these possibilities in this section of the report.

4.1 Geomorphologic Interpretation

The geomorphology of East Forelands was well defined during the 2012 bathymetric survey. Benthic reviewed three Bathymetric surface products, both the draped and undraped Acoustic Intensity Mosaic, individual GeoBars, and the slope analysis in order to develop a sense for the character of the East Forelands of Cook Inlet.

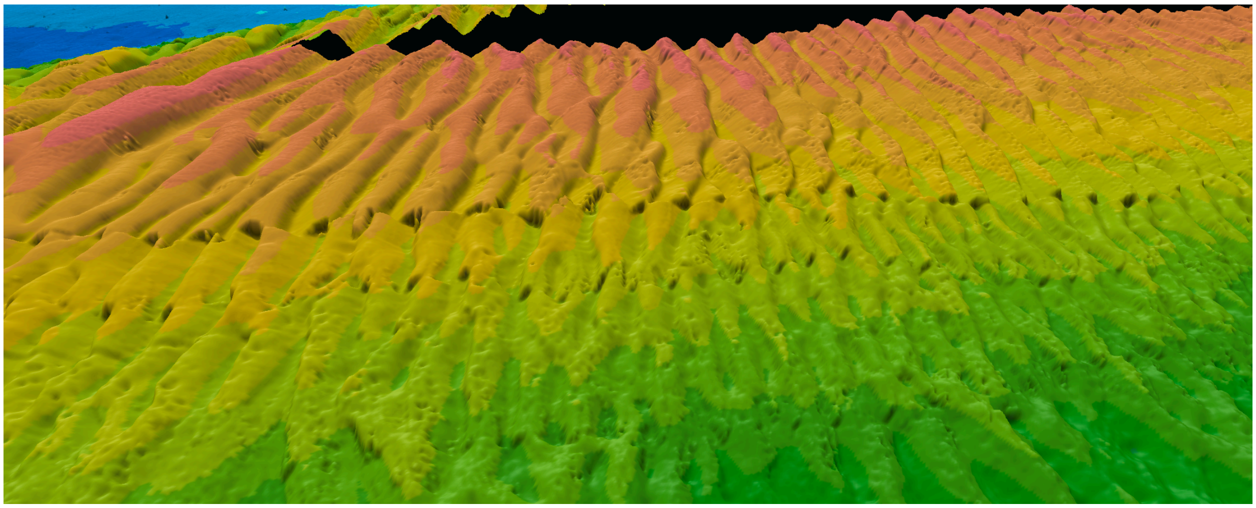
Geomorphologic Zones draped over bathymetry

		Color	Area	Key Name
1	☐		3.089 km²	Dune Field A
2	☐		1.397 km²	Dune Field B
3	☐		1.385 km²	Mid Channel Shoal
4	☐		1.327 km²	Deep Scour
5	☐		254569.56 m²	Pipeline Corridor
6	☐		6.095 km²	Thin Sediment Covering Seafloor
7	☐		1.024 km²	Southern Nearshore Shoal
8	☐		405977.95 m²	Southern Nearshore Scour

Table of Geomorphologic Zones

4.1.1 ***Dune Field A (Erg A)***

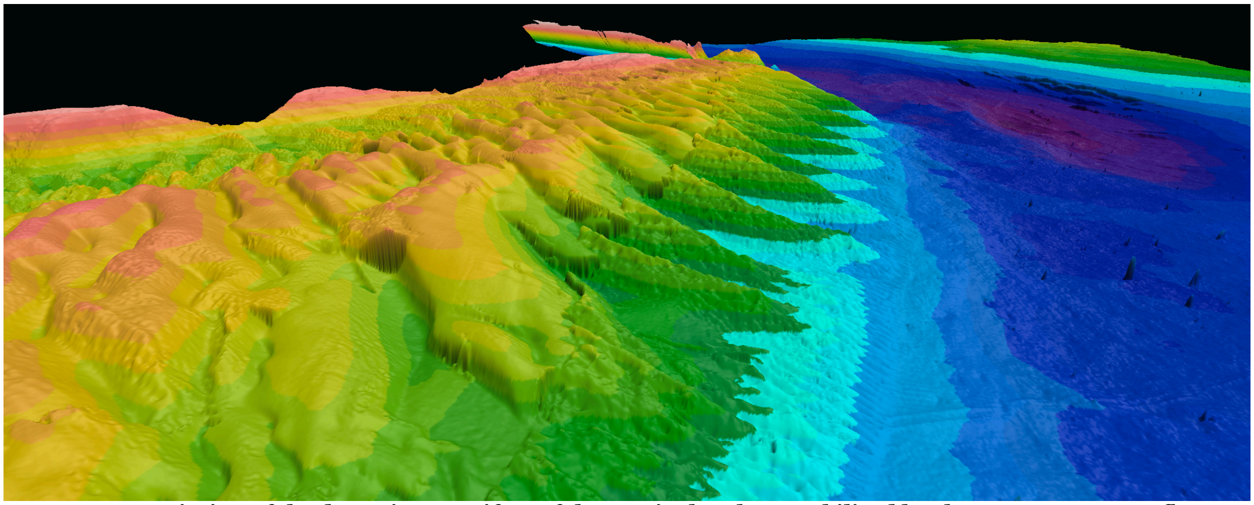
Dune Field A (Erg A) is a highly mobile traverse dune zone within the northern portion of the project area. The dune placement indicates rapid migration with significant variation over the period of each tide cycle. This shoal zone was surveyed over a period of several days when the vessel could operate in the vicinity at higher tide events. This allowed for significant periods of time between each survey event, and the result is observable in the product surface. The dunes, with sand moving at rapid velocity with the tide, migrate quickly through the dune field. When the vessel was again allowed to return to the shoal area, the dunes had migrated significantly.



Separate survey periods (separated by many hours) display dunes almost 180° out of phase

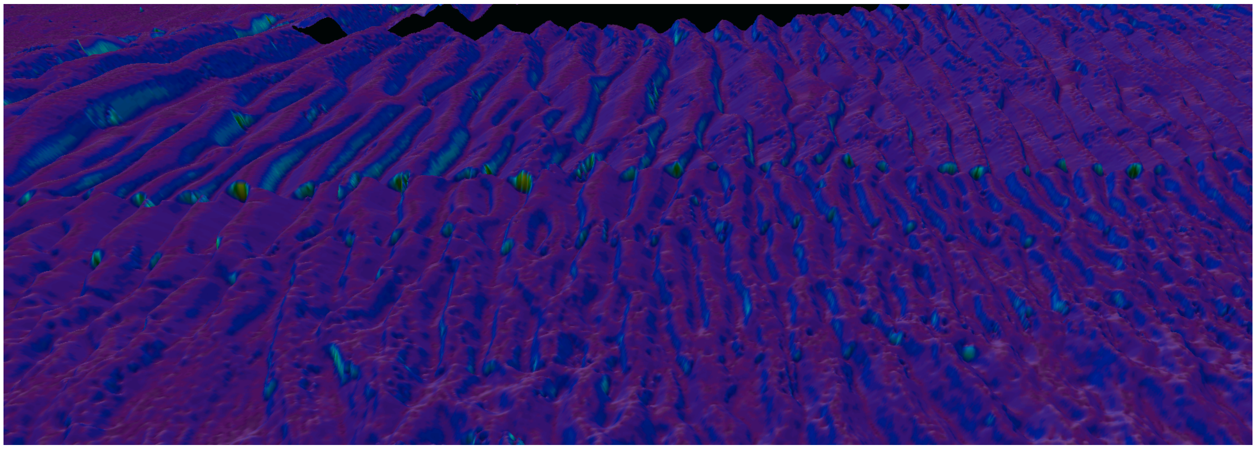
The dunes are interpreted to be composed mostly of well sorted fine to medium grain sands with other unsorted clasts erratically dispersed beneath the sands, swallowed at some earlier period and now sheltered from the high current energy. It is unknown where the source of the mineral which composes these dunes is sourced or what cyclical processes reenergizes the sand through the project site.

Another artifact observable in this seafloor surface is the dune texture, which relates to the phase of current flow during acquisition. Dunes surveyed while trivial current flowed appear smooth and untextured, while the dunes measured at high flow appear to be dimpled and erratically textured. The textured appearance is a result of the acoustic signal reflected off of different density concentrations within the lens of sand flowing over the dunes during this time of high flux. This period of flow does not represent an inaccurate seafloor measurement, it is instead measuring correctly a period of instability of the seafloor. The sediment bed itself has broadened and thickened. During this phase of the tide cycle, it is difficult to precisely define where within this lens of sand flow each acoustic signal has returned from. Using the relatively high frequency of 300kHz, this MBES was particularly well suited to highlight this phenomenon.



Texture variation of the dunes is an artifact of the particulate lens mobilized by the extreme current flow through the dune field

Erg A is a highly mobile zone of sediment. All future planning and design should account for its unstable nature when considering infrastructure buildout.

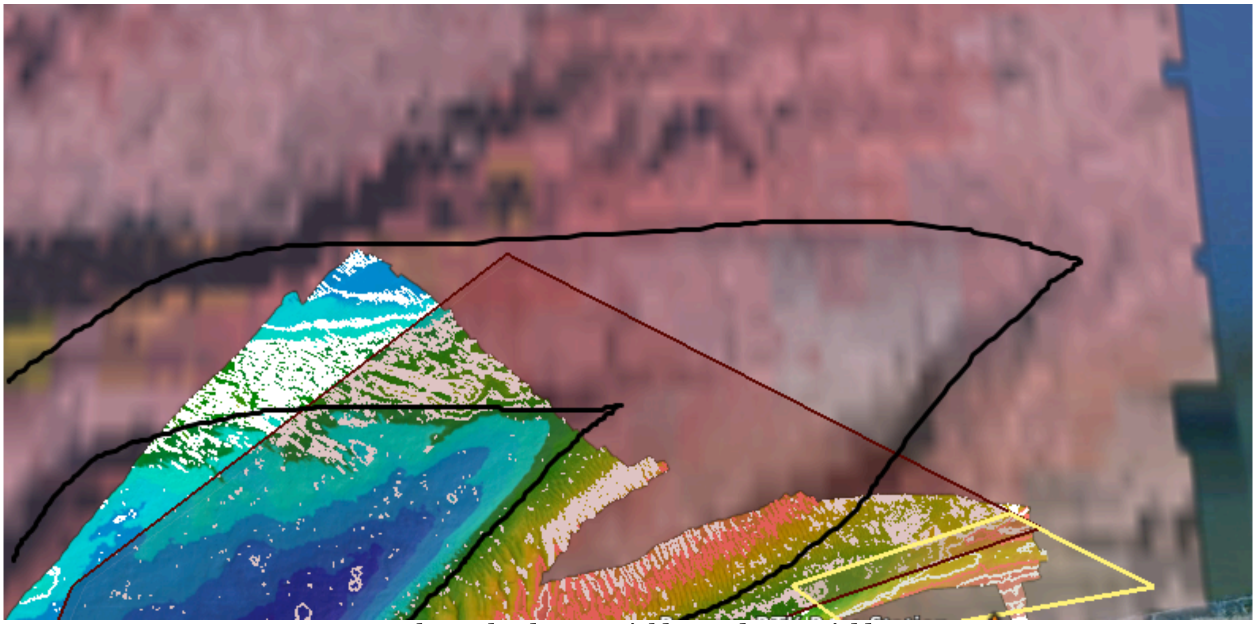


Please note the confusion associated with various passes of the sonar, the gentle stoss (current flow side) and the slip (leeward side) faces of the dunes flip sides based upon the direction of current flow at different tide stages

4.1.2 *Dune Field (Erg B)*

Dune Field B (Erg A) was not extensively surveyed and is interpreted to be part of a large shoal structure directly to the north (outside of the survey area). The geology is expected to be different than the fine to medium sands interpreted in Erg A. The dune structures present with linear structure with steeper faces that display more balance without well defined stoss or slip faces. The mineral or grain size appears to display significantly more absorptive acoustic nature than the sands of Erg A. Benthic will need more information before identification of the geologic material can be interpreted with confidence.

The purpose of extending the survey polygon to the north was to ensure that the transition boundary between that shoal and the trough was fully imaged. Benthic surveyed to the north until confident that we had measured the foot of the Northern Shoal (Erg B) and far enough to the East to identify where Erg B joined with the Erg A.



Northern Shoal, Dune Field A, and Dune Field B

Benthic does not believe that the relationship between Dune Field A, Dune Field B, the Northern Shoal, and the Mid Channel is well understood, nor do we believe that this survey will provide significant understanding for the relationship, if any, which might exist between these large loose unconsolidated deposits. This portion of the survey defined transition boundary between the trough and the Northern Shoal, in hopes that if desired at a future date, this survey would act as a baseline measurement and could be used to enlighten the design team as to any, if any, migration patterns this field exhibits over time.

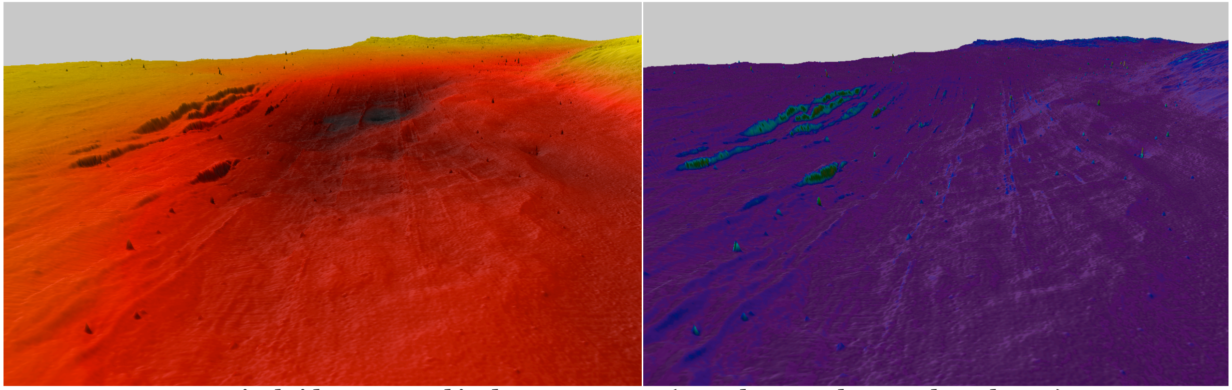
4.1.3 *Mid Channel Shoal*

Mid Channel Shoal was outside of the survey area, however, Benthic surveyed this western portion in order to describe the transition bounding environments of the primary tough. The goal was to define the boundary, and if necessary or if desired at a future date, to compare future surveys in order to analyze if the Mid Channel Shoal is encroaching upon the trough or any infrastructure placed in the vicinity.

4.1.4 *Deep Scour*

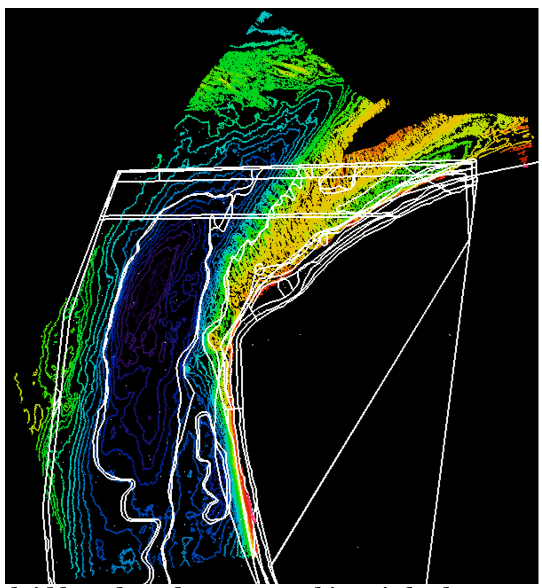
The geomorphology of the Deep Scour area is unique and will be of special importance for the geologic interpretation. This area demonstrates erosion of the thin sediment overlay that dominates other portions of the survey area. It reveals exposure of vertical ridges which are interpreted by Benthic to indicate a consolidated sedimentary stratigraphic horizons at a steep dip of orientation.

No Direct correlation was inferred by examining the bluff on the shoreline of East Forelands with the orientation of the submarine stratigraphy interpreted by Benthic. We are not confident that no correlation exists at this early stage of investigation, however, currently, Benthic has not identified coincident ridge dips of the exposed structure with the surrounding shoreline exposures. This may indicate faulting in the immediate vicinity of the project site.



Vertical ridges exposed in deep scour area (1: Scale = Depth, 2: Scale = Slope%)

When referenced against historic referenced produced by NOAA during previous charting efforts, this scour zone appears to be stable with little change over the period of the last decade. Referencing the published Approach/Harbors layer of the NOAA ENC, Benthic observes little change between topographic contour of the historic surveys with the current trough visualized during the 2012 survey.

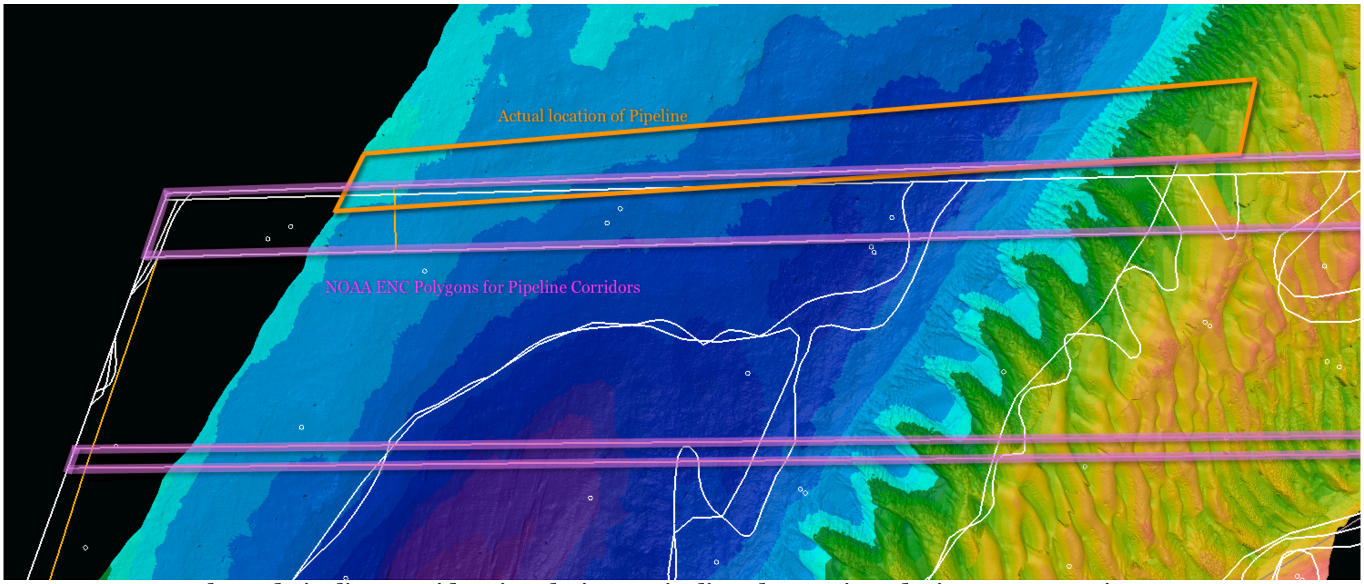


2012 Bathymetric Contour overlaid by selected NOAA ENC historic bathymetry polygon indicates little change in the trough structure over the last decade

4.1.5 *Pipeline Corridor*

Although not a true geomorphological distinct area, the two pipeline corridors that were identified in the MBES surface have been flagged to ensure that their correct positioning is known and remain an important consideration for future planning. Please note that the polygon was digitized based upon the visualized position within the processed surface. This is the correct position for the pipeline on the seafloor, but the polygon displayed does not consider easement, lease corridor, nor NOAA Chart information. It should not be assumed that the locations charted on the nautical maps are correct nor that the polygons presented on the Geomorphologic products are related to those charts. It should not be assumed that the actual easement listed by the State of Alaska is correctly positioned.

The polygons in the Geomorphologic Interpretation are to be used in order to avoid encroaching upon the pipelines with anchors, moorings, power cables, or other infrastructure unknowingly and unplanned.



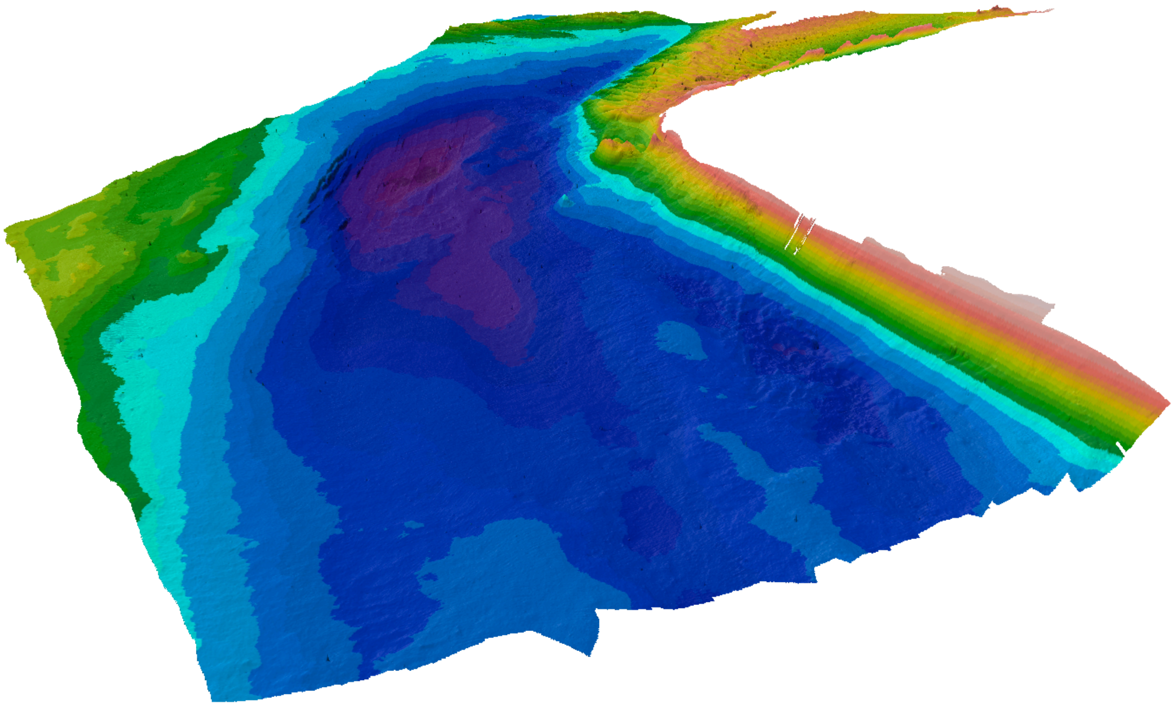
NOAA Charted Pipeline Corridors in relation to pipeline observations during Interpretation

4.1.6 *Thin Sediment Covering Seafloor*

The zone of Thin Sediment Covering is mostly unknown with little indication of the nature of the geology underlying. Most geologic and hazard observation is obscured by the migrating sediment. Assumptions can be developed regarding the character of this zone by analyzing the areas surrounding it, but in general, the area simply appears to have developed a balance with the current energies that it experiences. Although the finer sediments are likely migrating with each tide and boulders may be transiting through this zone over longer cycles, this area does not reveal its underlying geologic composition, fault history, or any particular accretion/erosion pattern.

4.1.7 *Southern Nearshore Shoal*

Southern Nearshore Shoal (SNS) is a small formation in the southern portion of the project area with a gentle rise of equal slope on both its west and east sides. The sediment makeup of this shoal is unknown, but Benthic recognizes two likely interpretations for this formation.



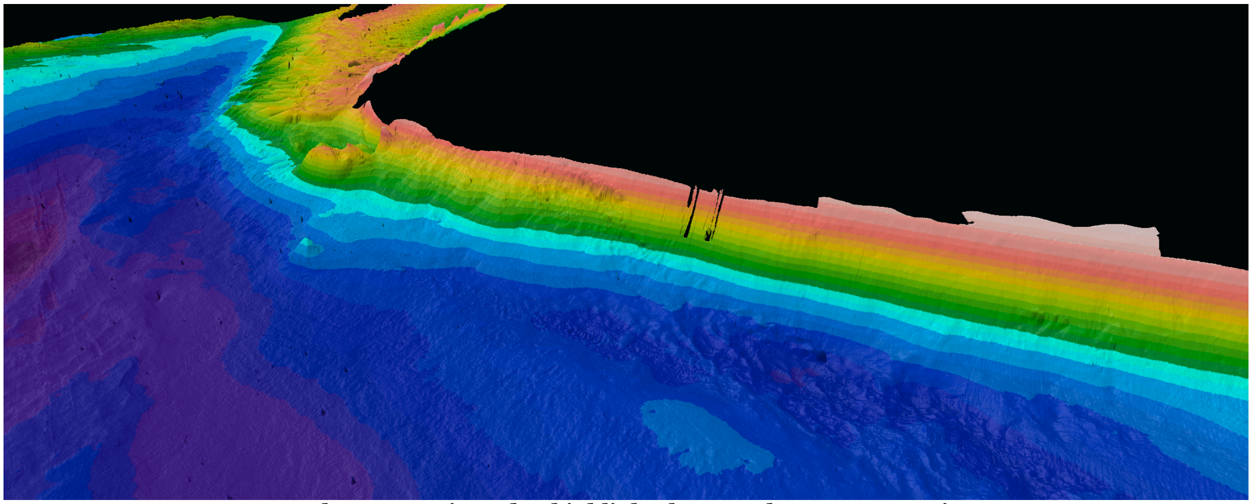
2012 Bathymetry oriented to highlight SNS, the zone of deposition between Erg A and SNS, and the rise west (potential dune) of SNS

The first interpretation identifies the probable connection between Erg A and NSN. This zone is likely composed of materials that have escaped from Erg A and spilled into the deeper trough. The flow of the material between Erg A and SNS appears as a confused poorly formed drift deposit with small accretion mounds throughout the area. The texture of this deposition is apparent even on the steep slope at the shoreline with a very distinct boundary.

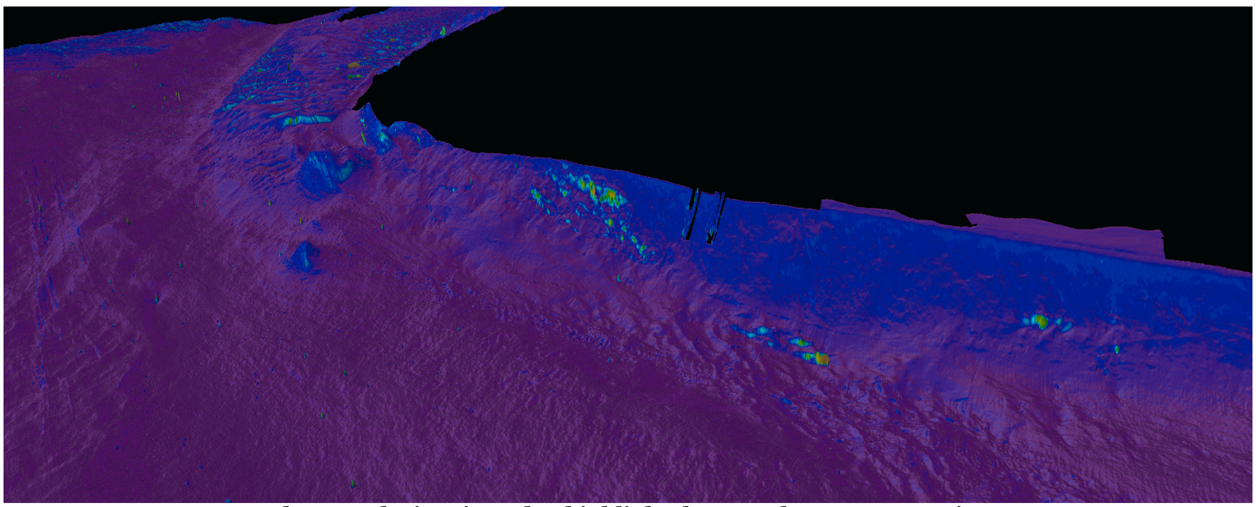
Although Benthic believes that the first interpretation is most probable, we acknowledge that the rise to the west of SNS appears to be of similar form. Other areas of Cook Inlet have presented as shoals migrating at a slow rate of speed from West to East across areas of Cook Inlet and they present in similar appearance to the relationship of SNS and the rise. Benthic recommends monitoring this area if infrastructure is developed in this area.

4.1.8 *Southern Nearshore Scour*

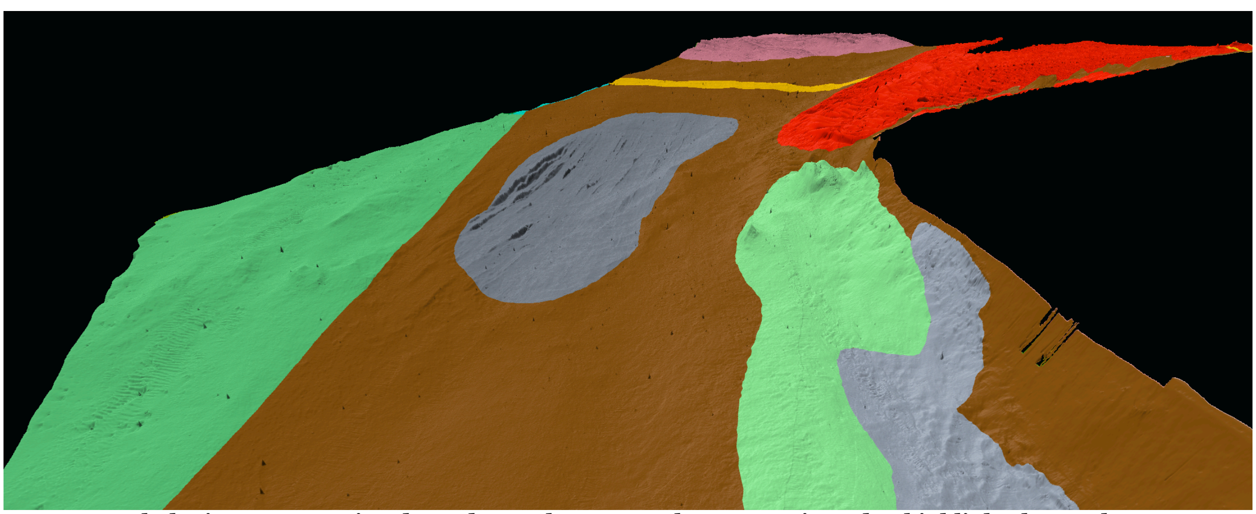
This zone of scour appears to be stable and does not demonstrate migration behavior when compared to historic survey ENC polygon contours. This zone is located directly below the smooth shoreline slope and directly inline with the textured sediment flow from Erg A. Benthic interprets this zone to be a highly turbulent zone reaching to the seafloor continually excavating the deposition from Erg A.



2012 Bathymetry oriented to highlight the Nearshore Scour erosion zone



2012 Slope Analysis oriented to highlight the Nearshore Scour erosion zone



Geomorphologic Interpretation draped over the 2012 Bathymetry oriented to highlight the southern zones

4.2 Conclusion

This survey was an important first step in understanding the Site Character of the ORPC East Forelands Tidal Power Site. This is a highly energetic nontrivial portion of Cook Inlet where significant power can be generated. This power is apparent in the geomorphology of the seafloor. This site characterization will be of significant use in establishing the foundation for future studies and during the planning phase for development. Further information will be needed to by engineers, scientists, and designers as they develop a comprehensive understanding for the current behavior, geologic structure, and plan for environmental controls which can preserve infrastructure.

This survey identified a significant amount of obstructions on the seafloor. Once optimum turbine locations are identified and cable needs are understood, this survey will provide a quality obstruction table and route planning tool for the design and operation teams.

This data set will also be very useful as a collaborative tool for future geophysical surveys that penetrate below the seafloor and into the subsurface. Together the geomorphologic and the subsurface geophysical will support our understanding of the geology and structure at East Forelands.

Although early in our understanding of the site character, Benthic finds no significant man-made infrastructure, geomorphology, or geologic obstruction that would preclude this site from future development for hydrokinetic power conversion activity. Although obstructions and zones for caution exist within the project boundaries, it is the opinion of Benthic GeoScience that no obstacle was identified that cannot be avoided, remediated, or otherwise overcome through skillful engineering. We recommend this site for further development for the purpose of hydrokinetic power conversion and we look forward to continuing to serve ORPC's remote sensing needs.