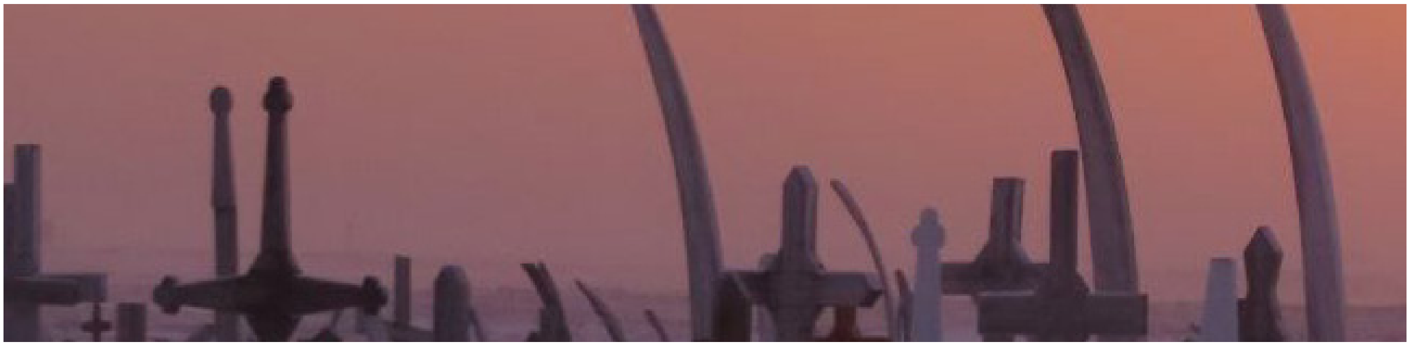
Engineering With Nature + Landscape Architecture

Tikigaq / Point Hope

ERDC EWN Dredge Research Collaborative EA AUBURN UNIVERSITY Weitzman SCHOOL OF DESIGN UNIVERSITY of PENNSYLVANIA UNIVERSITY of VIRGINIA



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This report covers findings from cooperative agreement W912HZ-18-2-0008 **Incorporating Engineering With Nature® (EWN®) and Landscape Architecture (LA) Designs into Existing Infrastructure Projects**, an agreement between the **U.S. Army Engineering Research Development Center** (ERDC) and **Auburn University** (AU) for FY2020.

This report has been prepared by the investigators at **Auburn University**, the **University of Pennsylvania**, and the **University of Virginia** and consultants from the **Dredge Research Collaborative**; it also incorporates concepts and text from ERDC's **Engineering With Nature®** project team and **EA Engineering.**

Engineering With Nature® is the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaborative processes.

Sustainable development of water resources infrastructure is supported by solutions that beneficially integrate engineering and natural systems. With recent advances in the fields of engineering and ecology, there is an opportunity to combine these fields of practice into a single collaborative and cost-effective approach for infrastructure development and environmental management.

The Dredge Research Collaborative is an independent 501c3 nonprofit organization that investigates human sediment handling practices through publications, an event series, and various other projects. Its mission is to advance public knowledge about sediment management; to provide platforms for transdisciplinary conversation about sediment management; and to participate in envisioning and realizing preferred sedimentary futures.

http://engineeringwithnature.org
http://dredgeresearchcollaborative.org/

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Introduction

This report outlines a series of research and analytical exercises conducted by our DRC team intended to assist the ongoing efforts to understand and characterize the cultural and ecological histories and processes in and around the city and village of Point Hope (Tikigaq) Alaska. Following ths analysis, our team assisted in the development and communication of a range of possible nature-based strategies that could address some of the concerns of the local Native Alaskan community. These concerns could be generalized as:

1. Coastal protection and cultural landscape preservation.

2) Loss of ice cellars (sigluaqs) due to permafrost melting and water intrusion.

3) Water access for boats.

4) Lack of emergency evacuation route to high ground.

The design concepts in this report combine Engineering With Nature® (EWN®) approaches to infrastructure design with landscape architectural (LA) approaches to infrastructure design in order to identify opportunities to incorporate "Natural and Nature-Based Features" (NNBF) into proposed project infrastructure for the community of Point Hope. As described by the EWN® initiative, NNBF "are landscape features that are used to provide engineering functions relevant to flood risk management, while producing additional economic, environmental, and/or social benefits. These features may occur naturally in landscapes or be engineered, constructed and/or restored to mimic natural conditions. A strategy that combines NNBF with nonstructural and structural measures represents an integrated approach to flood risk management that can deliver a broad array of ecosystem goods and services to local communities."

The analysis and proposals in this report were the product of a strong collaboration with EA engineering and their ongoing relationship with members of the local Native Alaskan community of Point Hope. Members of our team also accompanied EA on a trip to Point Hope in the summer of 2021 to assist in data collection and community outreach. The material in this report is not intended to be comprehensive of all of the work being done by the larger EA team, but instead outline our contributions and serve as a supplement to that larger effort.

This report is divided into two main sections, the first being the various components of **Analysis** undertaken by our team and the other, the collection of **Proposed NNBF features**.

Part I: Landscape Analysis

As an unfamiliar landscape for many of our team members, the Point Hope community and the larger region of Northwestern Alaska demanded a considerable amount of research and analytical work in order to even begin to contextualize design strategies. This research included a survey of written text, primarily by non-native scholars, on the cultural and historical value of the region, infrastructural reports and surveys done by state and federal agencies, a search for native accounts of the landscape and its meaning, and our own analytical work using available geospatial information.

Part I of this report documents particularly important points of that research and analysis and is broken down into:

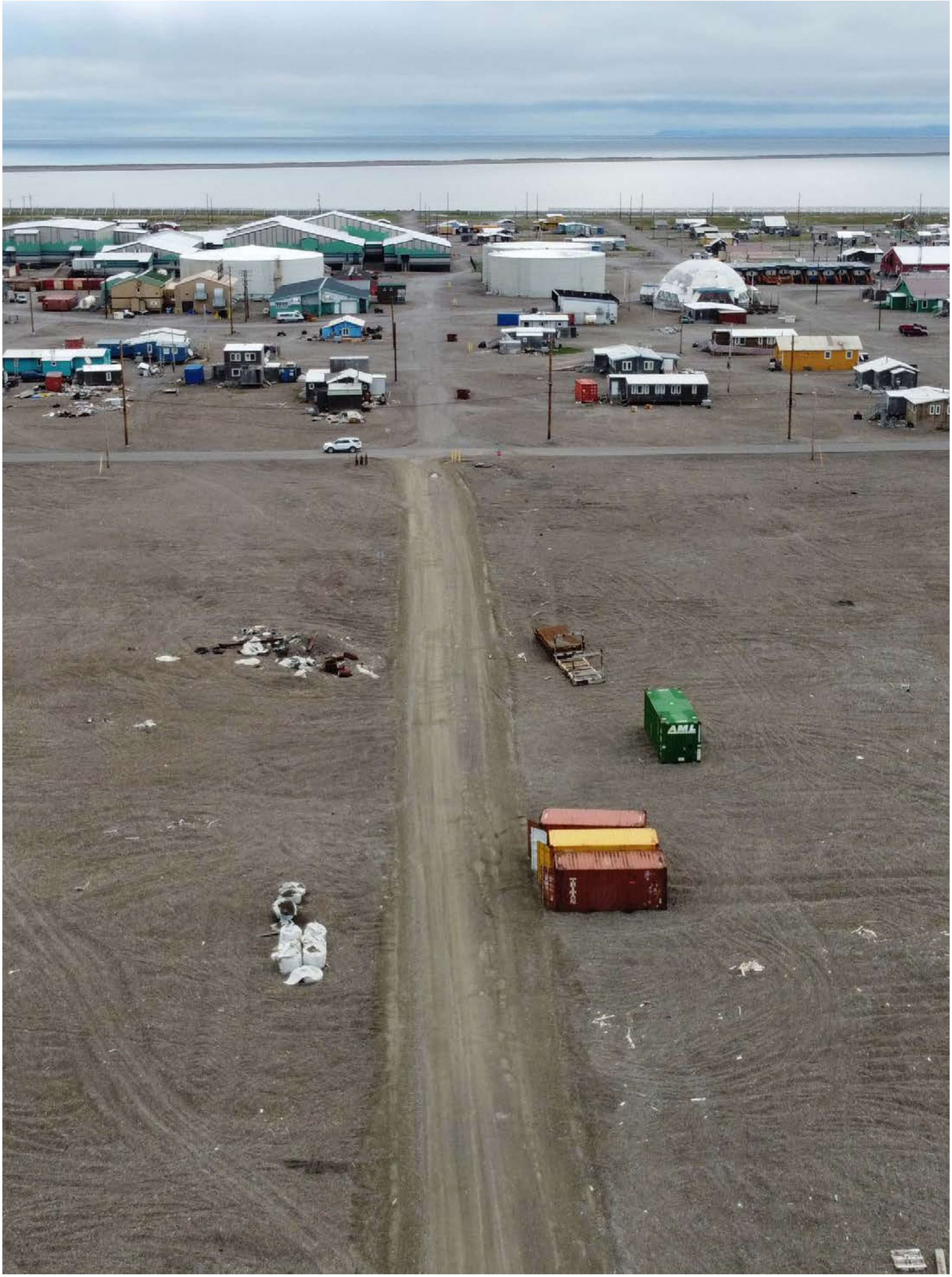
1.1. An introductory overview of the cultural landscape of the Tikigaq region as we have come to understand it though our research and experience.

1.2. Existing conditions surveys showing the current location of local features and the vertical conditions of the larger landscape.

> 1.2.1. This survey consists of a collection of georeferenced maps showing to location of important phsycal elements of the landscape.
>
> 1.2.2. The development of a series of sectional studies intended to communicate the various topographical conditions that exist across the westernmost portion of the Tigara Peninsula, within which Point Hope is located.
>
> 1.2.3. A Digital Elevation model that was derived from drone-acquired imagery and ground-collected RTK points, combined through photogrammetry software.

1.3. The results of a series of landscape transformation exercises done to test the ability of available geospatial information to document the coastal changes of the Tigara Peninsula.

> 1.3.1. The collection of satellite-acquired multi-spectral imagery during ice-free times, both before and after storm events, in an attempt to see if inferences regarding patterns of erosion or sediment transport can be derived from them.
>
> 1.3.2. The collection of satellite-acquired multi-spectral imagery during ice formation and break-up, in an attempt to see if inferences regarding patterns of ice movement can be derived from them.



1.1 Cultural Landscape Overview

As a preface, we, the authors of this report, are not archeologists or indigenous scholars. Our intentions for this section are to present the findings of our cursory research (the majority of which come by way of western, colonial scholarship) and our general impressions of the landscape as we came to understand it as landscape-minded scholars and designers. It is in no way meant to be understood as comprehensive or without bias, but instead simply our initial assessment of the factors we believe could be helpful in considering how alternative coastal management decisions could impact the resilience of the Tigara peninsula. Our personal experience of the landscape is limited to the short week we stayed there during the month of July 2021.

Part 1. The Physical Landscape

Arriving by small plane and looking down over the far eastern tip of the Tigara Peninsula where Point Hope is located tells a particular story. From the air, it is easy to see the collection of ridges that characterize the landscape. The sheen of water between these ridges indicates just how low they are and even from this height, make it clear that this entire landscape has very little relief and sits very close to the level of the Chukchi Sea surrounding it. This beach ridge system is not entirely unique in the arctic, but Point Hope is one of few locations where this type of landscape has been inhabited continuously by the Iñupiat for over a thousand years.

The Arctic breach ridge landscape is the product of a complex mixture of storm events, tidal conditions, ice transformation, and in the case of Point Hope, alluvial outputs from the nearby Kukpuk River.[1] These interacting systems have led to a landscape that has been changing shape continually for many thousands of years. Many of the previous settlements in the beach ridge landscape (both at Point Hope and in similar landscapes such as Cape Espenberg to the south) appear to have concentrated dwellings and burial sites on the ridges themselves.[2] It is within these ridges where homes and sigluaqs (underground ice cellars used for storing whale meat and blubber) were dug.[3]

The first concentrated archeological effort in Point Hope took place in 1939-1940 by a team led by Froelich Rainey and Helge Larsen. This team dug hundreds of pits across the landscape and excavated many former home sites. In this process they also collected many local artifacts for study that, as we were anecdotally told, were never returned to the community, and effectively stolen. Many of these artifacts are illustrated in the various reports generated by Larsen and Rainey. This process, no matter how disrespectful and extractive, did generate a collection of maps showing the general location of several of the previous habitation sites on the peninsula, and several of these

1 Larsen, Helge and Rainey, Froelich. Ipiutak and the Arctic Whale Hunting Culture. *Anthropological Papers of the American Museum of Natural History*. Volume 42 (1948) 19.

2 Darwent, John, et al. 1,000 Years of house change at Cape Espenberg Alaska: A case study in Horizontal Stratigraphy. *American Antiquity* 78. No 3 (2013) 435.

3 Larsen, Helge and Rainey, Froelich. Ipiutak and the Arctic Whale Hunting Culture. *Anthropological Papers of the American Museum of Natural History*. Volume 42 (1948) 20.

maps have been georeferenced in this report. The oldest of these settlements was an Ipiutak settlement that spanned along the southern shore of the Marryat lagoon. More recently settlements at the "old" and "new" Tigara sites were also documented. These sites are located farther to the west, closer to the tip of the peninsula. Here you can still see the remains of houses, and many of the sigluaqs used by the community are still here. Due to the erosion of the north and western coasts of the peninsula, the town was moved from the Tigara site to a slightly more upland location roughly 2.5 miles east of the tip of the peninsula in the mid 1970s. In the switch from Old Town, lost were the ancestral homes crafted from the jaw bones of Bowhead whales and dug into the permafrost. Instead, the new community received paved and gridded streets with elevated wood homes and a centralized water and sanitation infrastructure. By the time of the move, former settlement sites consisting of homes, burial locations, and sigluaqs had been identified across almost the entire peninsula. Larsen and Rainey went so far as to describe the entire area as "one vast cemetery." [4] So it should come as no surprise that the site selected for the relocation was also the location of many previous homes and burials. Local residents sadly told stories of how they were relocated on top of their own people. Interviews conducted by visiting scholar Chie Sakakibara in the early 2000s also describe the tremendous spiritual shift associated with the move, and many of the spiritual beings that had occupied the tundra where the new town was constructed, migrated to Old Town and were becoming "restless."[5] While as an act of engineering, moving a town can be understood rather pragmatically, addressing the spiritual qualities of the landscape is altogether different.

The new town of Point Hope is built over top of the beach ridge system, using large amounts of gravel to level out the landscape and create a site for a rectangular town of gridded streets that feels familiar to anyone with experience in a small American town. There is, however, instead of a courthouse or city hall, a large well-designed central school building that clearly serves as the hub of the community. During our short time there, very few complaints were heard about the new town and the amenities (e.g playgrounds, basketball courts), and the services it provided seemed to be well used and appreciated.

All that said, this town, so clearly modeled after some ideal new-england settlement, perched atop both the geologic and cultural past of this place was somewhat off-putting. The moving of the town, while clearly necessary, also transformed a way of life that, over thousands of years, had adapted to the particularities of this landscape. We are not here to say whether this is good or bad, but to simply offer it as an observation. It is true that the level of erosion over the last century is likely without cultural precedent to the residents. And yet there are local histories associated with the landscape transformation, including

4 Larsen, Helge and Rainey, Froelich. Ipiutak and the Arctic Whale Hunting Culture. *Anthropological Papers of the American Museum of Natural History*. Volume 42. (1948) 20.

5 Sakakibara, Chie. Our Home is Drowning: Iñupiat Storytelling and Climate Change in Point Hope, Alaska. *Geographical Review* 89. No 4 (Oct 2008) 461.

the actions of Little People who dig into the shoreline to hide from the waves.[6] These holes along the coast have been understood to exacerbate the erosion there.

We were also told that the community has pleaded for help in addressing the erosion for decades, without a comprehensive response. There were many isolated attempts, including small armor-stone walls, a levee of crushed automobiles, and the continual sandbagging of the shoreline, but none of these have been successful. The movement of the town in the 1970's seems to have served as a sign of simply giving up and giving in to the Chukchi Sea. While we were there, we visited the location of the Old Tigara settlement, known colloquially as "Old Town", and saw the wood and whale bone structures of homes and sigluaqs falling down onto the beach, soon to be washed out to sea.

Part 2. What is at stake?

As is likely known, the former settlements in the Tikigaq region are some of the oldest in North America, with Ipiutak artifacts dating back almost 1500 years.[7] Point Hope has also been studied extensively by many anthropologists and archeologists, who have taken cultural artifacts from this landscape and dispersed them across the world in museums. The British Museum and the Smithsonian, in particular, have extensive collections of artifacts spanning decades of extraction from Point Hope. This fact alone should clearly indicate the interest and importance of the cultural value of the Tikigaq region. Watching these settlements (and presumably more artifacts of cultural value to the community) literally fall into the sea begs the question of why more has not been done to preserve and protect this landscape and its residents?

Located on the national register of historic places (#66000157) and as a National Park Service (NPS) National Historic Landmark, the Ipiutak site that spans most of the peninsula has been repeatedly identified as having national value.[8] It also appears that the federal government is well aware of the coastal erosion and structure loss that has been occurring at Point Hope, as both the state and federal government have attempted small emergency responses in the area. The NPS is no stranger to the need for climate change responses in order to protect sites of cultural value. Large and elaborate reports have been generated, supported by large numbers of scholars and institutions, to assess the risks to places such as Jamestown and Point Lookout.[9] The 1999 moving of the Cape Hatteras lighthouse is another example of the use of large amounts of federal money to protect something that is deemed of cultural value from an eroding shoreline. More specifically, 11.8 million dollars was spent to move the brick lighthouse and its

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6 Sakakibara, Chie. Our Home is Drowning: Iñupiat Storytelling and Climate Change in Point Hope, Alaska. *Geographical Review* 89. No 4 (Oct 2008) 461.

7 http://www.north-slope.org/our-communities/point-hope

8 https://www.nps.gov/places/ipiutak-site.htm
https://nationalregisterofhistoricplaces.com/AK/north+slope/state.html

9 https://www.usgs.gov/news/featured-story/safeguarding-our-cultural-past-future-climate-change-stories-cape-lookout

associated structures less than 3000 feet inland.[10] And this cost came as a last resort after several expensive attempts at shoreline stabilization through groins and other coastal infrastructure.[11]

To be clear, Federal and state governments have been spending considerable amounts of money in Northwestern Alaska. The construction and relocation of the present-day town of Point Hope is no exception to this. And a stop-over flight in Kivalina, a small community 70 miles southeast of Point Hope, displays the newly constructed evacuation road snaking over seven miles inland, the foundation of a community relocation project estimated at costing over 100 million dollars. But the projects in Point Hope in the 70's and currently underway in Kivalina are not about cultural protection, they are about the state and federal governments taking seriously their responsibility to protect the lives of their citizens, although many would argue they are failing at this responsibility as well.[12]

From our perspective, the time to showcase the value and importance of our indigneous peoples, cultures, and beliefs is long overdue. And while there are some feel-good connections between the more sensitive and contextual engineering strategies associated with Engineering with Nature and what we may think we understand as indegineous land management practices, we must not conflate the two. We also must admit that the scale of landscape change being faced in places such as Point Hope may require investments and strategies that extend far beyond strategic ecologically-inspired actions of coastal management (NNBF). And while we believe that this is not the case for this exercise, we must ensure that indigeous communities are not seen as the test subjects for coastal strategies that would be seen as unacceptable elsewhere. We believe this is not the case considering all of the strategies proposed here have been proposed elsewhere and in non-indigneous contexts. But just as those previous studies, what is presented here is intended to describe a range of possible NNBF strategies, not to preclude the consideration of other strategies.

And while the landscape around Point Hope has been in continual transformation for all of recorded history, there is no doubt that the changes that have been experienced recently are likely without precedent. The temperatures of the Artic have never been warmer, and with those warm temperatures comes reduced ice coverage that protects the shoreline during most of the year. Warmer temperatures also have melted the permafrost used for the sigluaqs and increased the erodibility of the soil. It has been speculated that this unique beach ridge landscape was likely created not because of slow shifts in water level over the centuries, but due to more stochastic storm events.[13] Assuming there is

10 https://www.nps.gov/caha/learn/historyculture/themovefaqs.htm

11 https://www.nps.gov/caha/learn/historyculture/movingthelighthouse.htm

12 https://www.hcn.org/issues/52.4/indigenous-affairs-justice-tribal-nations-demand-response-to-climate-relocation

13 Mason, Owen K. and Ludwig, Stefanie L. Resurrecting Beach Ridge Archaeology: Parallel Depositional Records from St. Lawrence Island and Cape Krusenstern, Western Alaska. *Geoarchaeology: An International Journal*, 5. No 4. 349-373 (1990) 370.

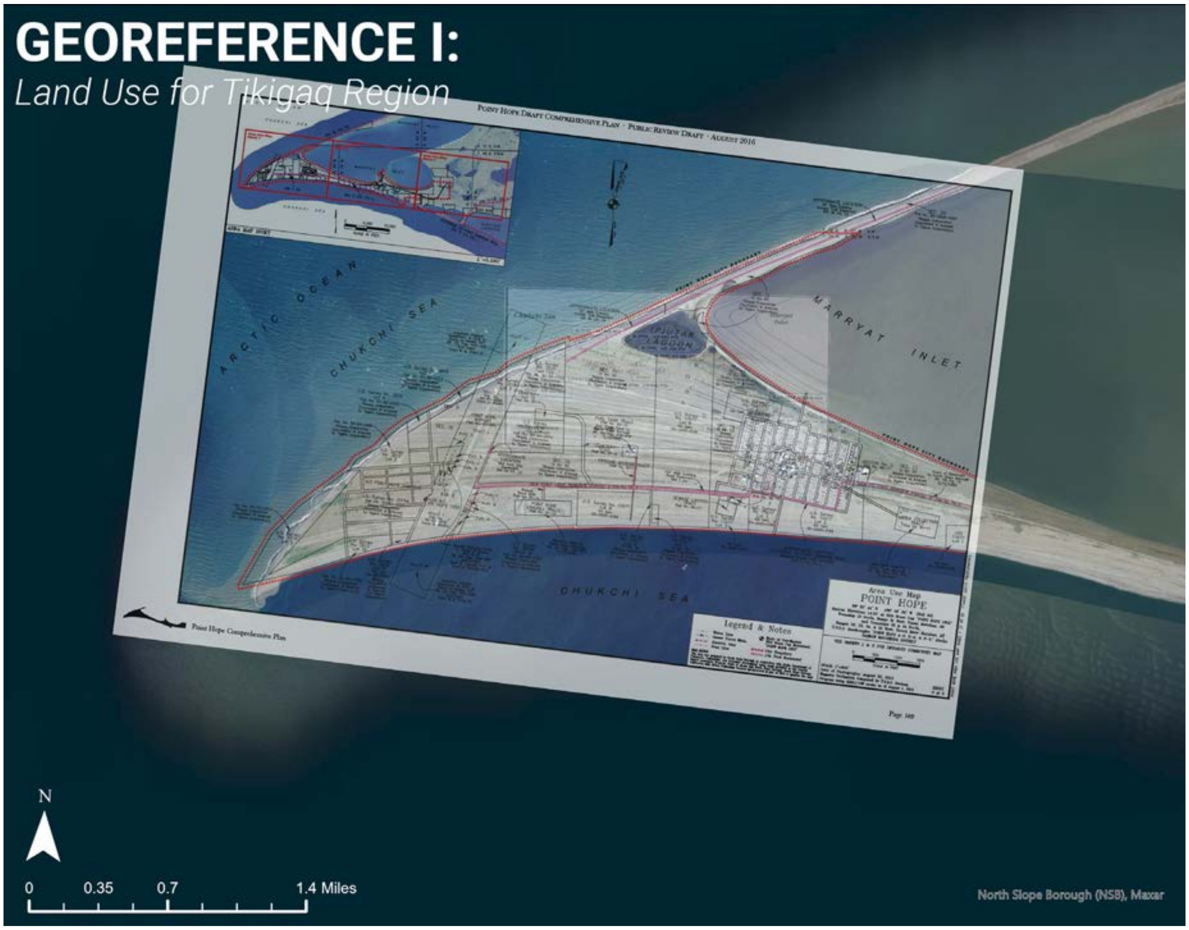
time to wait is a tremendous gamble here, as it will likely be a dramatic storm event that causes the complete loss of the cultural landscape at Point Hope and also potentially lives of the local community. While it is the subject of this report, whether or not NNBF is an appropriate strategy here is of less importance than the fact that a concerted infrastructural effort is highly needed.

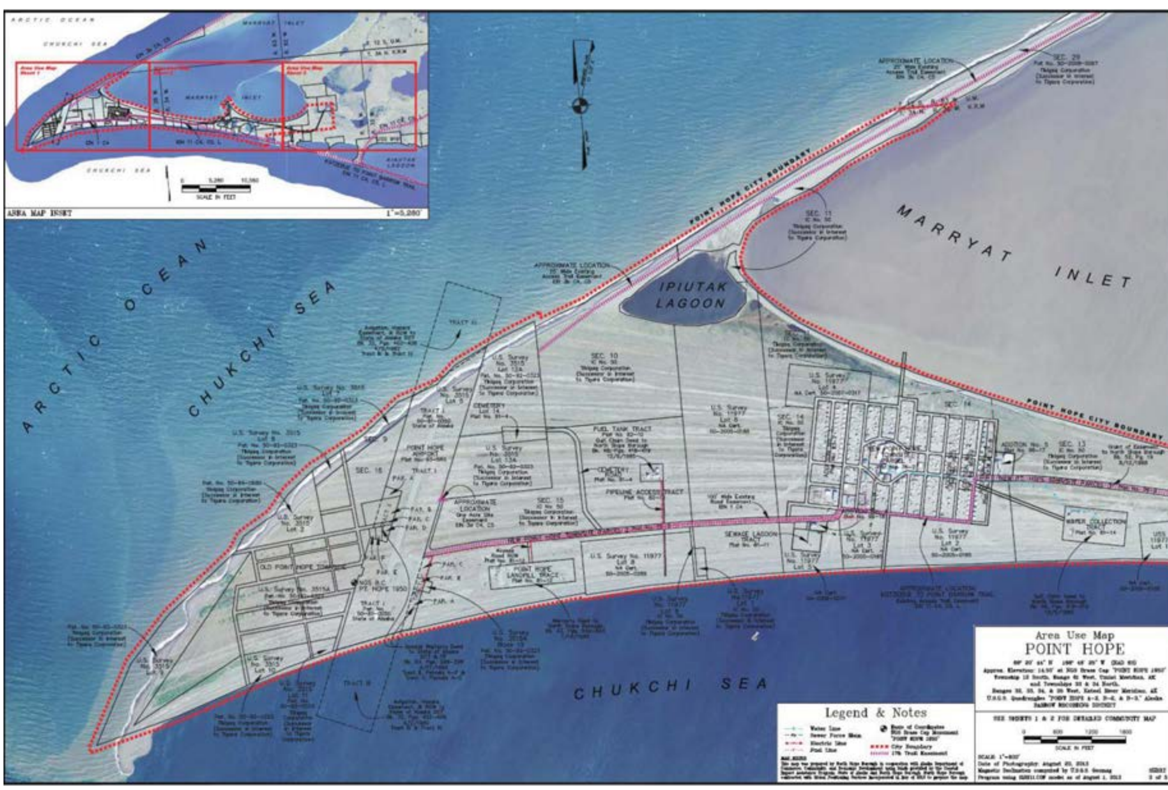
1.2.1. Georeferencing

This exercise attempted to pull from available resources in an attempt to collocate the positions of important physical elements in and around Point Hope. This survey looks specifically a human-constructed or managed elements and does not attempt to describe the ecological conditions found on the Peninsula. While the location of many of these elements would need to be field verified, this survey attempted to locate important cultural features such as dwelling structures (both current and historical); other architectural or infrastructural elements such as community facilities, fuel storage, ect; and subsurface landscape features such as ice cellars (Sigluaqs) and cemeteries.

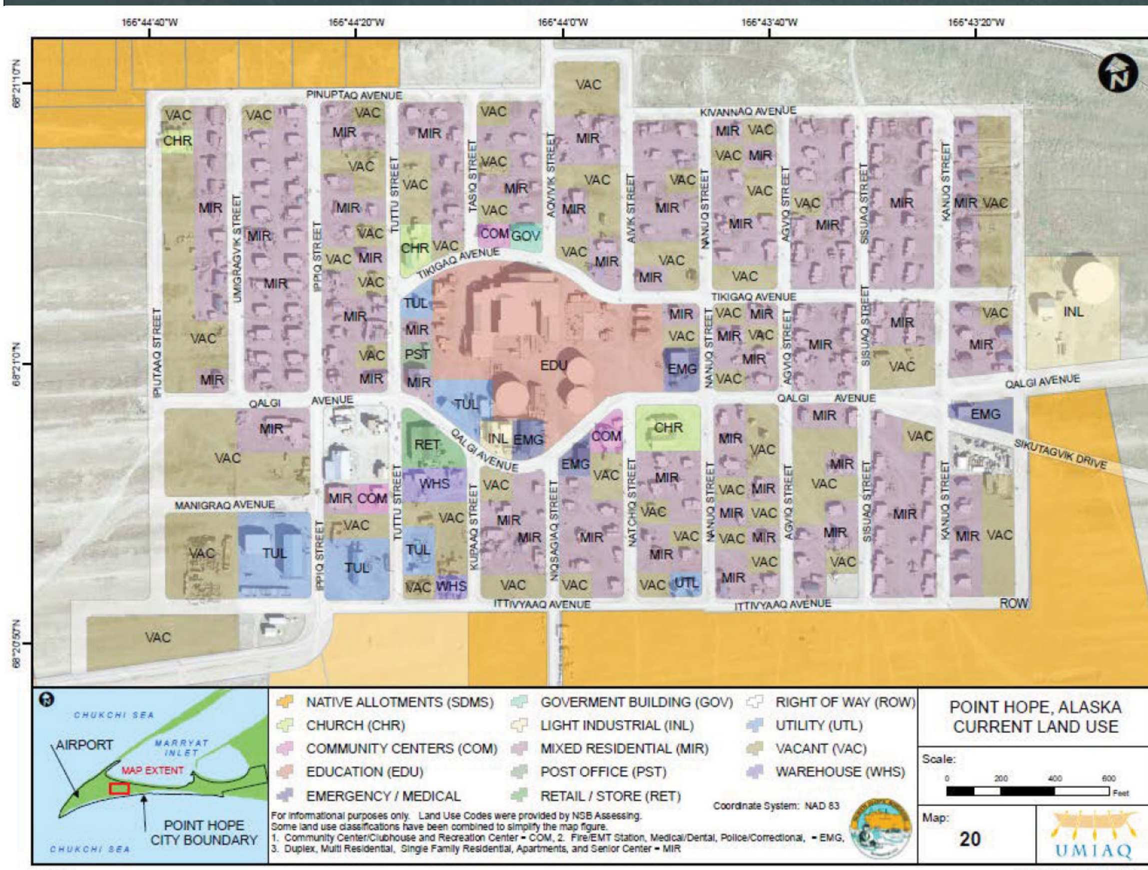
Method
Existing maps and aerial photographs were georefrenced using ESRI ArcPro to commonly co-locate the elements of study. For clarity these maps are presented individually on the following pages, however, they could easily be collectively visualized as needed.

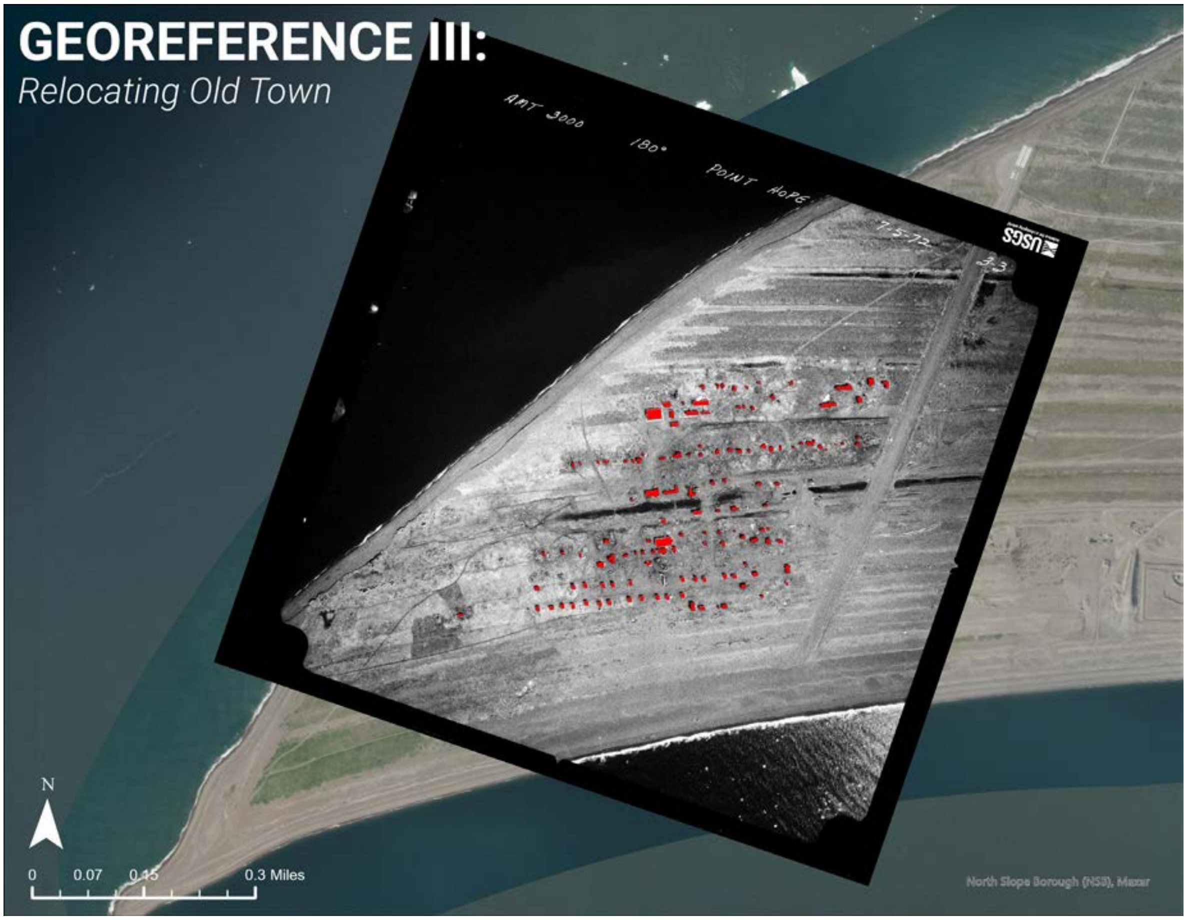
Image I: Land Ownership map from the Point Hope Comprehensive Plan
Image II: City Zoning map from the Point Hope Comprrhansive Plan
Image III:USGS Aerial photograph from 1972
Image IV and V: Scanned maps from the Larsen and Rainey Report

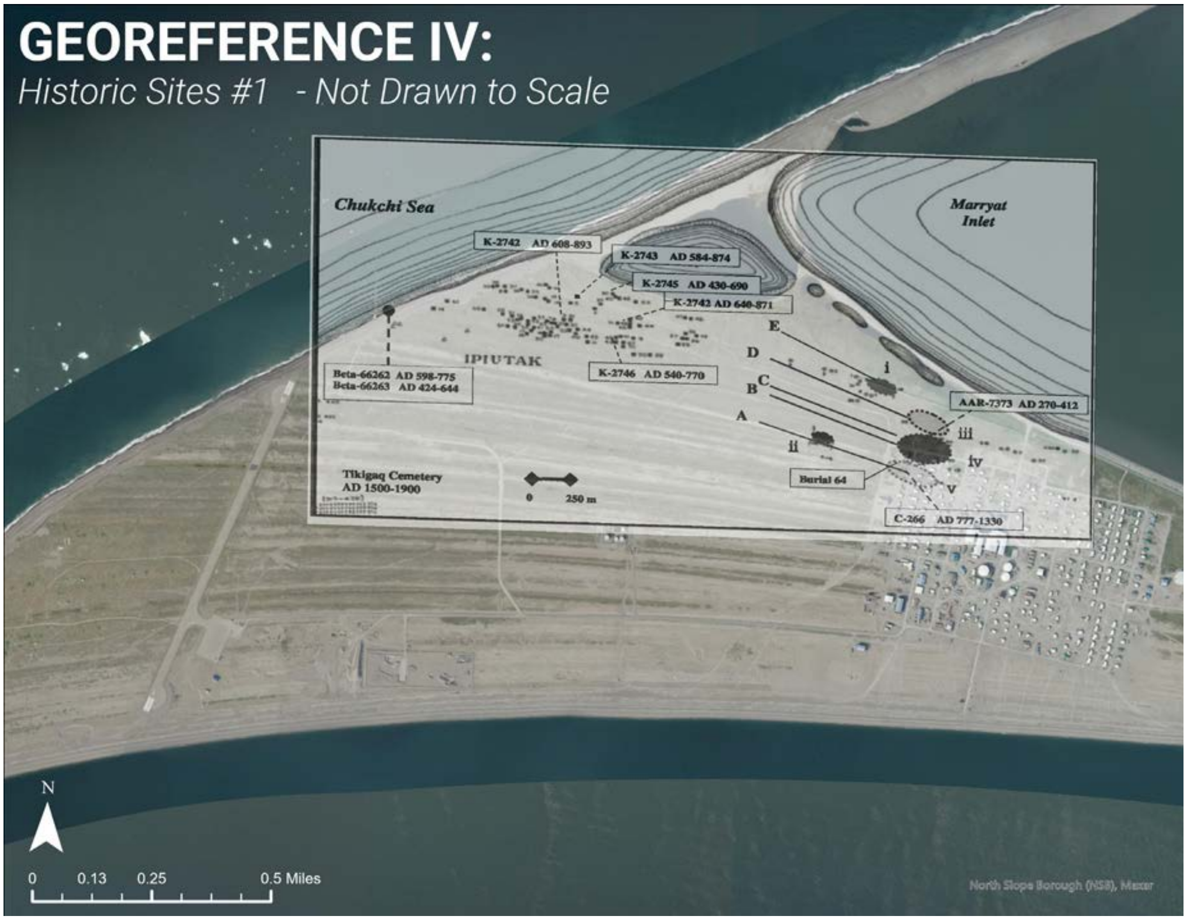

GEOREFERENCE I:
Land Use for Tikigaq Region
ARCTIC OCEAN
CHUKCHI SEA
MARRYAT INLET
CHUKCHI SEA
N
0 0.35 0.7 1.4 Miles
North Slope Borough (NSB), Maxar

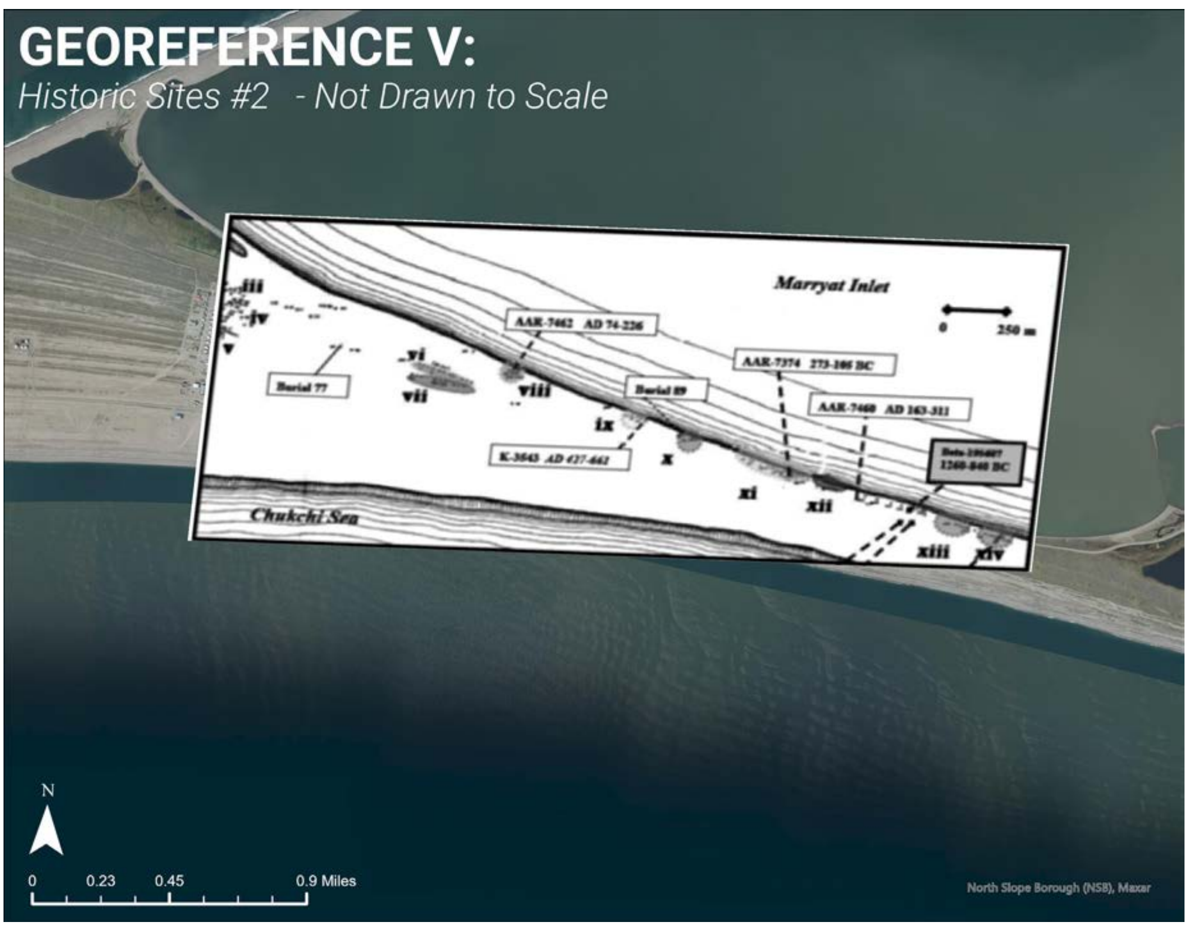

ARCTIC OCEAN
CHUKCHI SEA
IPIUTAK LAGOON
MARRYAT INLET
POINT HOPE CITY BOUNDARY
CHUKCHI SEA
Legend & Notes
Area Use Map
POINT HOPE

GEOREFERENCE II:
Land Use for Tikigaq Town




GEOREFERENCE III:
Relocating Old Town
AMT 3000
180°
POINT HOPE
7-5-72
USGS
N
0
0.07
0.15
0.3 Miles
North Slope Borough (NSB), Maxar


GEOREFERENCE IV:
Historic Sites #1 - Not Drawn to Scale
Chukchi Sea
Marryat Inlet
K-2742 AD 608-893
K-2743 AD 584-874
K-2745 AD 430-690
K-2742 AD 640-871
IPIUTAK
K-2746 AD 540-770
Beta-66262 AD 598-775
Beta-66263 AD 424-644
E
D
C
B
A
i
ii
iii
iv
v
AAR-7373 AD 270-412
Burial 64
C-266 AD 777-1330
Tikigaq Cemetery
AD 1500-1900
0 250 m
N
0 0.13 0.25 0.5 Miles
North Slope Borough (NSB), Maxar


GEOREFERENCE V:
Historic Sites #2 - Not Drawn to Scale
Marryat Inlet
0 250 m
iii
iv
v
vi
vii
viii
ix
x
xi
xii
xiii
xiv
Burial 77
AAR-7462 AD 74-226
AAR-7374 273-106 BC
AAR-7460 AD 163-311
Chukchi Sea
N
0 0.23 0.45 0.9 Miles
North Slope Borough (NSB), Maxar

1.2.2. Sectional Studies

This exercise assembles a collection of landscape sections, stretching from the water through various areas of interest. The sections are intended to show the vertical locations of various elements, and the general topographic conditions of the larger landscape. The locations of the sections can found on the Key Plan below.

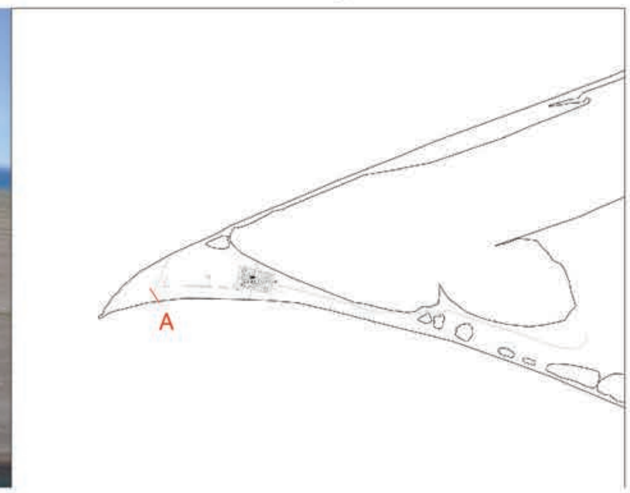
Method

Recent Lidar data collected by the USACE was used in ESRI ArcPro to establish elevations of the study area. Section profiles were then taken from ArcPro at the indicated location and brought into Adobe Illustrator in order to generate a vertical exaggeration in the sections and add addition detail. Both exaggerated and true elevations are included in the following pages.

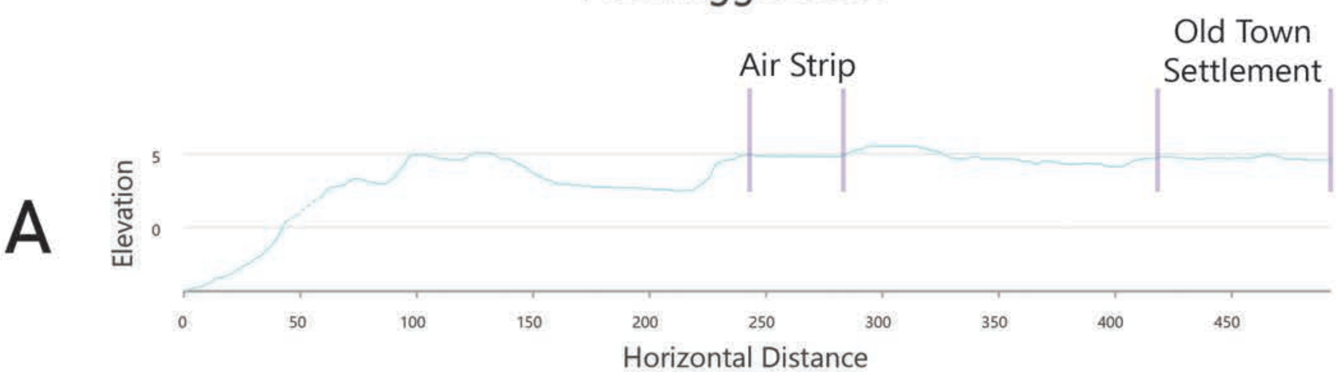
SECTION A:
Old Town and Low Points at Runway

Aerial Photograph

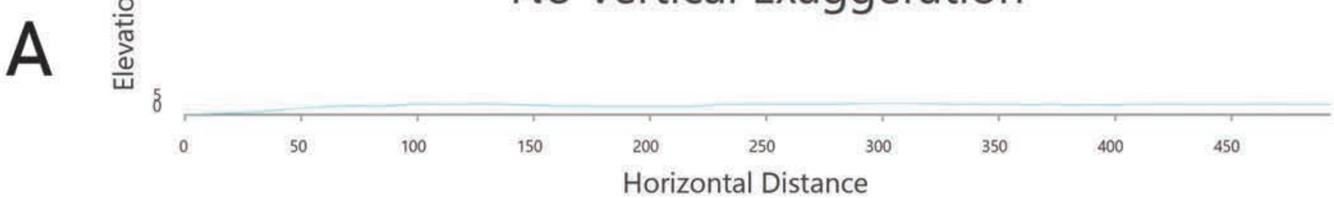
Key



10x Exaggeration



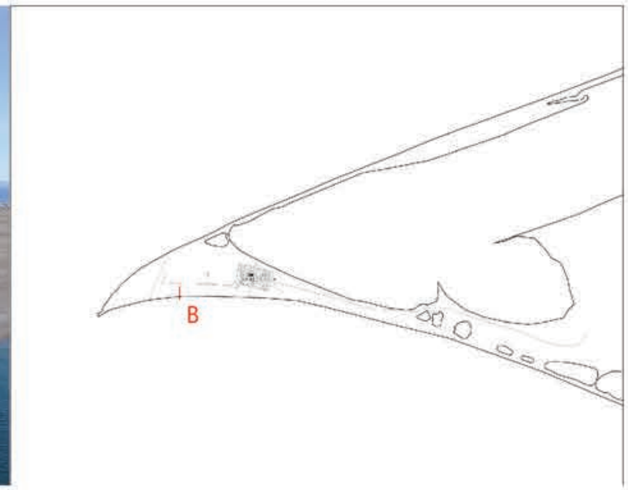
No Vertical Exaggeration



SECTION B:
Sea to Tikigaq Landfill

Aerial Photograph

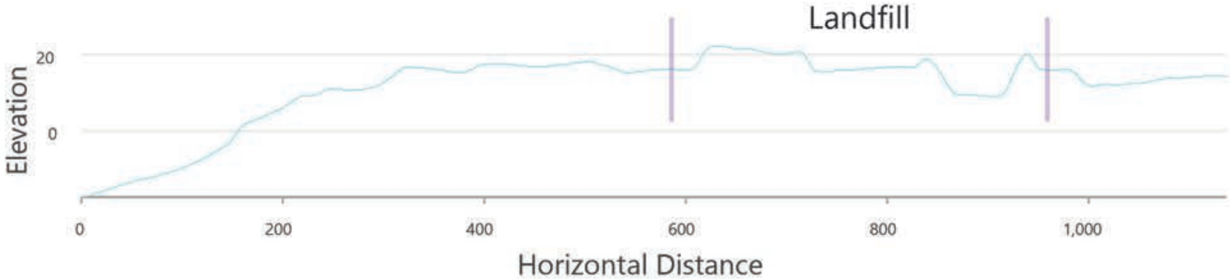
Key



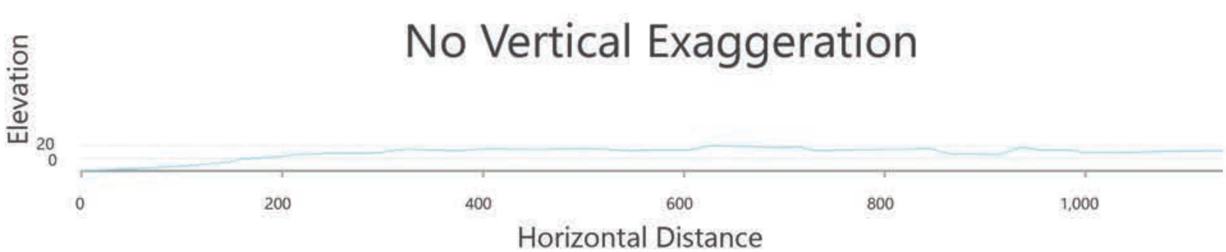
B

10x Exaggeration

B



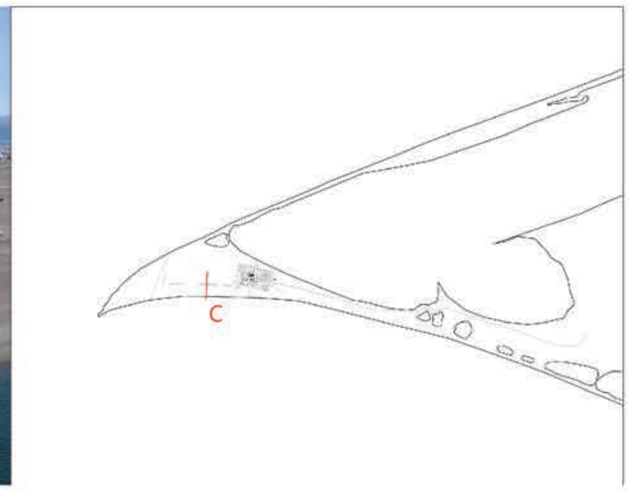
B



SECTION C:
Sea to Fuel Extraction

Aerial Photograph

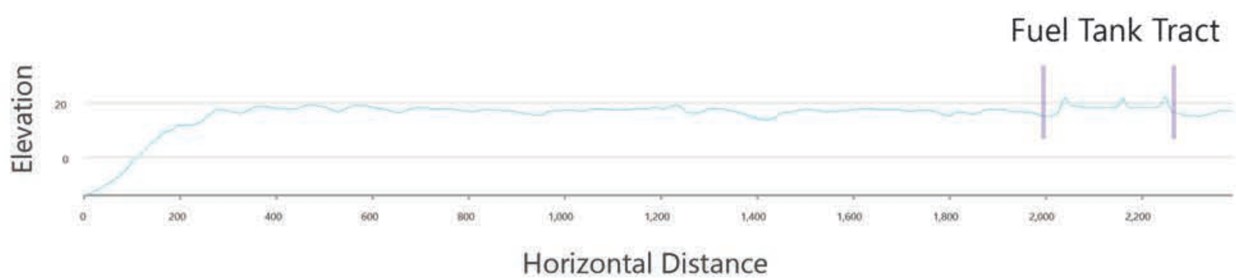
Key



C

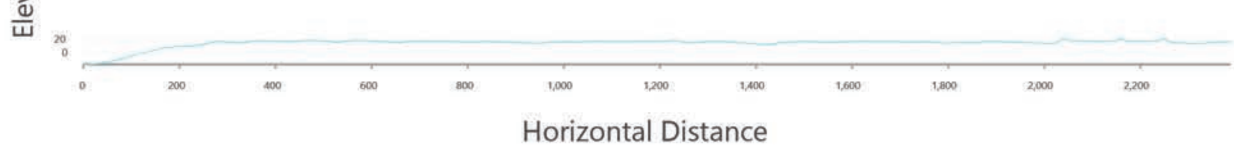
10x Exaggeration

C



No Vertical Exaggeration

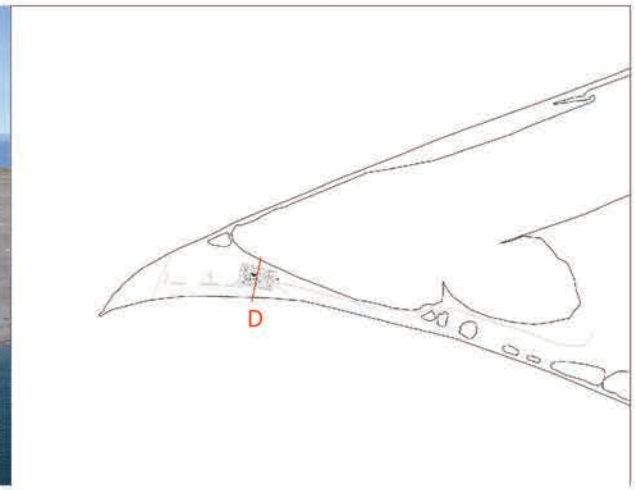
C



SECTION D:
Sea through Community and Oil

Aerial Photograph

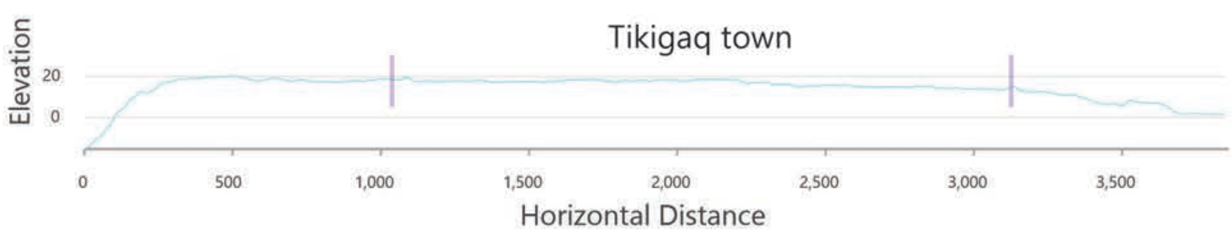
Key



D

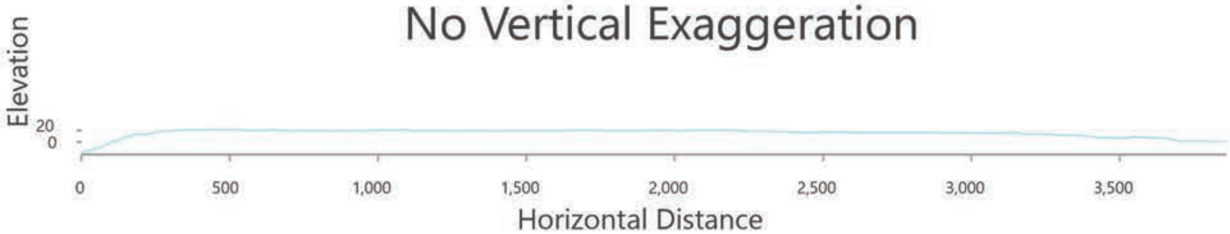
10x Exaggeration

D



No Vertical Exaggeration

D



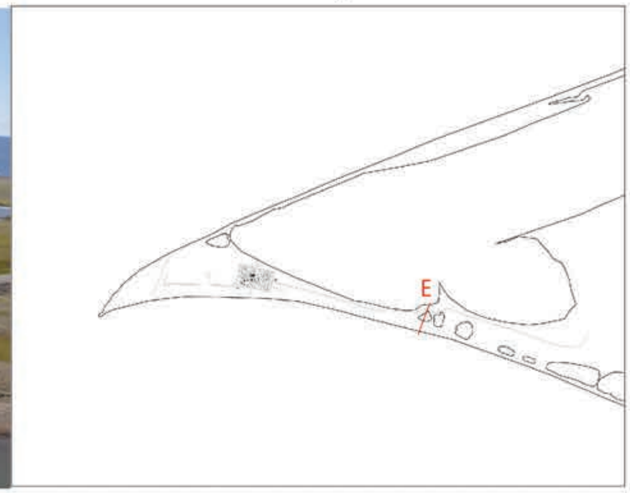
SECTION E:

Evacuation Route to High Ground #1

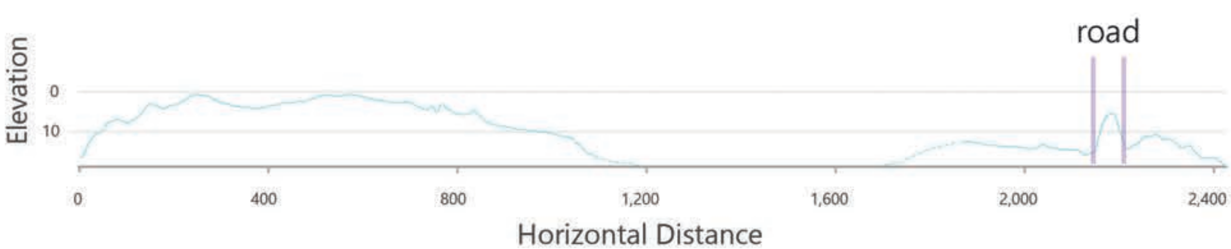
Aerial Photograph

E

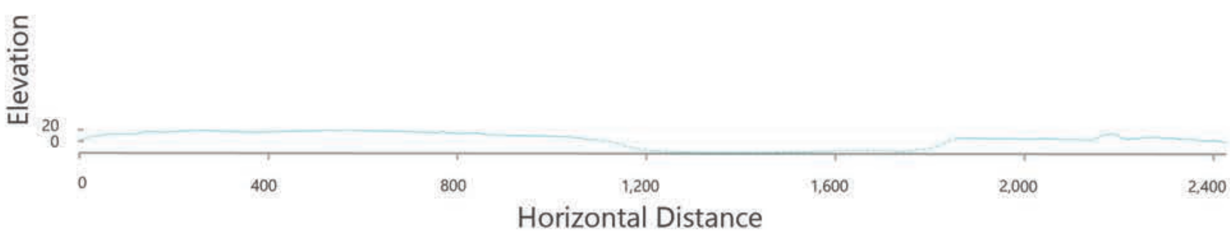
Key



E



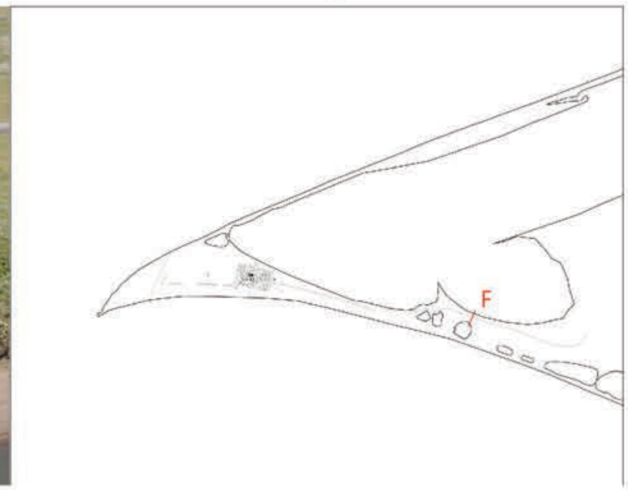
E



SECTION F:
Evacuation Route to High Ground #2

Aerial Photograph

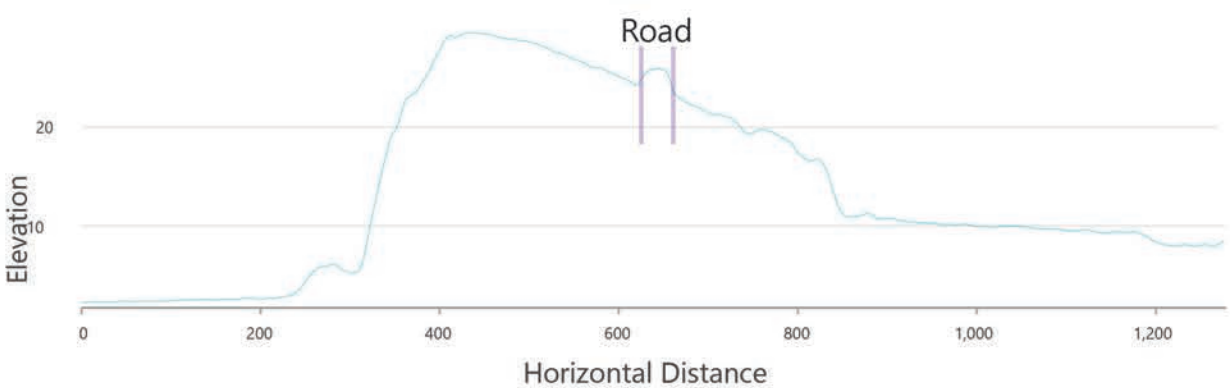
Key



F

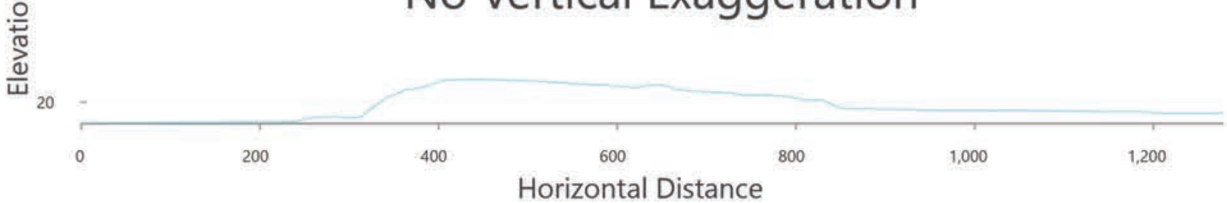
10x Exaggeration

F



No Vertical Exaggeration

F

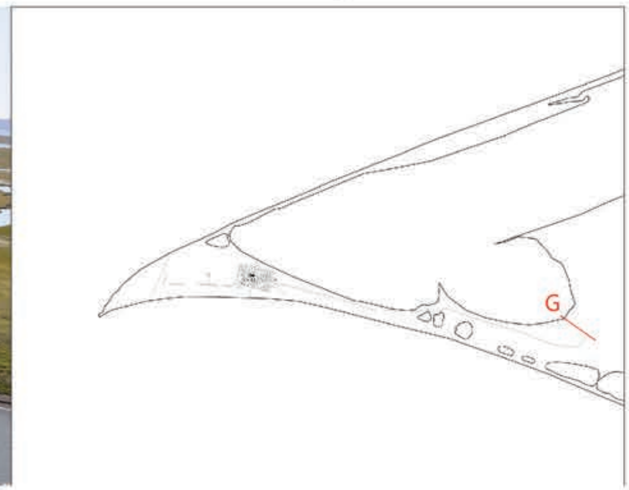


SECTION G:
Evacuation Route to High Ground #3

Aerial Photograph

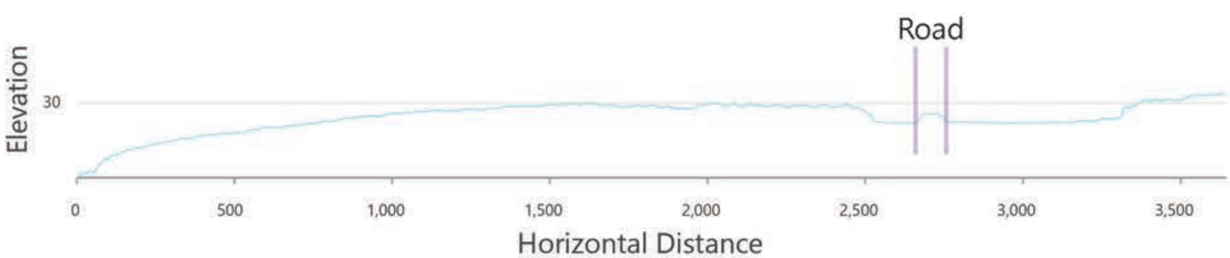
G

Key



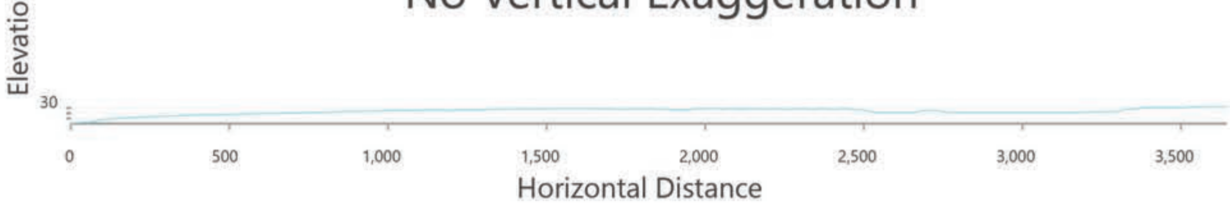
10x Exaggeration

G



No Vertical Exaggeration

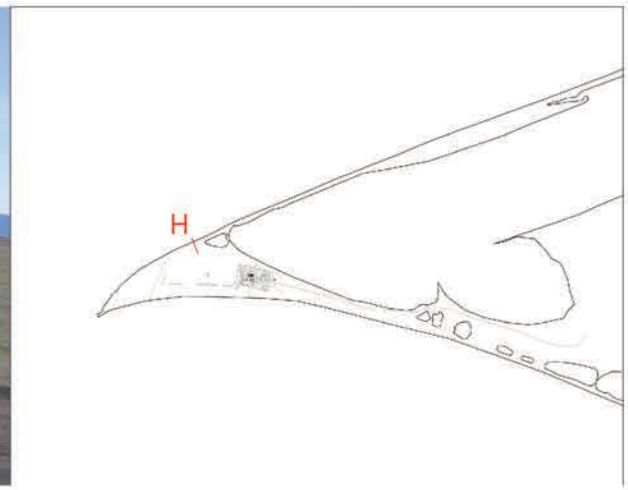
G



SECTION H:
Sea to Ice Cellars

Aerial Photograph

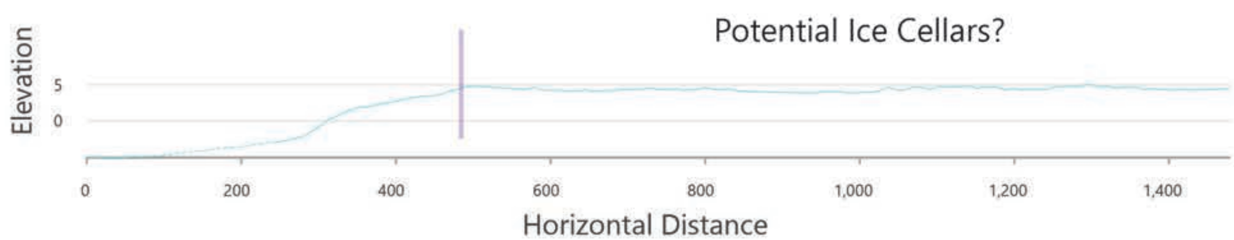
Key



H

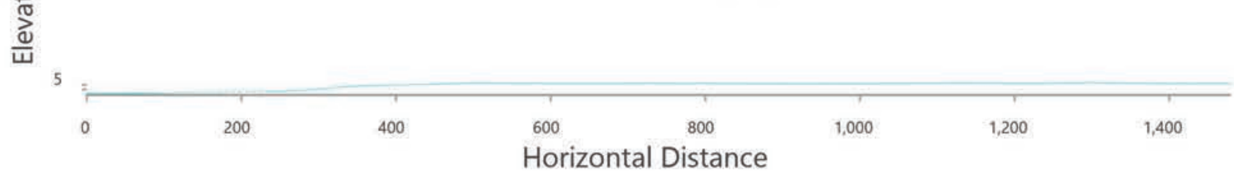
10x Exaggeration

H



No Vertical Exaggeration

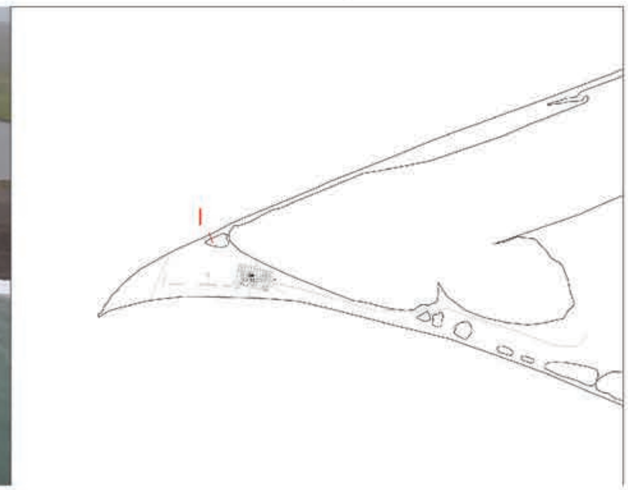
H



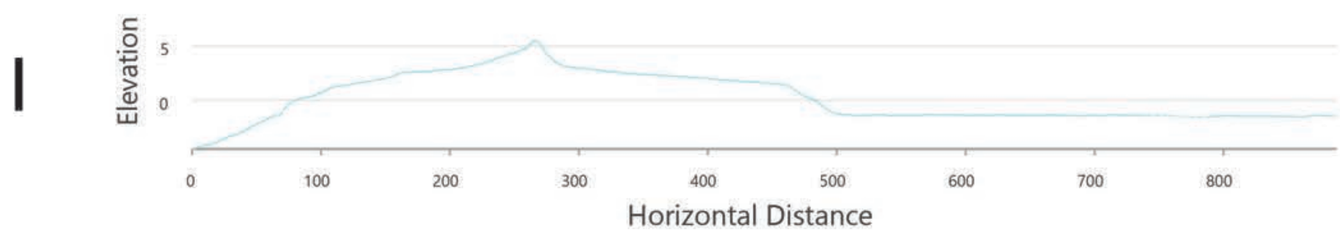
SECTION I:
Sea to Lagoon

Aerial Photograph

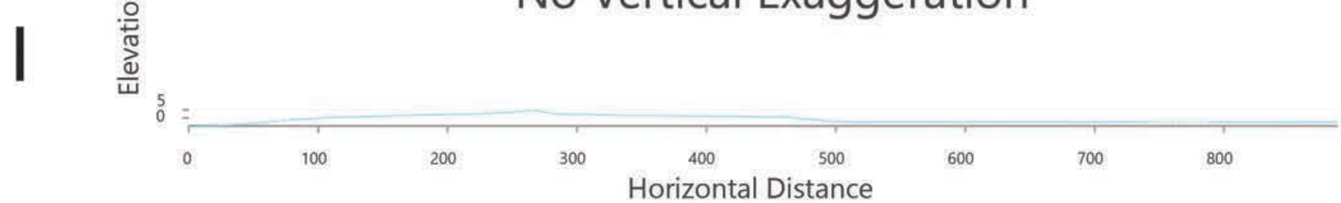
Key



10x Exaggeration



No Vertical Exaggeration



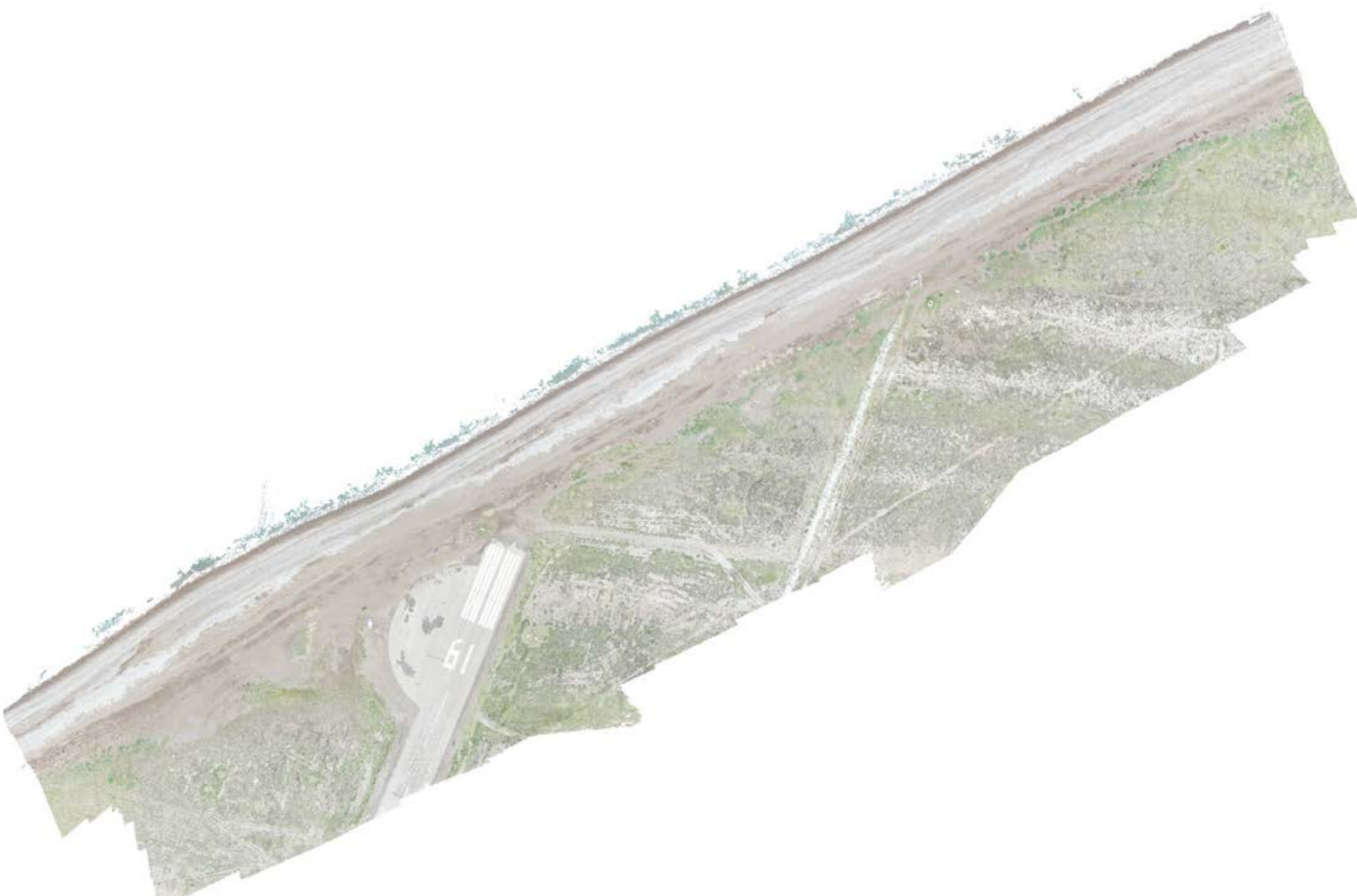

19

1.2.3. Drone/RTK Survey Report

Agisoft Metashape

Processing Report

15 December 2021



Survey Data

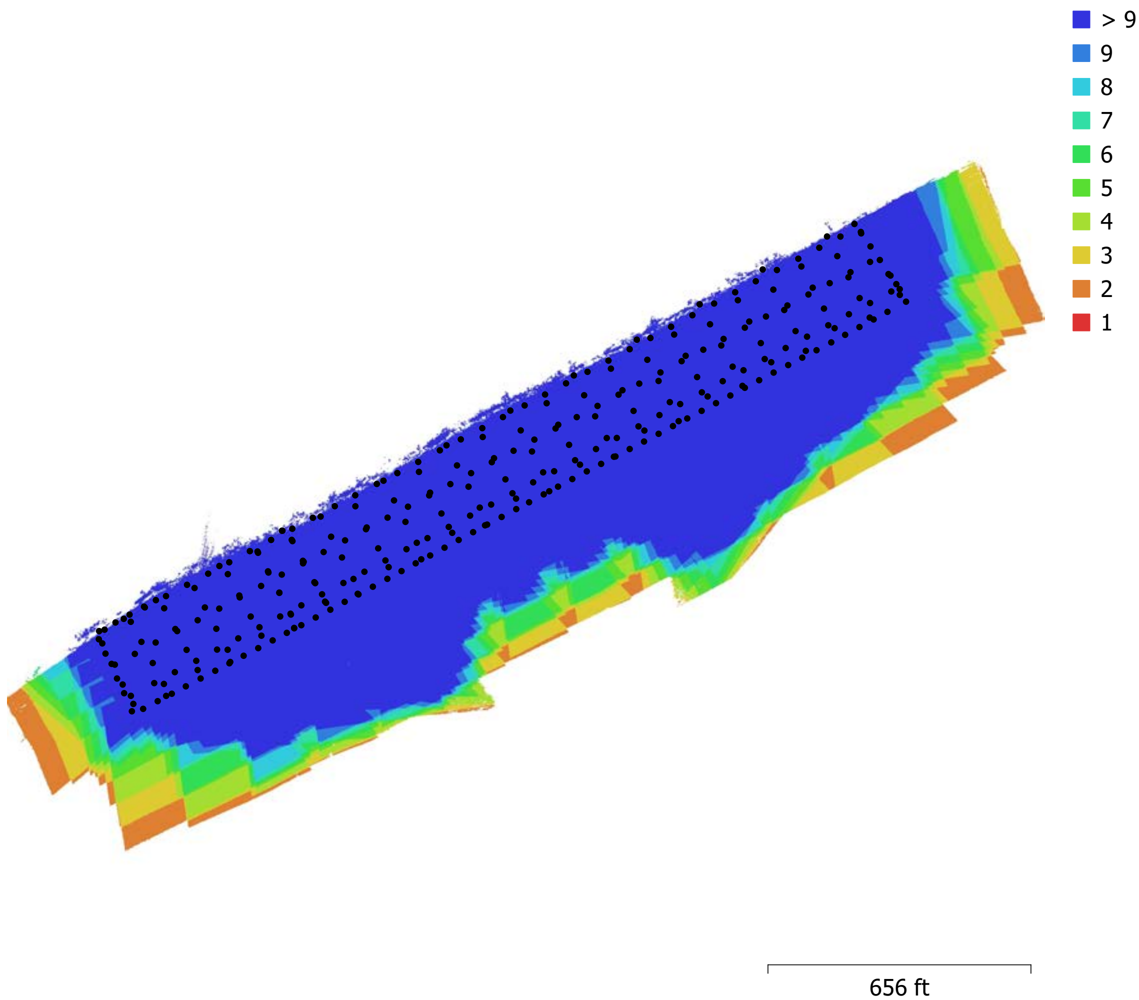


Fig. 1. Camera locations and image overlap.

Number of images:	304	Camera stations:	304
Flying altitude:	302 ft	Tie points:	110,337
Ground resolution:	0.101 ft/pix	Projections:	1,009,910
Coverage area:	1.52e+06 ft²	Reprojection error:	0.811 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
Test_Pro (4.386mm)	4000 x 3000	4.386 mm	1.58 x 1.58 µm	No

Table 1. Cameras.

Camera Calibration

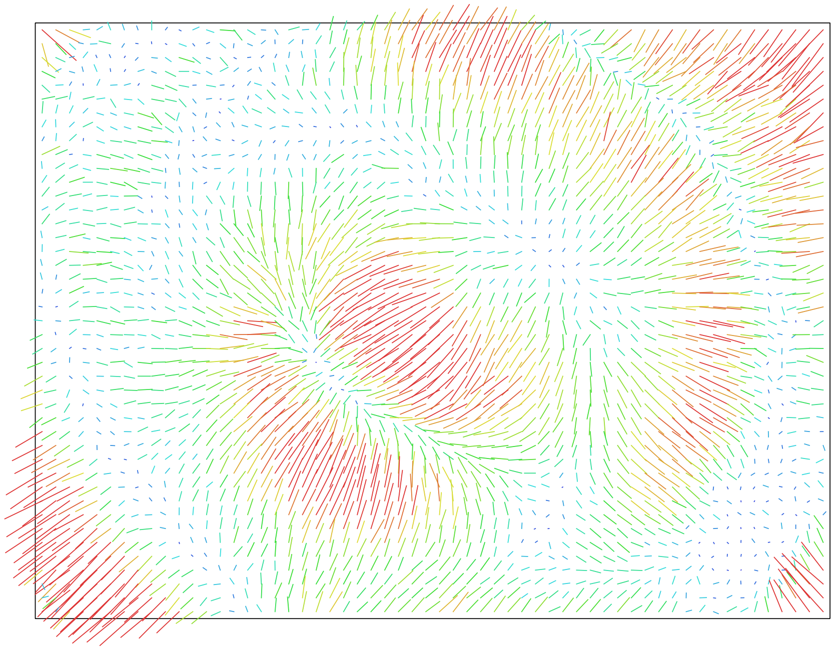


Fig. 2. Image residuals for Test_Pro (4.386mm).

Test_Pro (4.386mm)

304 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4000 x 3000**	**4.386 mm**	**1.58 x 1.58 µm**

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	**2895.91**	0.098	1.00	0.02	-0.92	-0.11	0.11	-0.11	0.02	0.04
Cx	**3.01756**	0.025		1.00	0.00	-0.02	0.02	-0.01	0.90	0.04
Cy	**-54.4767**	0.055			1.00	0.01	-0.03	0.05	0.00	0.25
K1	**-0.0316482**	3.5e-05				1.00	-0.97	0.91	-0.03	-0.09
K2	**0.0392502**	0.00011					1.00	-0.98	0.02	0.03
K3	**-0.0304716**	0.0001						1.00	-0.02	-0.03
P1	**-0.000202099**	2.6e-06							1.00	0.05
P2	**-0.00192498**	2.2e-06								1.00

Table 2. Calibration coefficients and correlation matrix.

Ground Control Points

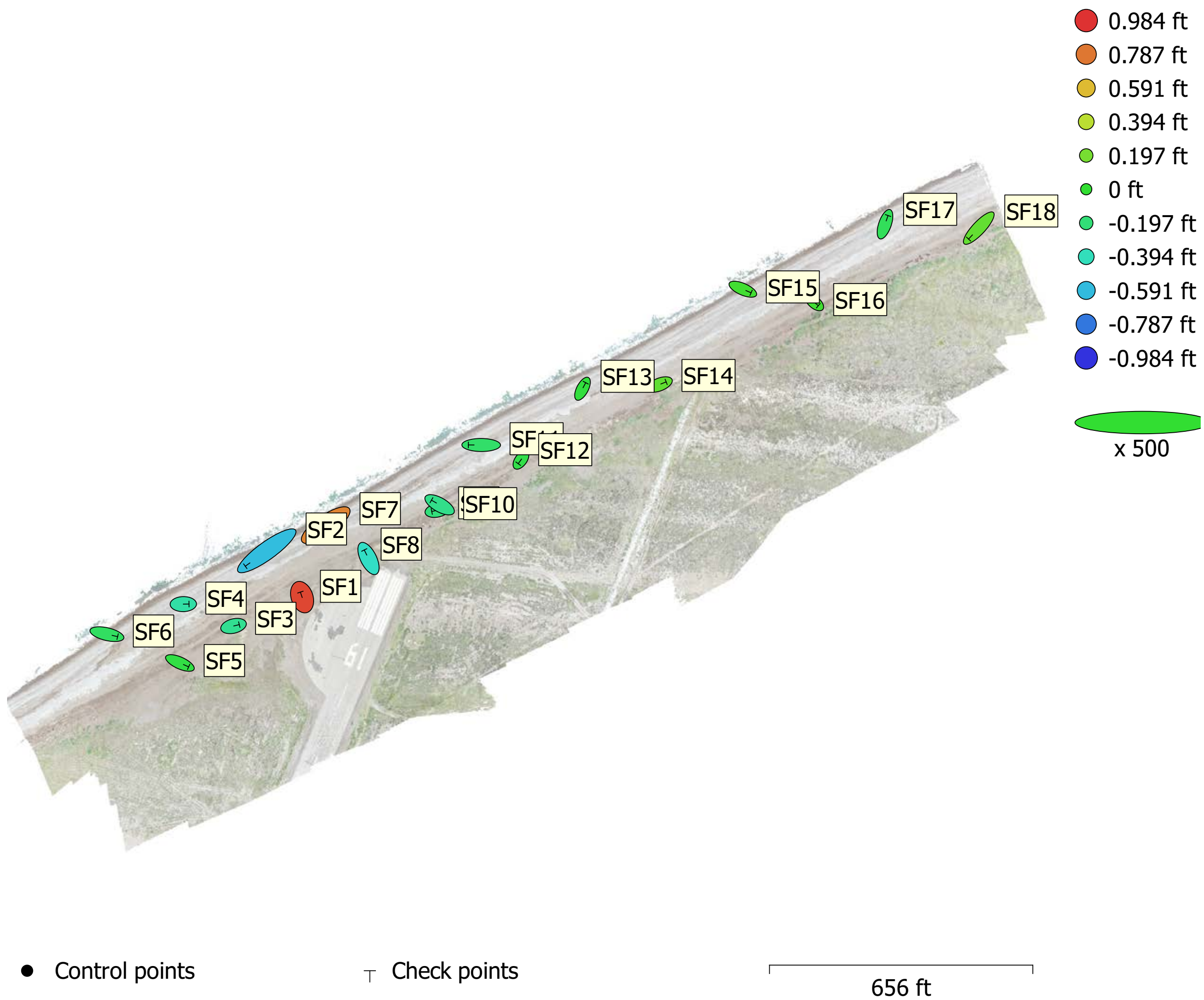


Fig. 3. GCP locations and error estimates.

Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.

Estimated GCP locations are marked with a dot or crossing.

Count	X error (ft)	Y error (ft)	Z error (ft)	XY error (ft)	Total (ft)
18	0.0910196	0.0653628	0.360284	0.112057	0.377308

Table 3. Check points RMSE.

X - Longitude, Y - Latitude, Z - Altitude.

Label	X error (ft)	Y error (ft)	Z error (ft)	Total (ft)	Image (pix)
SF1	-0.0167011	0.0497873	0.925791	0.92728	0.619 (45)
SF2	-0.214014	-0.153819	-0.587161	0.6436	0.821 (45)
SF3	0.0569865	0.013998	-0.271575	0.277843	0.678 (38)
SF4	0.0566223	0.000970883	-0.33006	0.334883	0.648 (30)
SF5	0.0871365	-0.0388435	-0.0528712	0.109073	0.636 (26)
SF6	0.106656	-0.0249178	-0.132923	0.172235	0.703 (17)
SF7	-0.154942	-0.107686	0.750951	0.774293	0.862 (50)
SF8	-0.042093	0.0848896	-0.42193	0.432439	0.834 (50)
SF9	-0.0563168	-0.0119284	-0.20517	0.213093	0.688 (46)
SF10	-0.081378	0.0456814	-0.251287	0.268057	0.756 (46)
SF11	-0.127732	0.000737006	-0.157017	0.202411	1.074 (50)
SF12	-0.0272905	-0.0374346	-0.064368	0.0793055	0.836 (47)
SF13	0.0319078	0.0605386	-0.0334425	0.0761671	0.636 (57)
SF14	0.0655877	0.0255394	0.133128	0.150589	0.572 (52)
SF15	0.0823458	-0.0355616	0.044221	0.100005	0.713 (42)
SF16	0.0395485	-0.0331033	0.0415783	0.066247	0.598 (35)
SF17	0.0303441	0.0864367	-0.115077	0.147088	0.477 (14)
SF18	-0.101984	-0.108873	0.140433	0.204879	0.541 (5)
Total	**0.0910196**	**0.0653628**	**0.360284**	**0.377308**	**0.745**

Table 4. Check points.

X - Longitude, Y - Latitude, Z - Altitude.

Digital Elevation Model

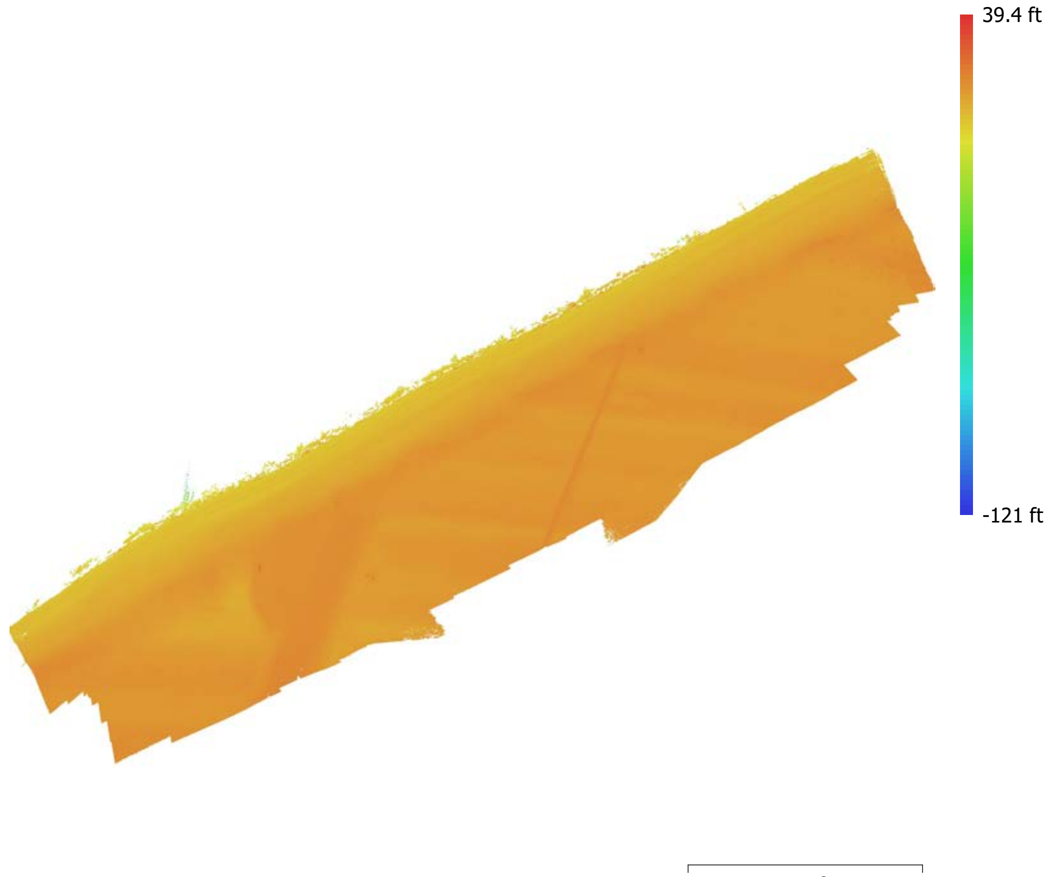


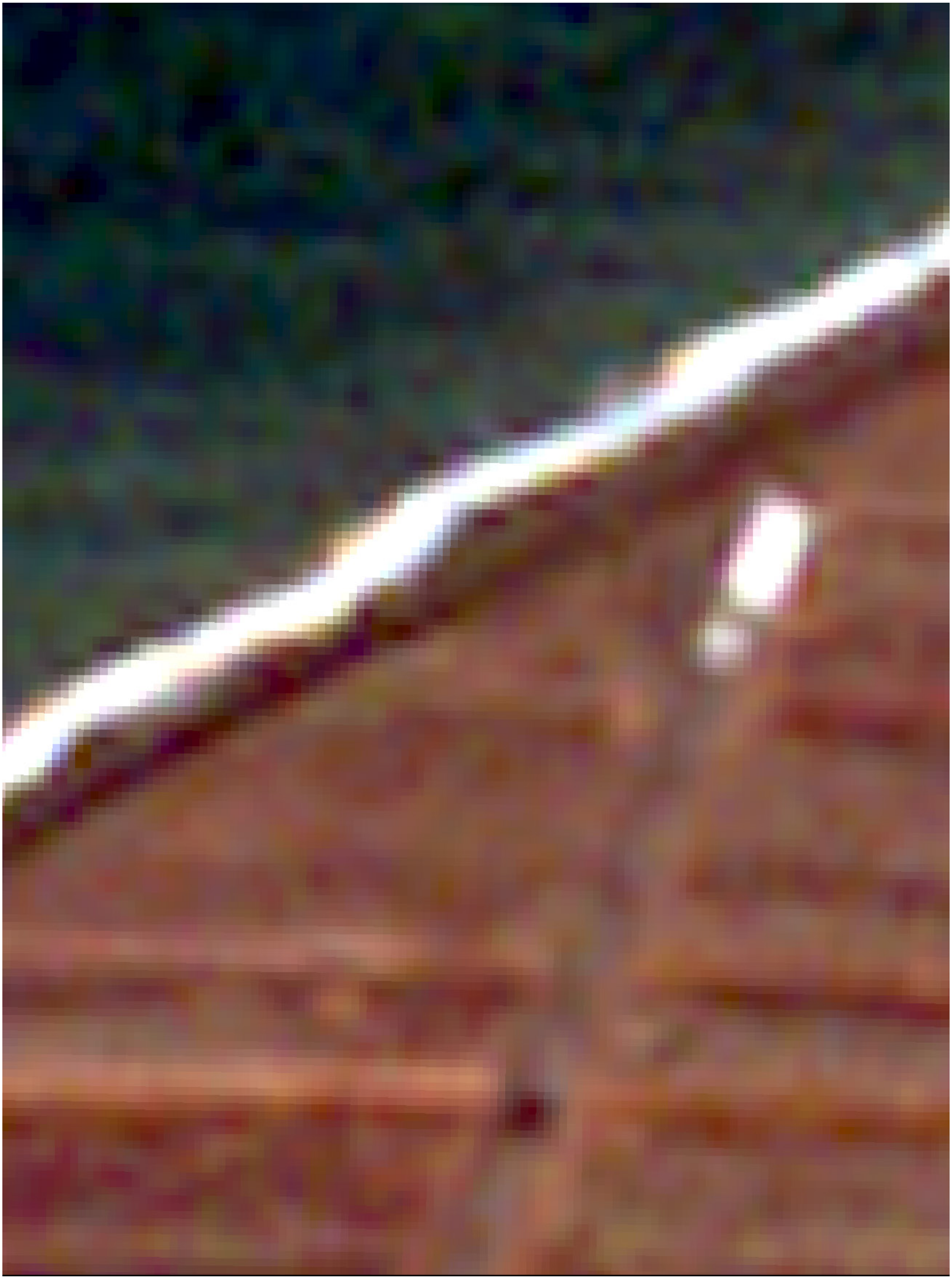
Fig. 4. Reconstructed digital elevation model.

Resolution:	unknown
Point density:	unknown

Processing Parameters

General	
Cameras	304
Aligned cameras	304
Markers	18
Coordinate system	WGS 84 (EPSG::4326)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	110,337 of 142,832
RMS reprojection error	0.324231 (0.811457 pix)
Max reprojection error	3.06768 (12.4615 pix)
Mean key point size	2.50004 pix
Point colors	3 bands, uint8
Key points	999.64 MB
Average tie point multiplicity	10.2217
Alignment parameters	
Accuracy	High
Generic preselection	Yes
Reference preselection	Source
Key point limit	40,000
Key point limit per Mpx	1,000
Tie point limit	4,000
Exclude stationary tie points	Yes
Guided image matching	No
Adaptive camera model fitting	No
Matching time	7 minutes 51 seconds
Matching memory usage	1.19 GB
Alignment time	9 minutes 59 seconds
Alignment memory usage	231.98 MB
Optimization parameters	
Parameters	f, cx, cy, k1-k3, p1, p2
Adaptive camera model fitting	No
Optimization time	15 seconds
Date created	2021:10:22 18:54:20
Software version	1.7.4.13028
File size	30.83 MB
Depth Maps	
Count	304
Depth maps generation parameters	
Quality	High
Filtering mode	Aggressive
Max neighbors	40
Processing time	3 hours 31 minutes
Memory usage	8.34 GB
Date created	2021:10:22 22:57:26
Software version	1.7.4.13028
File size	1.04 GB
Dense Point Cloud	
Points	37,426,456
Point colors	3 bands, uint8
Depth maps generation parameters	

Quality	High
Filtering mode	Aggressive
Max neighbors	40
Processing time	3 hours 31 minutes
Memory usage	8.34 GB
Dense cloud generation parameters	
Processing time	58 minutes 15 seconds
Memory usage	5.88 GB
Date created	2021:10:22 23:55:42
Software version	1.7.4.13028
File size	553.89 MB
System	
Software name	Agisoft Metashape Professional
Software version	1.7.4 build 13028
OS	Windows 64 bit
RAM	31.81 GB
CPU	Intel(R) Xeon(R) CPU E3-1535M v6 @ 3.10GHz
GPU(s)	Intel(R) HD Graphics P630
	Quadro P4000



1.3.1a. Multi-Spectral Coastlines

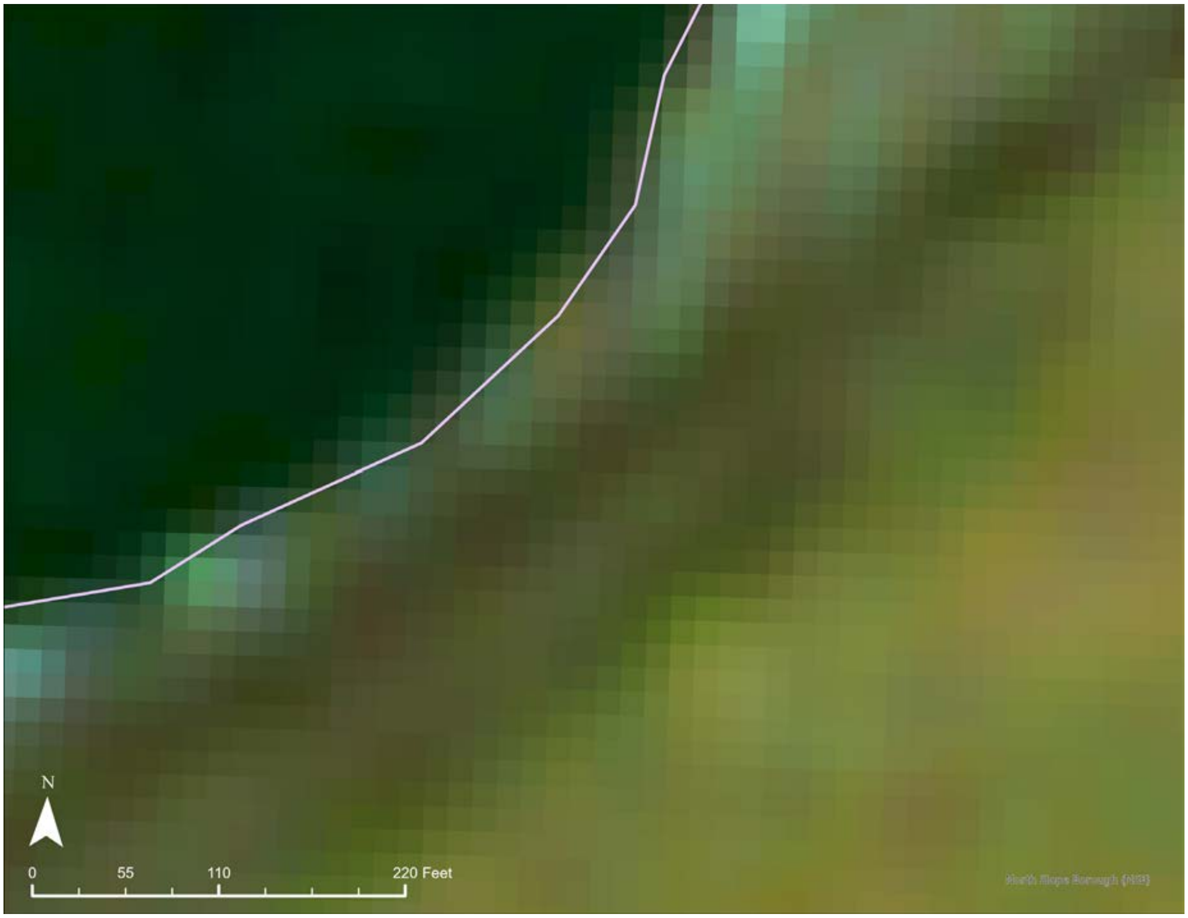
For this exercise, our team collected a wide range of multi-spectral imagery from the ESA's Sentinel 2 program in order to test the possibility of using this data to compare annual shorelines from 2018 - 2020.

Method

Multi-spectral data was collected from the SentinelHub EO Browser (https://www.sentinel-hub.com/explore/eobrowser/). This data requires a subscription, of which our team has contributed. The data collected ranges in resolution based by band, but visible light bands and Near Infrared bands are available at 10-meter resolution, other bands are available at 20 and 60 meter resolutions. In particular, imagery was selected that provided a clear view of the study area with < 10% cloud cover and occurred during the months when there is little to no sea ice. Using the 10 meter resolution of the shoreline was traced for each year with the available data.

Results

As can be seen on the following pages, it is generally possible to track shoreline change using these datasets, however only in very general terms. The 10 meter resolution means that shifts smaller than 30 feet will not be overly evident. However, over the course of season, the dramatic shifts in shorelines on the north shore of the peninsula are visible.

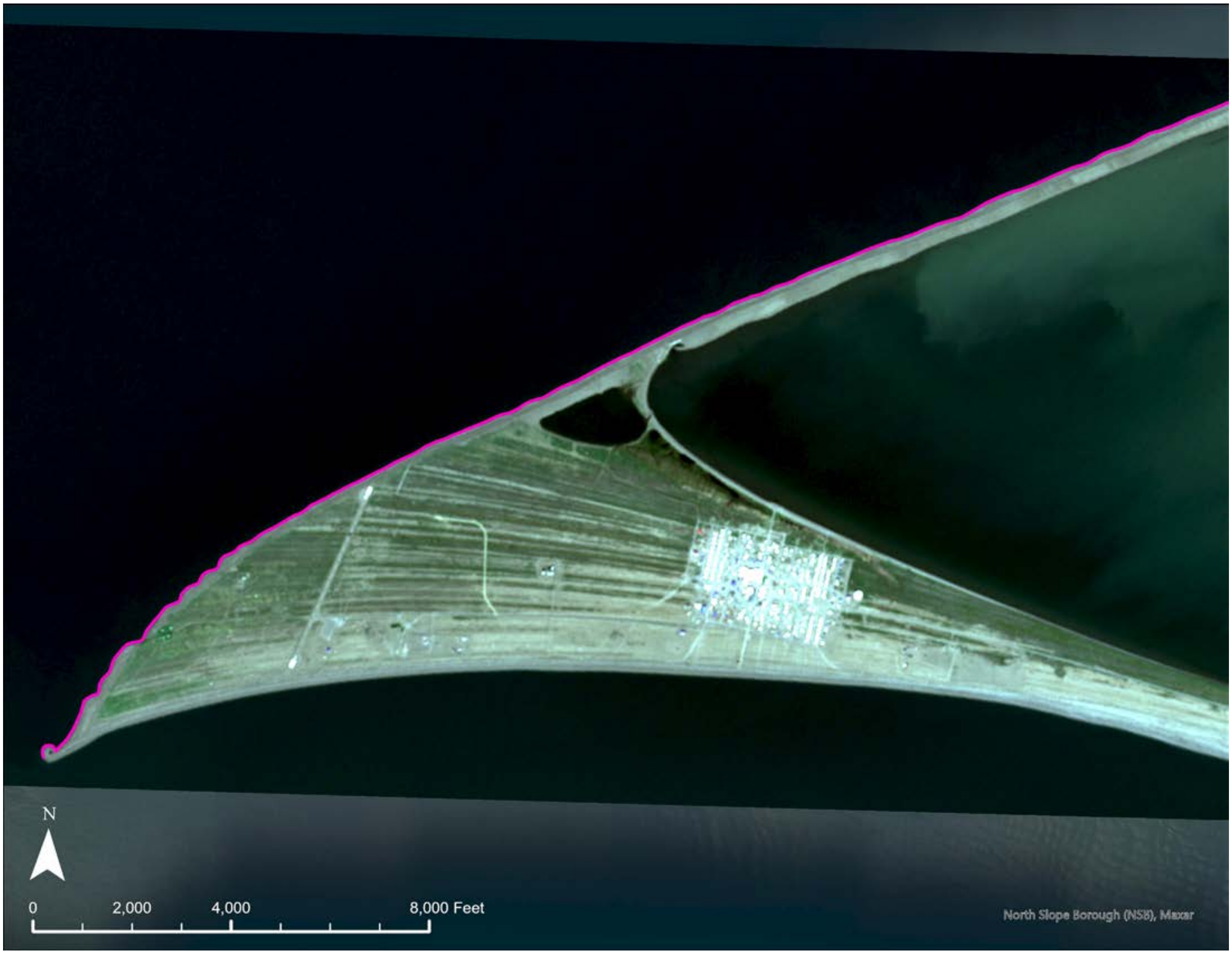


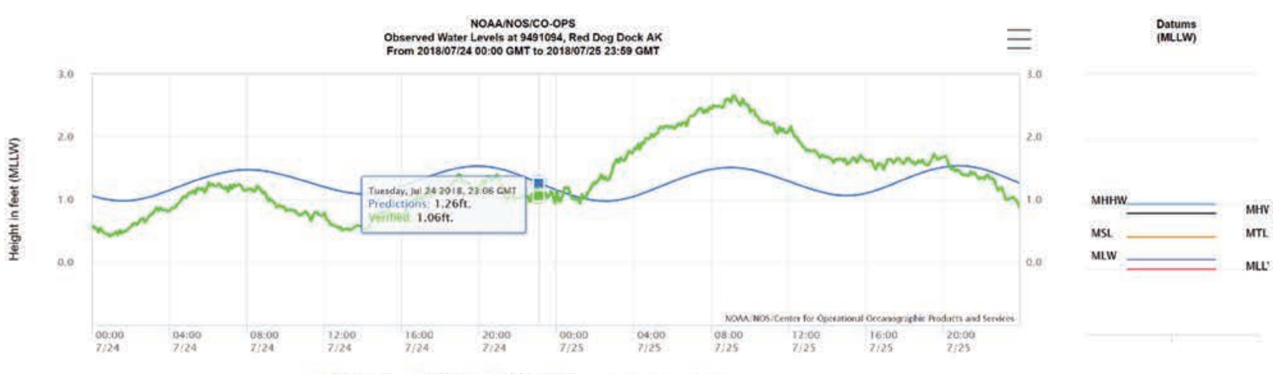
Locating the Shoreline
Using bands 4, 3, and 2 of the Sentinel 2 satellite creates a natural color image at 10 meter resolution. This zoom in shows the 10 meter pixels created from the process and establishes the lack of exacting data to deduce the actual shoreline. Despite this, shorelines were traced in 2018, 2019, and 2020. The timestamp of the satellite images taken were then crossed referenced with NOAA Tide and Current Bouys to make sure that they were not taken during opposing Mean Low Low Tides and Mean Higher High Tides. Bouy readings used the readings from Red Dog Dock roughly 100 miles from Tikigaq, as this is the closest bouy that stores tidal data over a long period of time.

NOAA BUOY

RED DOG DOCK, AK [9491094]

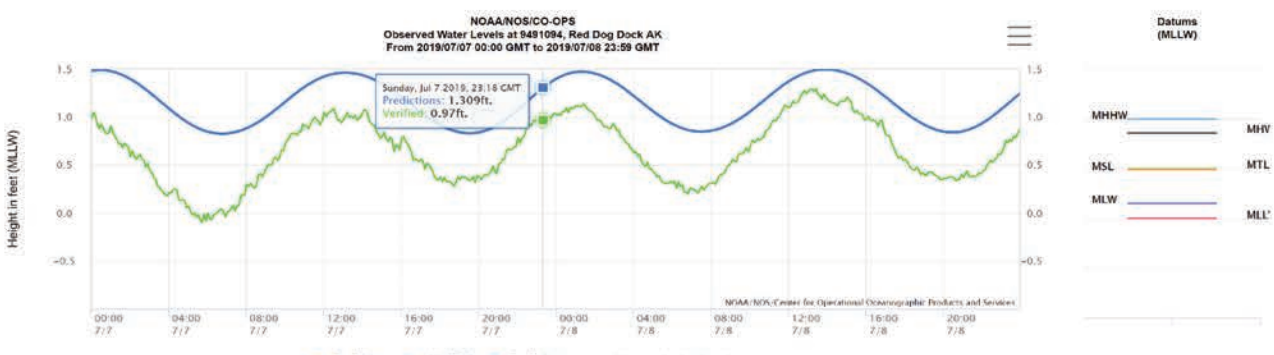
07-24-2018





1.06’ ABOVE MEAN LOW LOW WATER LEVEL

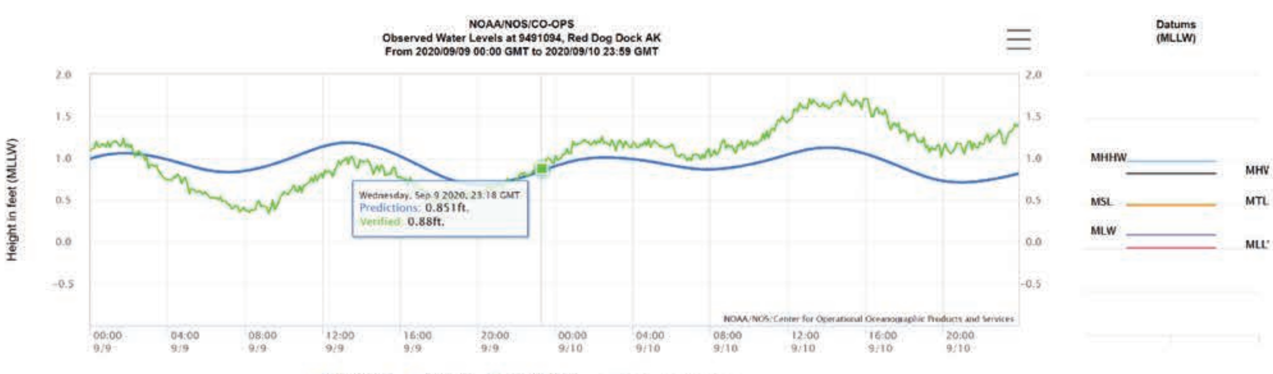
07-07-2019



.97' ABOVE MEAN LOW LOW WATER LEVEL

09-09-2020

*PLEASE NOTE: NO DATA WAS AVAILABLE FOR JULY (2020 OR 2021) WITHOUT ICE COVERAGE, <10% CLOUD COVER, OR WITH SIMILAR TIDE LEVELS



.88' ABOVE MEAN LOW LOW WATER LEVEL

COMPOSITE

Comparing Yearly Shorelines
The compiled shorelines can be used to recognize shoreline change. By focusing in on two seperate sites, it is clear that the the tip of the Tikigaq's peninsula (site 1), has experienced the greatest change in shoreline, while towards the shoreline closest to the lagoon (site 2), seems to be less extensive. However, as these are aerial photographs, erosion may still be greater at site 2 with a greater loss of topography. Additionally, site 2 appears to be the location where the most extensive efforts are taken to protect the shoreline through the community's creation of earthen barriers.


SITE 1
7-24-2018
7-07-2019
9-09-2020
N
0
500
1,000
2,000 Feet
North Slope Borough (NSB), Maxar


SITE 2
7-24-2018
7-07-2019
9-09-2020
N
0
500
1,000
2,000 Feet
North Slope Borough (NSB), Maxar

1.3.1b. Multi-Spectral Storm Erosion

For this exercise, our team collected a wide range of multi-spectral imagery from the ESA's Sentinel 2 program in order to test the possibility of using this data to track annual soil erosion before and after storm events.

Method

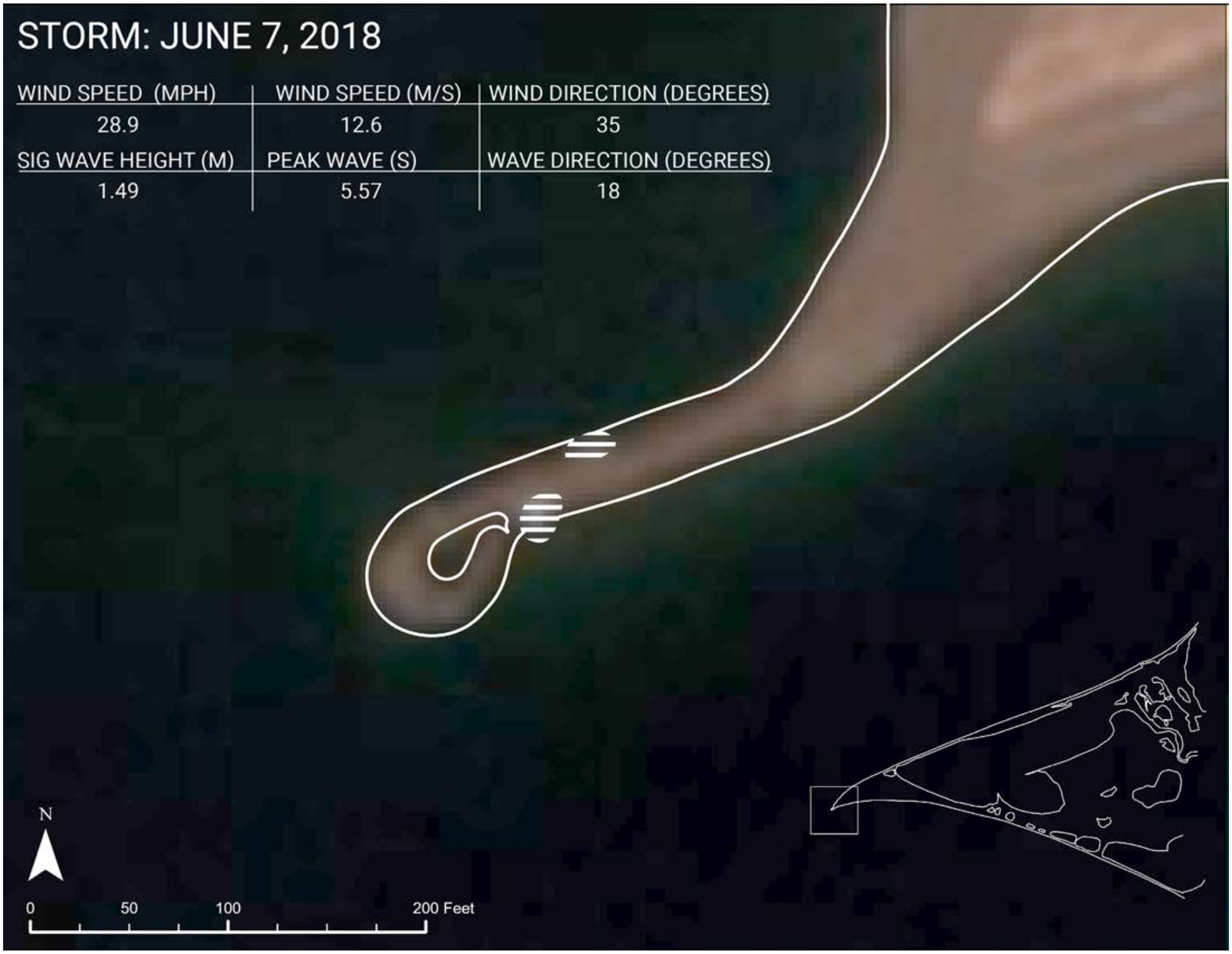
Multi-spectral data was collected from the SentinelHub EO Browser (https://www.sentinel-hub.com/explore/eobrowser/). This data requires a subscription, of which our team has contributed. The data collected ranges in resolution based on band, but visible light bands and Near Infrared bands are available at 10-meter resolution, other bands are available at 20 and 60 meter resolutions. In particular, imagery was selected that provided clear view of the study area (< 10% cloud cover) and occurred as close to storm events as possible, both before and after. The storm events were provided by EA based on observations from the local WISC Station. This data was then split based on whether there was ice cover at the time of the event or if there was not. A collection of six events were chosen for the years of 2017, 2018, and 2019. These years coincided with the availability of Sentinel 2 corrected data, which became available for our study area in 2017, and the available storm data which extended through 2019.

The images were used to both evaluate the possibility of quantifying shoreline moment between storm events using visible spectrum imagery and also looking at imagery directly after storms to using different multi-spectral bands to view suspended sediment patterns in an attempt to derive some inference on near shore sediment dynamics.

Results

Similar to the results of 1.2.1a, the fidelity and availability dates of observation data limits the value of this survey method. However, as can be seen on the following pages, it is generally possible to track storm-induced change in particular areas, specifically the western tip of the peninsula.

BEFORE STORM - JUNE 4, 2018



Tracing a storm

The best storm available to trace shoreline change occured on June 7, 2018. The before aerial photograph was taken on 3 days prior to the storm on June 3. Using the 10 meter resolution, the shoreline was traced, except in areas denoted by a white hatch which is ice coverage which show no clear indication of the shoreline's edge.

AFTER STORM - JUNE 12, 2018

Tracing a storm
The shoreline can be traced 5 days after the storm event on June 12 using the same procedure. In this aerial photograph, the north shore is covered in ice, which makes tracing the shoreline inaccurate, however a great difference in the peninsula's tip can be examined.

COMPARISON

Tracing a storm
By overlapping the two shorelines, we can measure the changes that took place following the storm. Here and in other aerial photographs, the tip of the peninsula appears to be an area of great shoreline movement especially following a storm event.

1.3.1c. Multi-Spectral Sediment

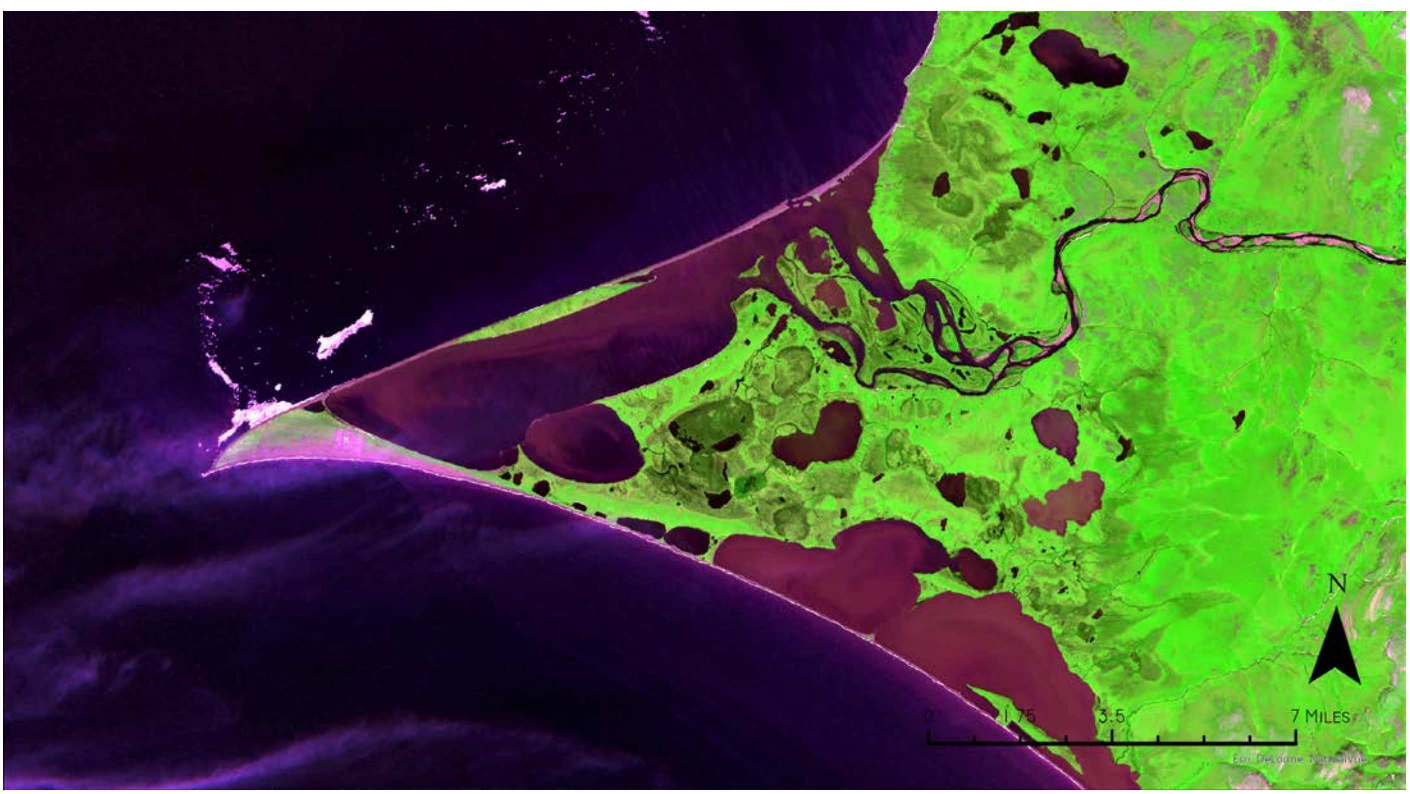
For this exercise, our team collected a wide range of multi-spectral imagery from the ESA's Sentinel 2 program in order to test the possibility of using this data to track sedimentation.

Method

Multi-spectral data was collected from the SentinelHub EO Browser (https://www.sentinel-hub.com/explore/eobrowser/). This data requires a subscription, of which our team has contributed. The data collected ranges in resolution based on band, but visible light bands and Near Infrared bands are available at 10-meter resolution, other bands are available at 20 and 60 meter resolutions. In particular, imagery was selected that provided clear view of the study area (< 10% cloud cover) and limited sea ice cover. Different band combinations were used to highlight sediments in the water ways. While experimental, this could help deduce the movement of sediment around the peninsula and within the lagoons.

INFRARED VEGETATION

SEDIMENT MOVEMENT



1.3.1d. Multi-Spectral Ice

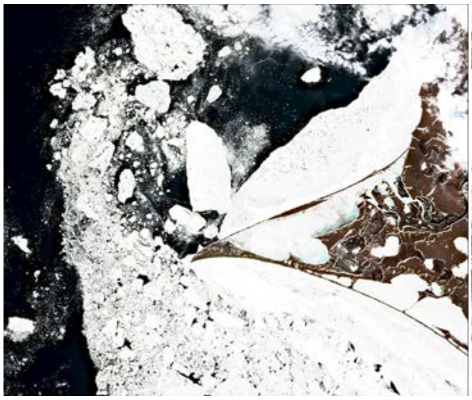
For this exercise, our team collected a wide range of multi-spectral imagery from the ESA's Sentinel 2 program in order to test the possibility of using this data track ice movement during ice build up and break up periods.

Method

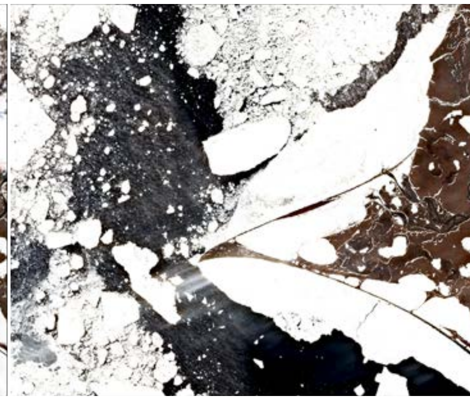
Multi-spectral data was collected from the SentinelHub EO Browser (https://www.sentinel-hub.com/explore/eobrowser/). This data requires a subscription, of which our team has contributed. The data collected ranges in resolution based on band, but visible light bands and Near Infrared bands are available at 10-meter resolution, other bands are available at 20 and 60 meter resolutions. In particular, data was collected during periods of ice movement in the spring and fall, where cloud cover was less than 10% and where clear images with ice were available in close sequence to one another. The assumption is that particular ice pieces or formations could be tracked (simply based on shape or color) between the two sequential images. For the sake of this experiment, only imagery from 2017 was used.

Results

As can be seen from the imagery, even in the rare chance when clear images are taken in close sequence (within only several days of one another), the ability to track ice movement is highly limited. Some characteristic pieces can be traced through the images, but dramatic shifts in ice location and cover are seen over just the period of a week. This leads our team to believe that perhaps sequential images from the Sentinel mission may not be overly helpful in tracking ice. However, they do a good job of visually describing ice condition at particular points in time, which could still have benefit.



05-28-2017



06-01-2017

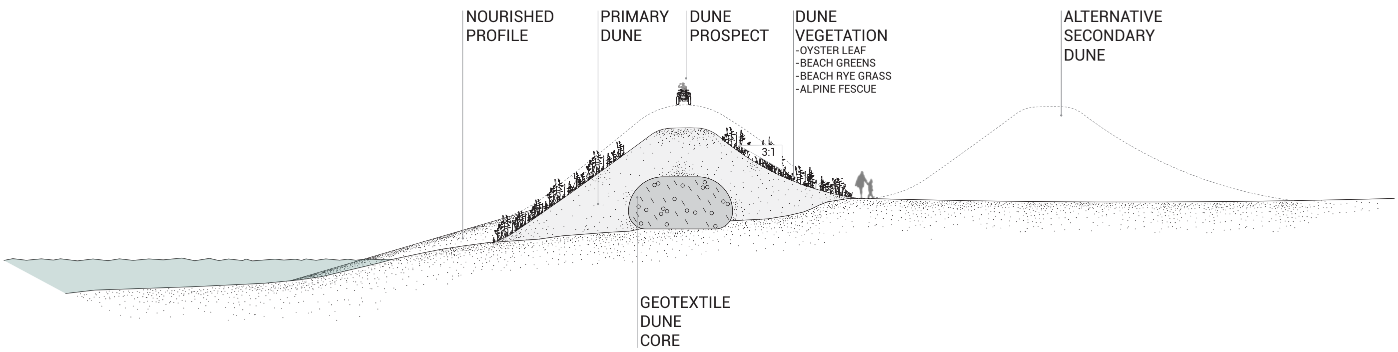
06-04-2017

Part II: Proposed NNBF Strategies

Part II of this report oulines a series of potential strategies aimed to respond primarly to the issues of coastal erosion along the northern side of the peninsula. Many of these strategies have been co-developed with the larger EA and EWN team and will look similar to those presented by that team elsewhere. While the co-developed alternatves (1-6) have been considered as somewhat feasable, a series of other alternatives could be possible and were discussed. Many of these other alternatives were understood as infeasable or impractical for various reasons. For example, several discussions around the reconfiguation or extension of the PHO airstrip were had, but due to political and land-ownership challenges, were not approved. For these resaons, the alternatives included here represent what could be feasable, and is not an exhaustive list of all options that were considered or could be possible under different circumstances.

As was described in the narratve, the question of whether NNBF strategies are the most effective or approriate in the Point Hope context is still up for debate. While the remoteness of the community makes heavy material transport and construction difficult, NNBF strategies shoud not be seen or developed as simply a "cheaper" alternative to a difficult challenge. If it can be demonstrated that NNBF perform equally or better than alternative methods of coastal infrastructure in this particular context, then we would strongly encourage their consideration. What this study is not intended to do is make a case for NNBF test projecs that might permit the forgoing of a larger infrastructual investment in Point Hope. Ideally these two strategies (hard and proven infrastructure and NNBF) could be married in this location in a way that deomonstrates cost-effectiveless, coastal resilience, and a strong (and much needed) commitment to the people and culture of Point Hope.

Alternative 1:
Artificial Dune Creation + Beach Nourishment

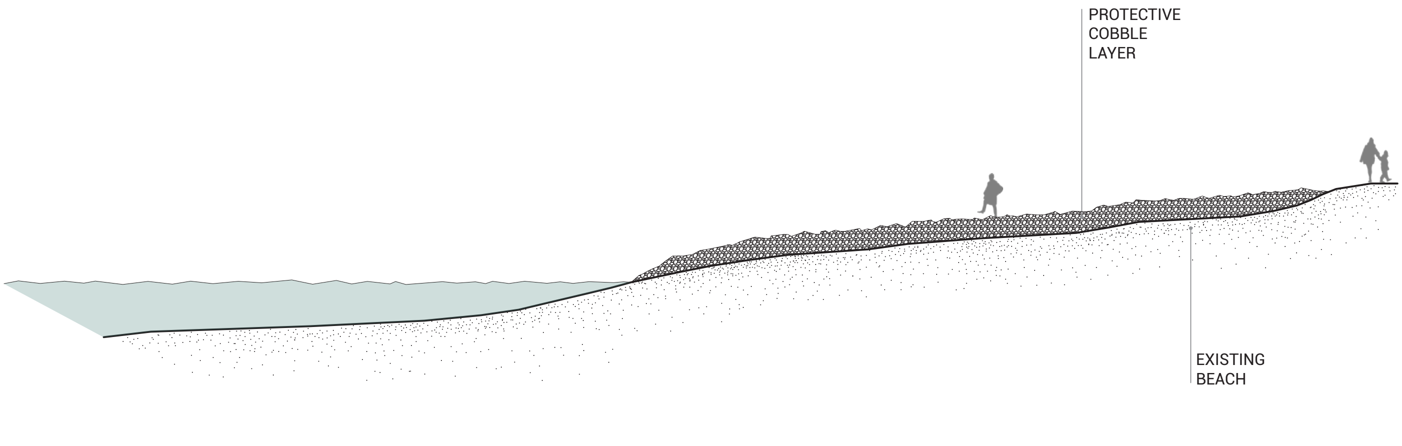


DRAWING NOT TO SCALE

Details
- Geotextile dune core
- Vegetation planting
- Beach nourishment
- Beach access points
- Goal to limit vehicle traffic over the dunes
- High points for subsistence hunting activities
- May want to consider including hard armoring for most at risk areas

Main Challenges:
- Unproven in Arctic regions
- Availability of beach nourishment material
- Availability of fill material
- Can require maintenance after large storms
- Construction feasibility
- Permitting

Alternative 2:
Dynamic Revetment

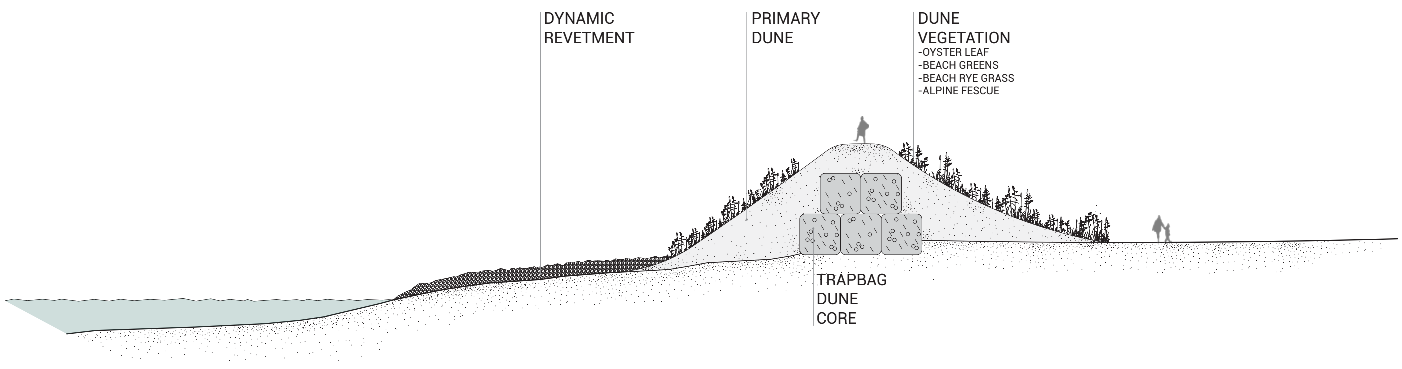


DRAWING NOT TO SCALE

Details:
- Placement of rocks/cobbles that are significantly larger than the natural beach material
- Rocks/cobbles dissipate storm impacts along length of the beach
- Storms work to rearrange rocks/cobbles into an equilibrium state, continuously shaped by nature
- Resilient against ice impacts
- Potential to help promote the formation of slush-ice berms
- Similar concepts have been implemented in cold regions

Main Challenges:
- Availability of rock/cobble material
- Construction feasibility
- Permitting

Alternative 3:
Dynamic Revetment + Artificial Dune

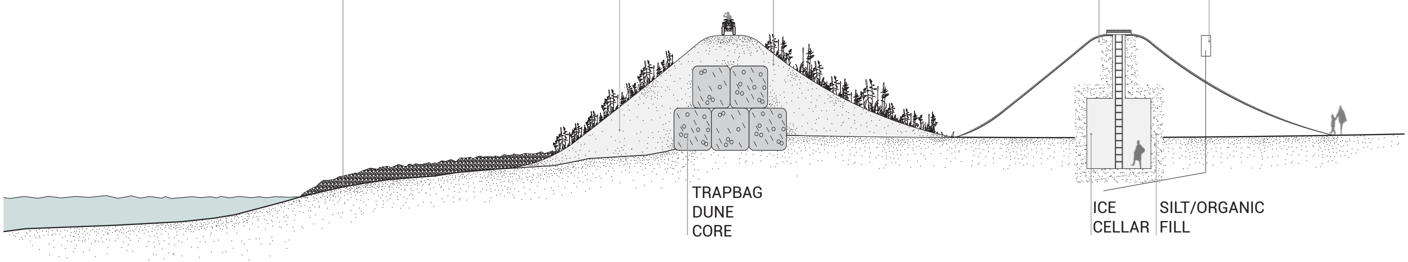


DRAWING NOT TO SCALE

Details:
- Combination of Alternatives 1 and 2 minus the beach nourishment
- Provides highest level a nature-based protection of all alternatives

Main Challenges:
- Unproven in Arctic regions
- Availability of fill material
- Availability of rock/cobble
- Can require maintenance after large storms
- Construction feasibility
- Permitting

Alternative 4:
Dynamic Revetment + Artificial Dune + Pilot Ice Cellar



DRAWING NOT TO SCALE

Alternative Details:
- Includes pilot ice cellar dune core
- Fine silt/organic fill around ice cellar to promote permafrost
- Hybrid thermosyphon to help mitigate permafrost thaw
- 1-3' of sod top layer
- Dune creation using suitable sand/gravel
- Dynamic revetment on ocean side for storm/erosion protection

Main Challenges:
- Novel concept and therefore untested and unproven
- Availability of fill material
- Availability of rock/cobble
- Can require maintenance after large storms
- Construction feasibility
- Permitting

Alternative 5a:
Strategic Sediment Placement - Single Cobble Motor

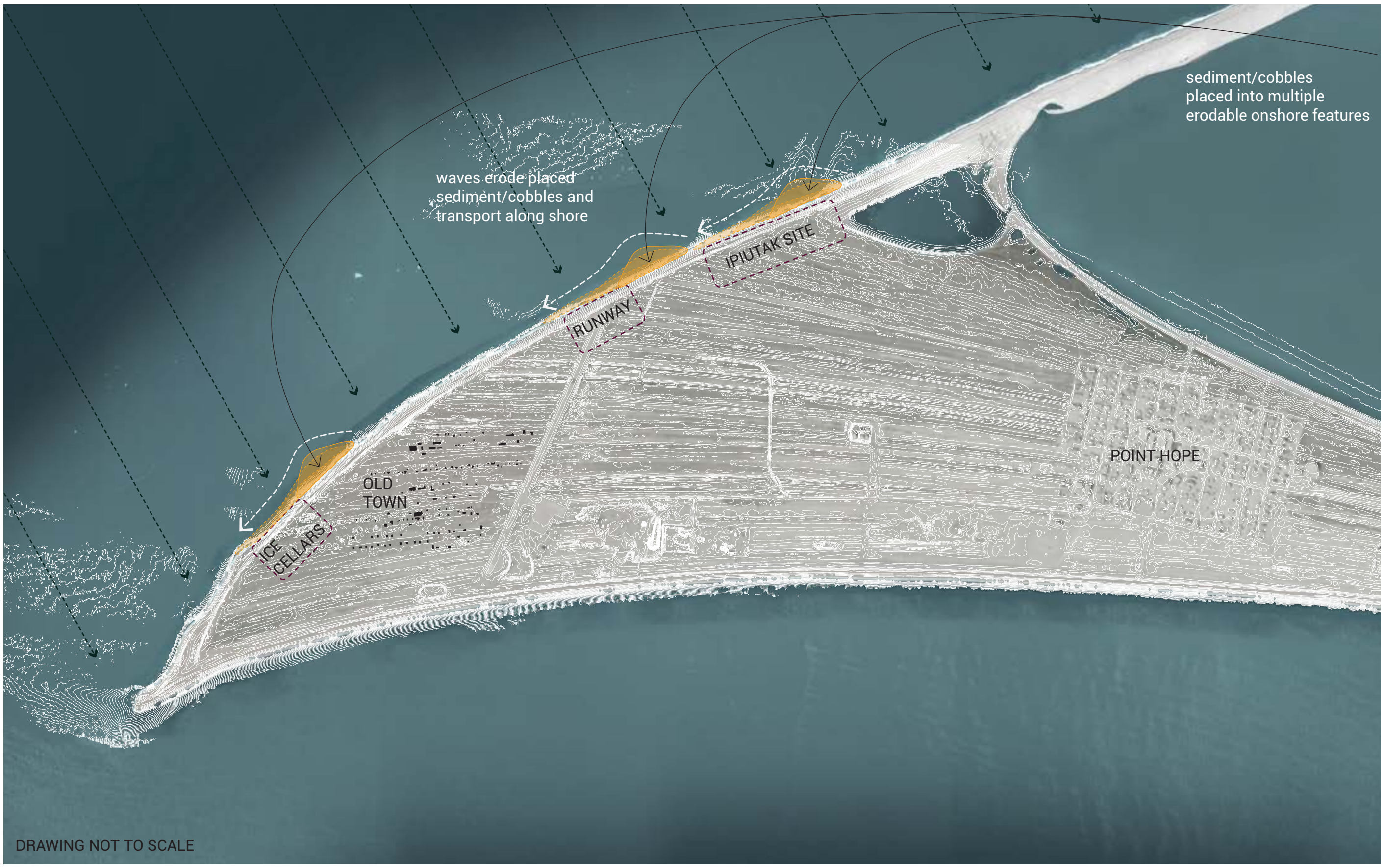
Details:

- Creation of a "cobble motor" to nourish the beach over time
- Material placed in a 'hook-shaped' peninsula
- Uses natural processes to redistribute material over time
- Immediate nature-based protection to the area located behind the nourishment
- Dredged channel provides boat access and continual sediment source

Main Challenges:

- Unproven in Arctic regions
- Availability of fill material
- Offshore depths increase quickly from the shore
- Does not provide immediate protection to downdrift areas
- Construction feasibility
- Permitting

Alternative 5b:
Strategic Sediment Placement - Multiple Cobble Motor



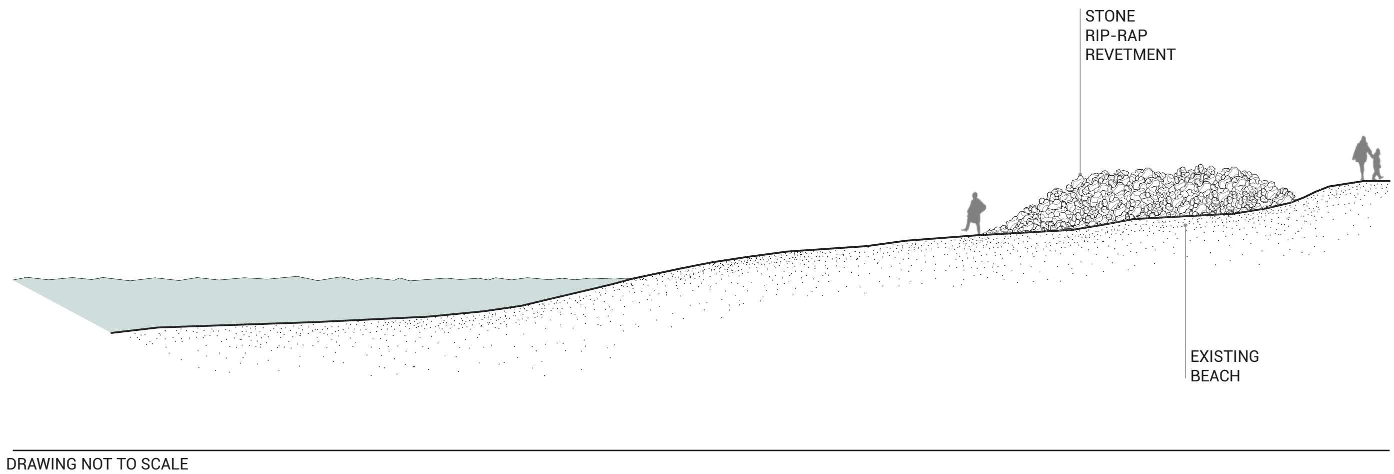
Details:

- Creation of a “cobble motor” to nourish the beach over time
- Material placed into several ‘hook-shaped’ peninsulas
- Uses natural processes to redistribute material over time
- Immediate nature-based protection to the areas located behind the nourishment
- Offers quicker protection to downdrift shoreline thatn 5a

Main Challenges:

- Unproven in Arctic regions
- Availability of fill material
- Offshore depths increase quickly from the shore
- Construction feasibility
- Permitting
- Transport distances are greater than 5a

Alternative 6:
Traditional Rip-Rap



Alternative Details:
- Composed of rock or stone
- Provides the highest level of protection
- Provides immediate protection
- Susceptible to ice damage
- Implemented in the Arctic already

Main Challenges:
- Not nature-based
- Availability of rock/stone
- Construction feasibility