Arctic solutions for cold

Design & Construction Lessons Learned in Cold Climates

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Agenda, Arctic solutions

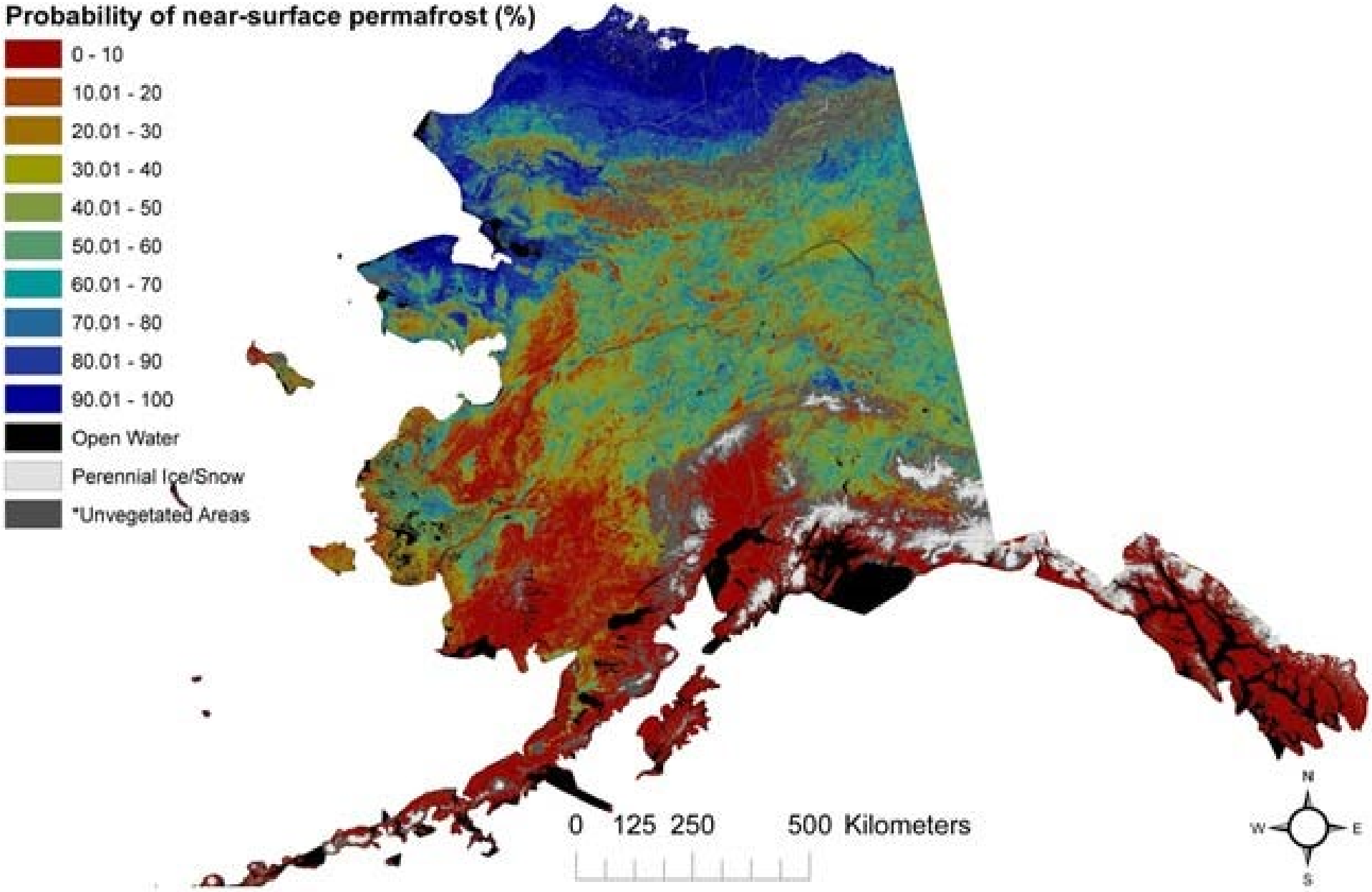
- Building on Arctic Ground
  - Permafrost, Foundations, Ice Lenses
  - Project Examples
- Case Studies:
  - Bethel Bank Stabiliation
  - Kaktovik / Barter Island
  - Deadhorse Airport Rescue and Firefighting Bldg
  - Galena High School
  - Unalaska Small Boat Harbor and Environmental
  - Cold Weather and Concrete
- Additional CONUS and OCONUS Examples & Lessons Learned
- What Does the Future Hold?

Arctic ground

- Frost susceptible soils
  - Permafrost
    - Site Selection
    - Thermokarst/Ice Lenses
    - Thermal Syphons
    - Thermal Piles
    - Thermal Syphons
    - Inspection and Maintenance
  - Frost jacking
  - Permafrost resistant foundation systems
    - Pile Foundation Systems
    - due to permafrost (Quarry Hill Rd w/ JV)
    - due to PFAS (KC-135 programming w/ JV)
  - Thermokarst/Ice Lenses

What is Permafrost?

- *Permafrost or perennially frozen ground, is defined as soil or rock having temperatures below 0º C during at least two consecutive winters and the intervening summer. (Anderland and Ladanyi 2004)*


Probability of near-surface permafrost (%)
0 - 10
10.01 - 20
20.01 - 30
30.01 - 40
40.01 - 50
50.01 - 60
60.01 - 70
70.01 - 80
80.01 - 90
90.01 - 100
Open Water
Perennial Ice/Snow
*Unvegetated Areas
0 125 250 500 Kilometers
N
W
E
S

Source - usgs

Alaska Bases and the ground beneath

- Good Ground at the Core of the Base AKA Sites that the military engineers did an excellent job of selecting.
  - Clear Space Force Station
  - Fort Greely – Gravel with areas of permafrost
  - Joint Base Elmendorf-Richardson
  - Eielson Air Force Base
  - Fort Wainwright
- Sites with Poor Ground
  - North Slope Radar Sites
  - Galena – Decommissioned Base

Building on Permafrost

- Golden Rule:

- - If it is frozen, keep it frozen.
- - If it is thawed, keep it thawed.

Photo – Ice Wedge on the ice bluffs of barter island Alaska

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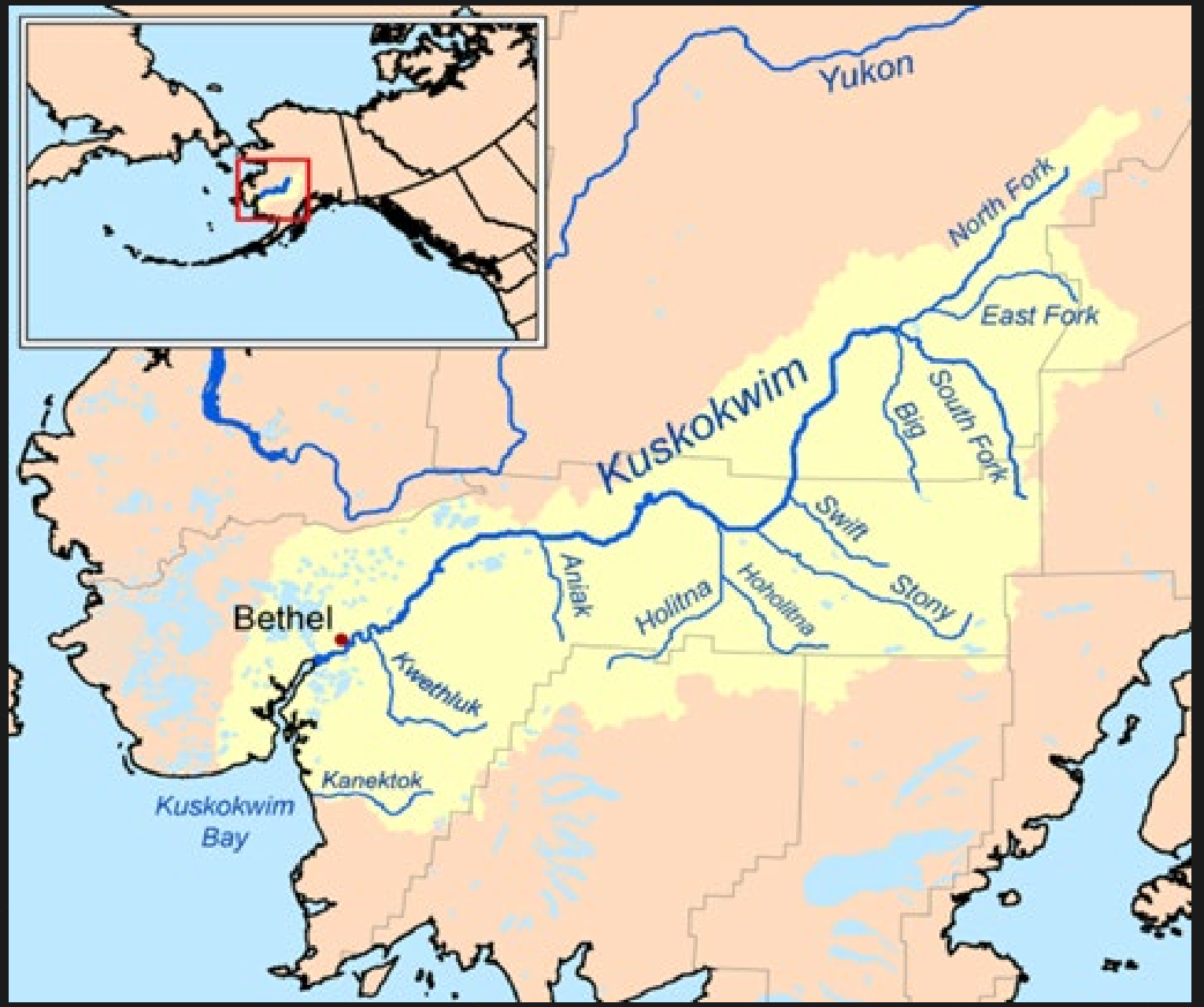
Bethel Bank Stabilization



Bethel Bank Stabilization

- Emergency Riverbank Stabilization.
- Client – City of Bethel and USACE
- Problem – Riverbank sloughed into the Kuskowim River and exposed permafrost. Started a chain reaction of melting and sloughing. Threatened a road, public school, and residential neighborhood.
- How to stop melting permafrost and sloughing riverbank when no local rock is available?

Kaktovik/Barter Island

- Project replacement of Barter Island radar tower guy wires
- Client - Arctec Alaska
- Owner – United States Air Force
- Problem – Existing guy wire anchors failing after 30+ years
- New anchors to have a 20 year design life

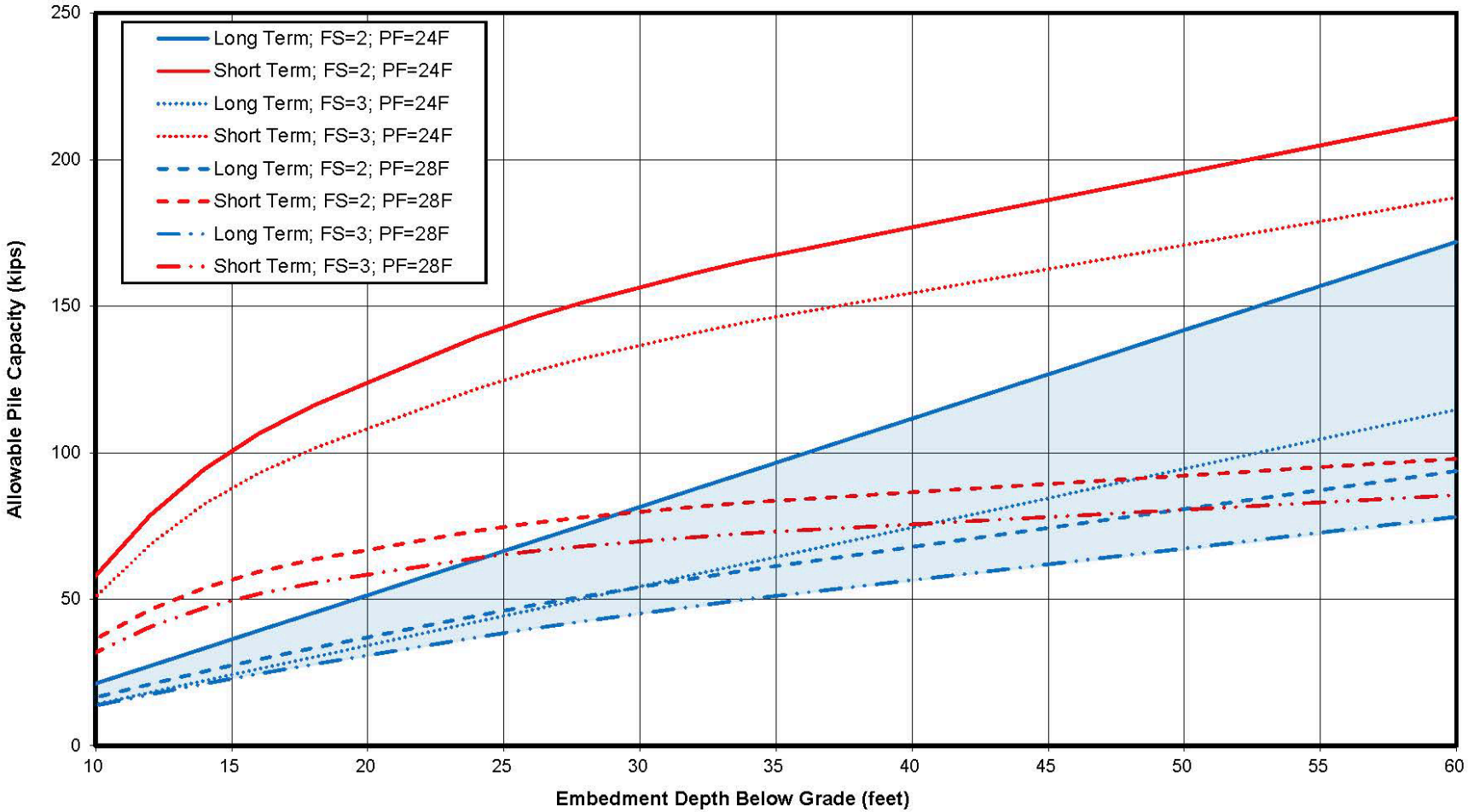

Barter Island


Massive ice layer within permafrost

Designing for the Risk of Warming Permafrost in Kaktovik

- Designing for the Risk of Warming Permafrost in Kaktovik
- Limited data
- Permafrost temperatures
  - March 1985 -5 18^0 (F) Shannon and Wilson
  - 2005 Study by Osterkamp and Jorgenson, suggested 2^0 to 3^0 Celsius warming between 1985 and 2004
  - Values extrapolated out to 2037 using this warming trend suggest that permafrost temperatures could rise in the upper layer 4^0 F in 20 years

Anchor Capacity w/ Temp& Depth



NOTES:

1. See the discussion in our report regarding warming permafrost temperatures and risk associated with warming permafrost to chose the design curve for this project.
2. Capacity curves presented in this chart are based on adfreeze strength, and assume permafrost is bonded. Soils at this site are saline; as temperature of permafrost increases, soils may not be bonded.
3. FS = factor of safety; PF = permafrost; F = degrees Fahrenheit

GEOTECHNICAL STUDIES
BARTER ISLAND GUY ANCHORS

ESTIMATED ANCHOR CAPACITY

August 2017 31-1-20033-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

FIG. 3

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Final Design

- Guy wire anchor depth increased from 45ft to 60ft to account for the risk of warming permafrost
- Thermosyphons added to each anchor to increase winter freeze back

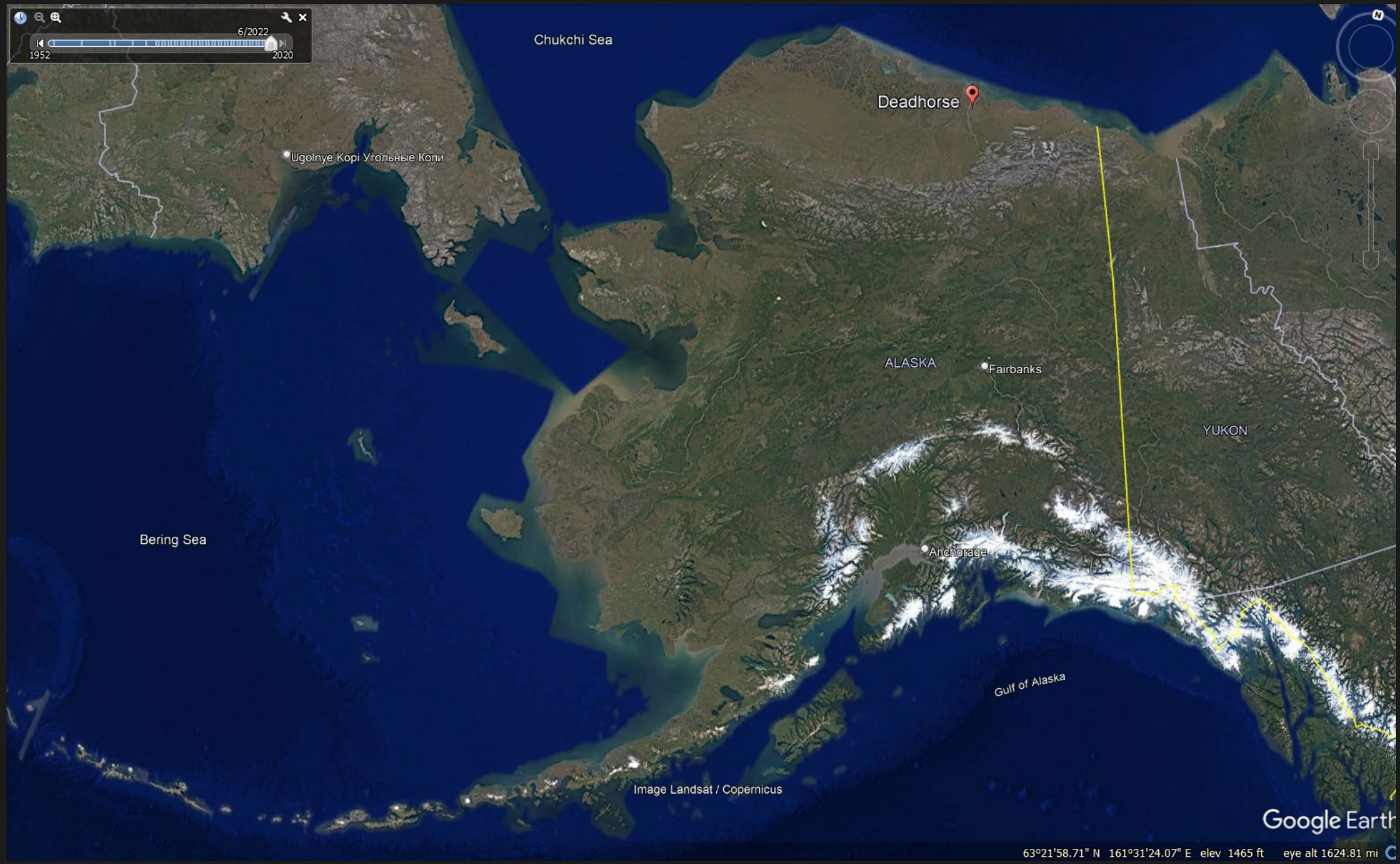
Photo Credit Wendy Presler Shannon and Wilson

Photo Credit Wendy Presler Shannon and Wilson

Rural Alaska Construction

- Anchors installed in fall of 2018 when sea ice receded enough to allow barge traffic to Barter Island
- Barge delivering equipment only made one trip to Barter Island due to near shore sea ice
- Drill rig flown back to Dead Horse as part of the de-mob

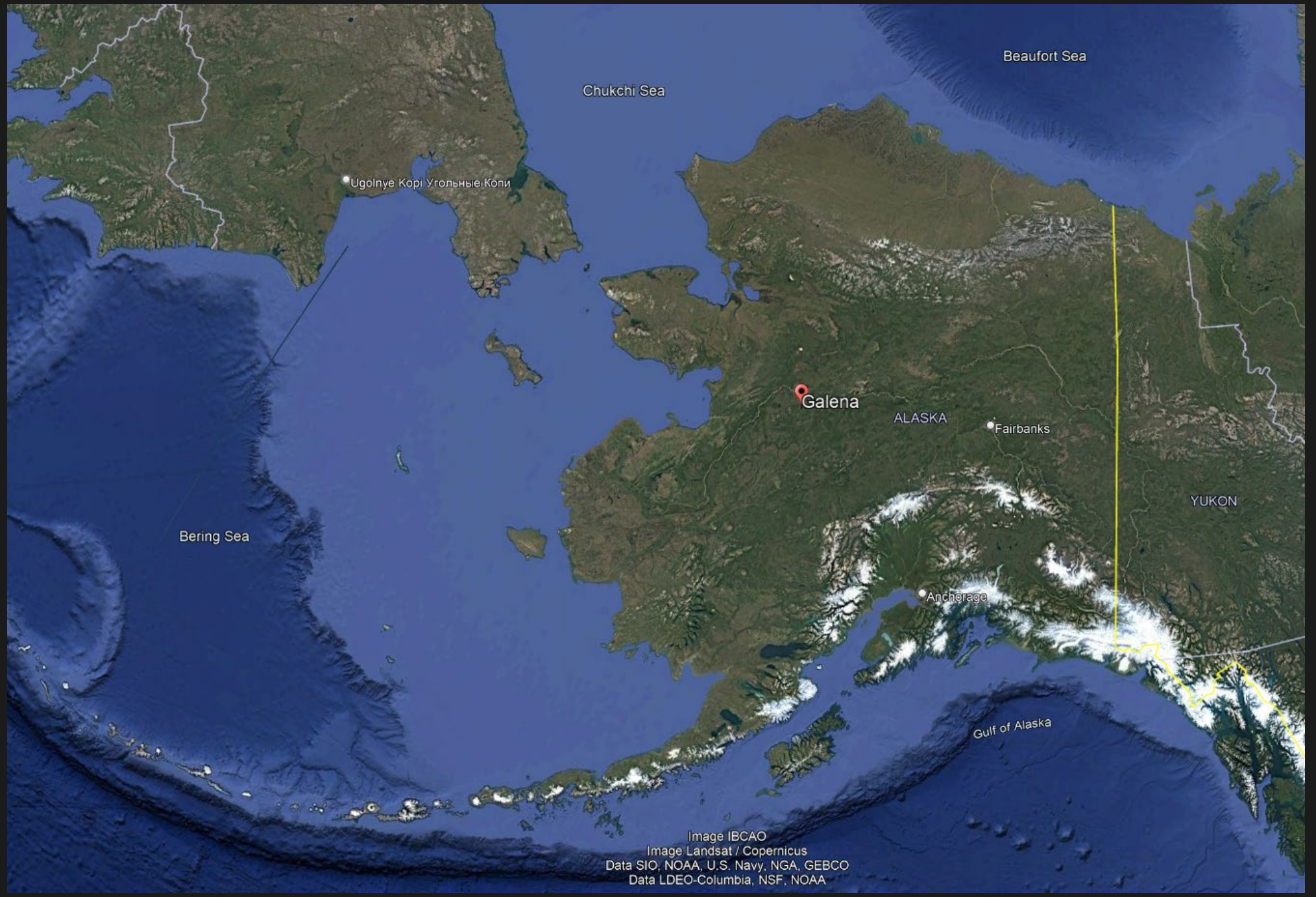
Photo Credit - Lynden Transport


6/2022
1952
2020
Chukchi Sea
Deadhorse
Ugolnye Kopi Угольные Копи
ALASKA
Fairbanks
YUKON
Bering Sea
Anchorage
Gulf of Alaska
Image Landsat / Copernicus
Google Earth
63°21'58.71" N 161°31'24.07" E elev 1465 ft eye alt 1624.81 mi

Deadhorse Airport Rescue and Firefighting Building (ARFF)

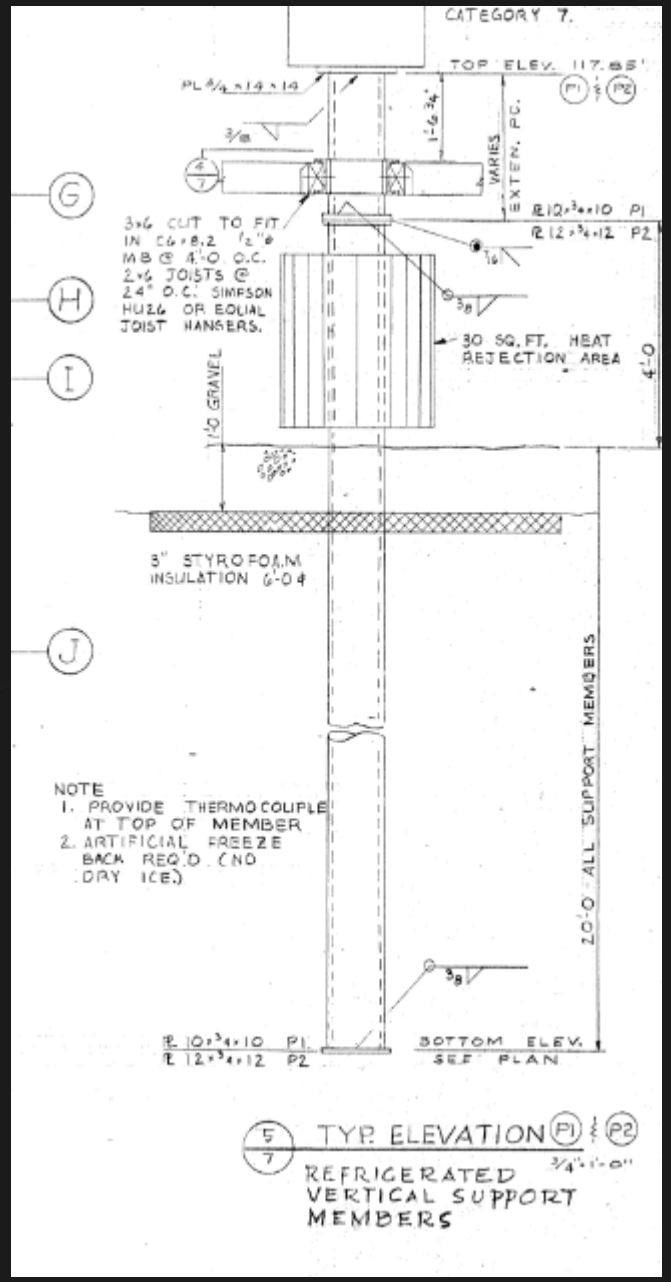
- 150ft x 102ft ARFF on permafrost
- Foundation used a passive freeze back system utilizing horizontal thermosyphons


SENSOR ST3/#3
IS THE PRIMARY
FOUNDATION FREEZE
SYSTEM CONTROL
SENSOR.
PLEASE RETURN THE
SELECTOR SWITCHES TO
INDICATE THE PRIMARY
FOUNDATION CONTROL
SENSOR WHEN ALL
READINGS ARE
DOCUMENTED.
242
TS-1
TS-2
TS-3
TS-4
TS-5
TS-6
TS-7


Beaufort Sea
Chukchi Sea
Ugolnye Kopi Угольные Копи
Galena
ALASKA
Fairbanks
YUKON
Bering Sea
Anchorage
Gulf of Alaska
Image IBCAO
Image Landsat / Copernicus
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA

Galena High School

- Constructed in the late 1970's
- Thermo Piles embedded 20ft into permafrost
- Building is starting to move around – Heave and Subsidence



Front Entrance and Ramp require seasonal adjustment

Thermo Piles

Thermopiles

High School

2022 project permafrost 18 to 20ft below grade

Unalaska – Logistical Challenges & Weather

- Project: Unalaska Small Boat Harbor and Env Cleanup
- Issue: Short Construction Season. Logistical challenges, and extreme weather
- Impacts: Must build in time for anticipated weather delays and plan construction activities and delivery of materials for short season.

Cold weather Concrete and use of Self-consolidating concrete

- Requires heating for 7 days – 3 days for type III concrete and formwork preheating
- A recent project in interior AK experienced poor consolidation when concrete was placed in extreme winter conditions. Harsh arctic temperatures and winds contributed to a decrease in labor quality and productivity consolidating the concrete. The proposed solution was use Self-Consolidating Concrete (SCC).
- SCC is a highly flowable, non-segregating concrete that allows concrete to spread, fill form work, and surround reinforcing steel without the need to use mechanical vibration.
- SCC is not covered in the Uniform Federal Guide Specs (UFGS). Requires a variance to use.
- SCC has been used successfully in densely reinforced concrete applications in arctic regions, but is not typically used for applications with a traditional amount of reinforcing. Use of SCC allows the concrete to be placed at a faster rate and removes the variable operator effort of consolidation. Laborers are not required to pause as concrete is mechanically vibrated.

CONUS & OCONUS Examples & Lessons

- Designing for decades in interior Alaska, Thule AFB, Reykjavik, Iceland, and other arctic/subarctic locations
- Design considerations & lessons learned include:
  - Building orientation – minimize snow drifts at entrance.
  - Building Envelop
  - Thermal Breaks
  - Entrance Wind Shelters
  - Snow hoods on exhaust and intakes
  - Cold Roofs , roof penetrations, and preventing Ice dams
  - Foundations – permafrost, discontinuous permafrost, seasonal active layer up to 17' thick, foundation rigid insulation
  - Snow slide calculations for rood, entrances, and parking

More CONUS & OCONUS Examples & Lessons

- Design considerations & lessons learned include:
  - Downspouts inside of buildings, no exposed PVC (becomes brittle)
  - Non-frost susceptible material
  - Fence posts and frost jacking
  - HVAC design
  - Generators (do we modulate generator bay ventilation?)
  - Year-round access to utility piping, Utilidors, Elecatrical/Comms Equipment, Gounrding, Arctic rated cabling)
  - Above grade long conduit runs. Must provide a design solution for expansion and contraction
  - Storm Drainage and accounting for freeze-thaw cycles
  - Bolting during extreme cold (thermal strains built-in that expand and buckles or shears bolts when it turns hot)

What does the future hold?

Changing Arctic

- Continually melting permafrost – from natural causes and due to construction
- Unexpected consequences of permafrost preservation – infrastructure stays in place while landscape around it deforms/sinks/melts