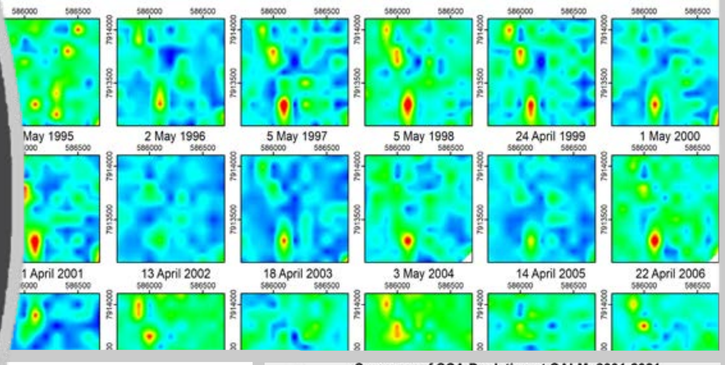
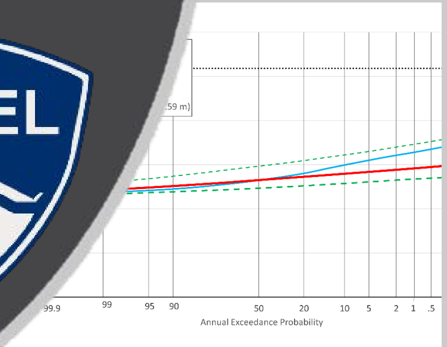
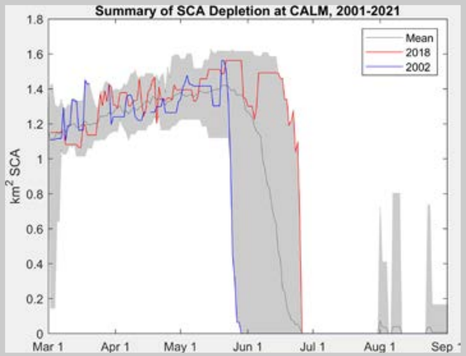
UTQIAĠVIK REVETMENT – SNOW MODEL HYDROLOGY PROJECT

Anna Wagner, Research Environmental Engineer – CRREL
Nathan Epps, Civil Engineer, AK District



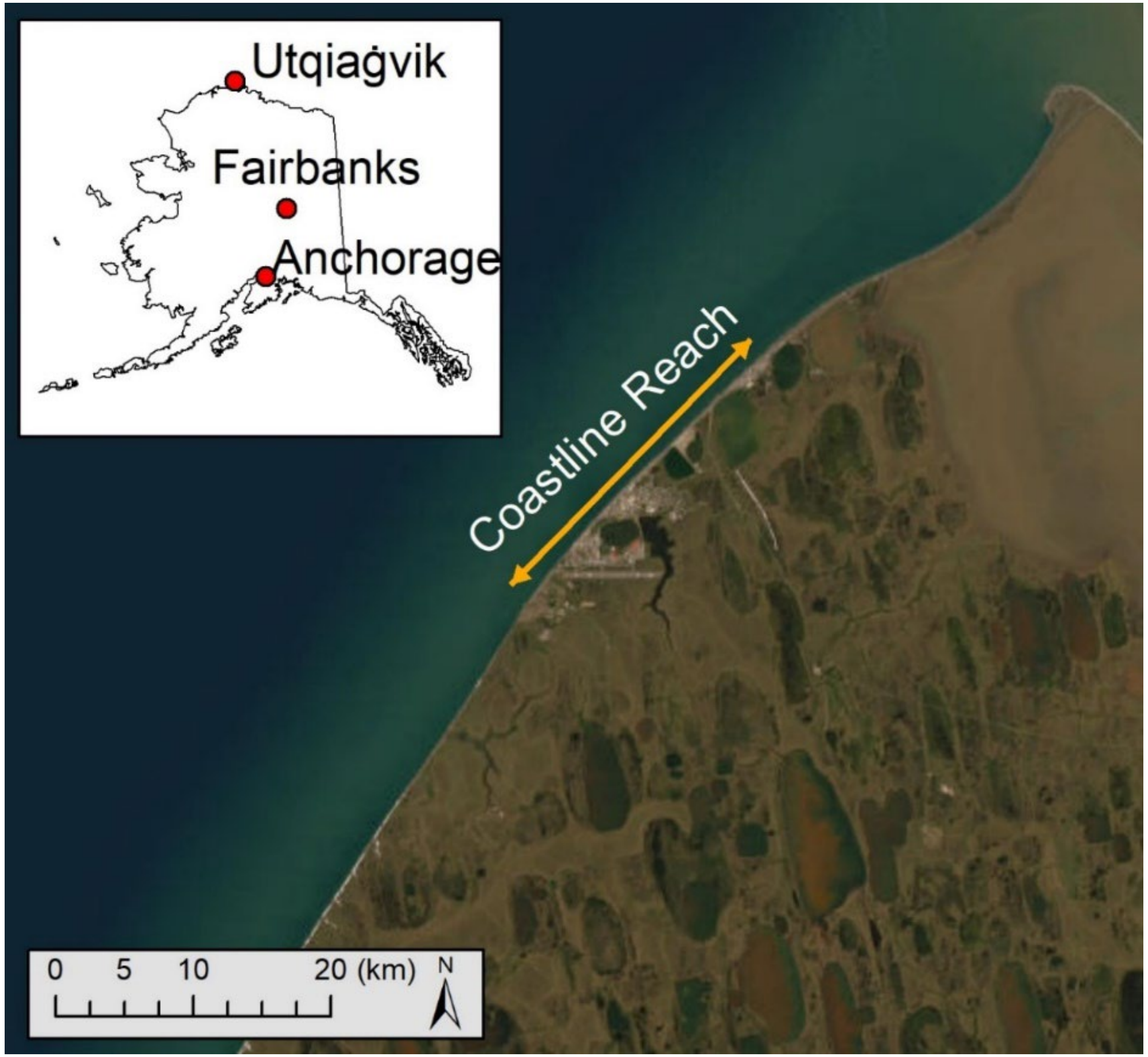




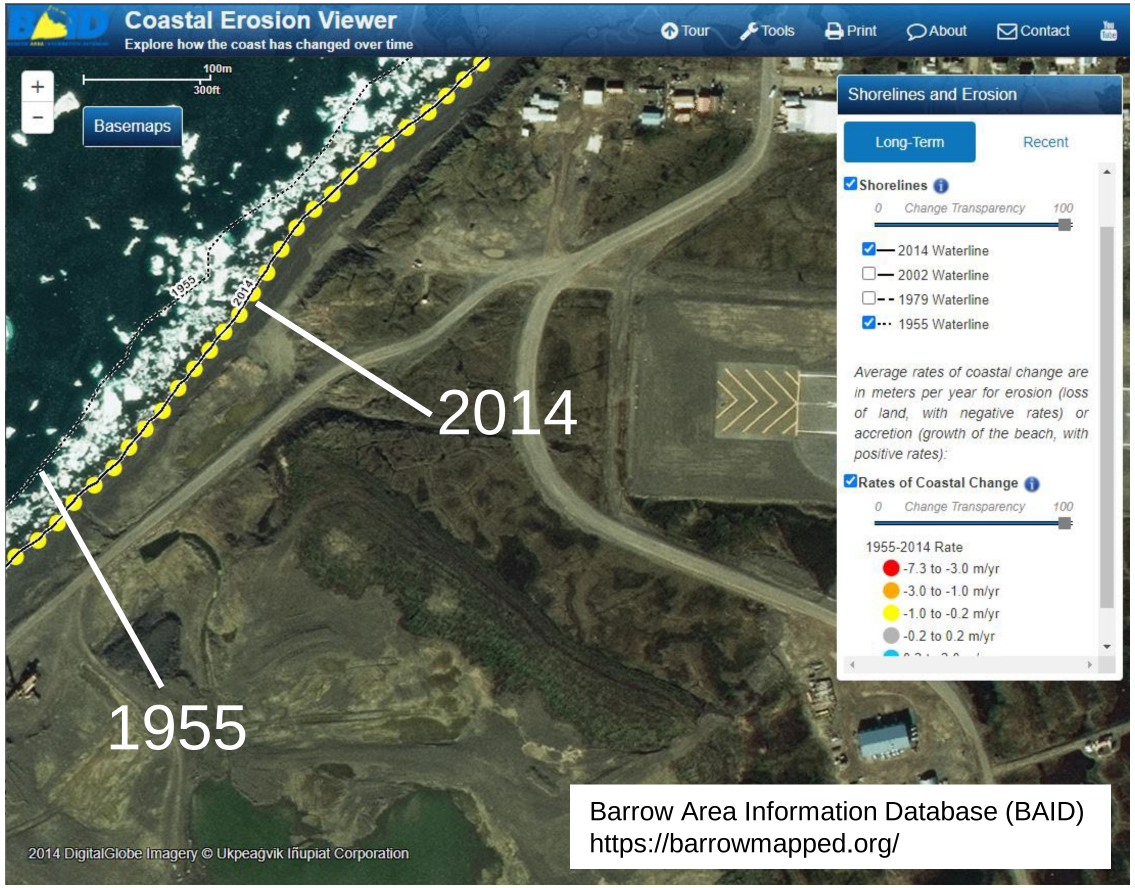
Utqiaġvik

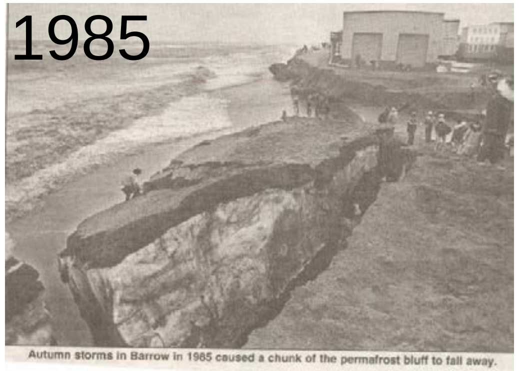
- Community of approximately 5,000 located on the Chukchi Sea approximately 750 miles by air north of Anchorage, AK.

- Multiple emergency declarations since 2015 exceeding $8.5 million per year due to erosion damages.



Coastal Erosion

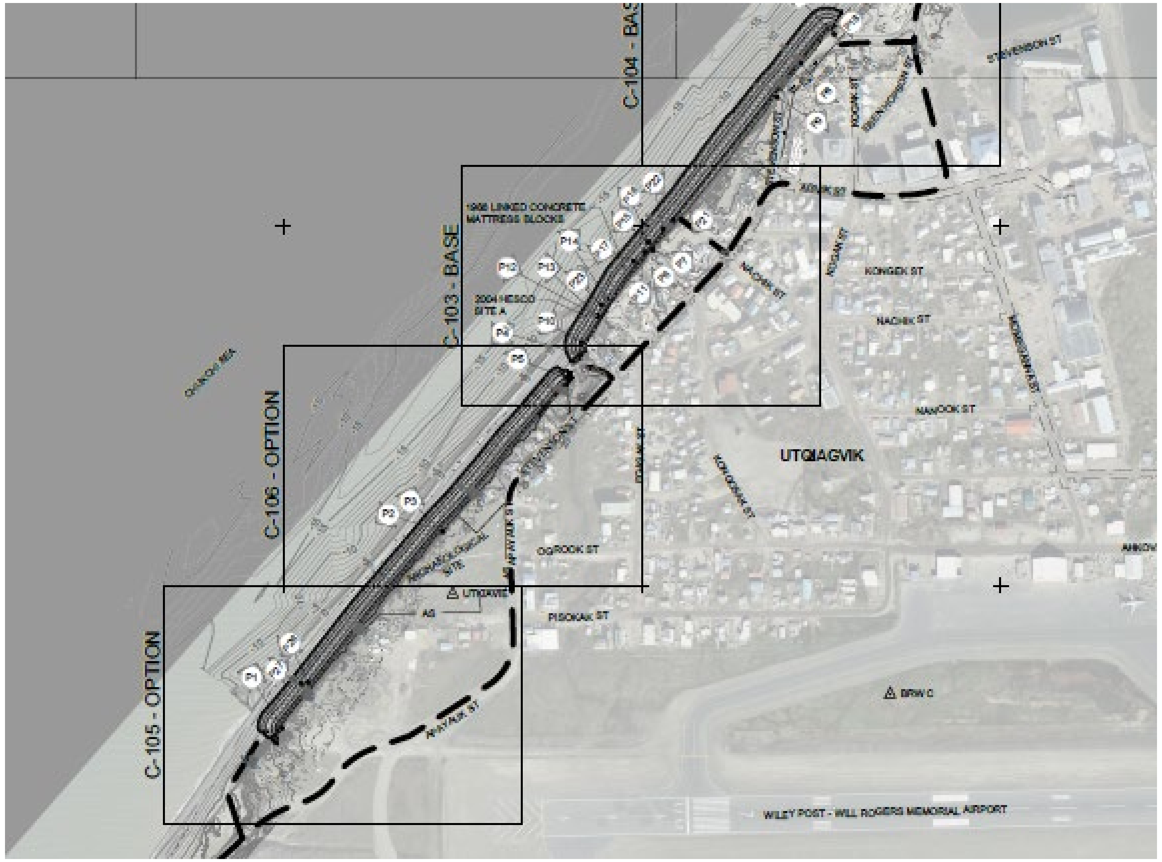




Dealing with the Problem

Authorized Plan

- Rock revetment along bluffs
- Revetted berm at lagoon
- Raising Stevenson Street

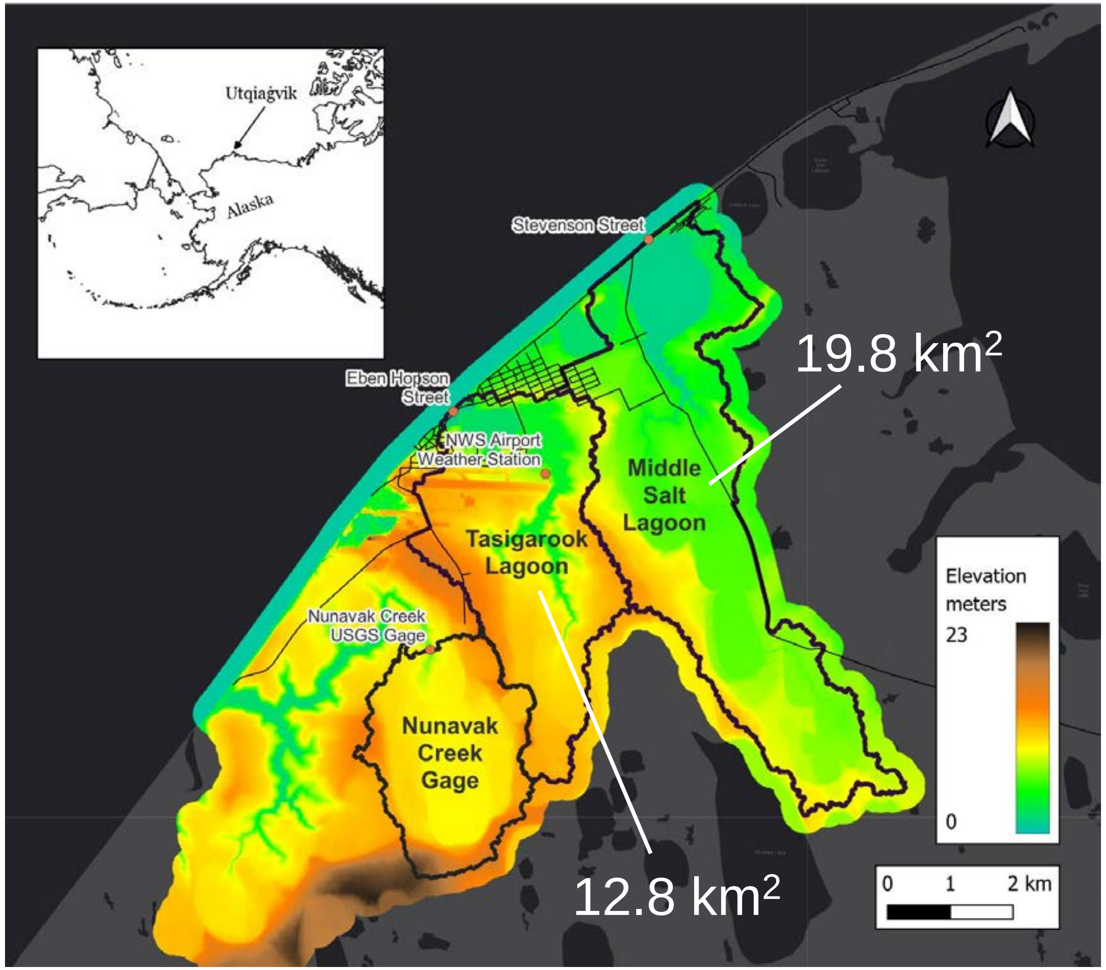


Study Objectives

- **Estimate water stage-frequency for both Middle Salt and Tasigarook Lagoons based on snowmelt runoff estimates into the lagoons**
- **Include confidence bounds which can be used in a risk-based framework for hydraulic structure design**

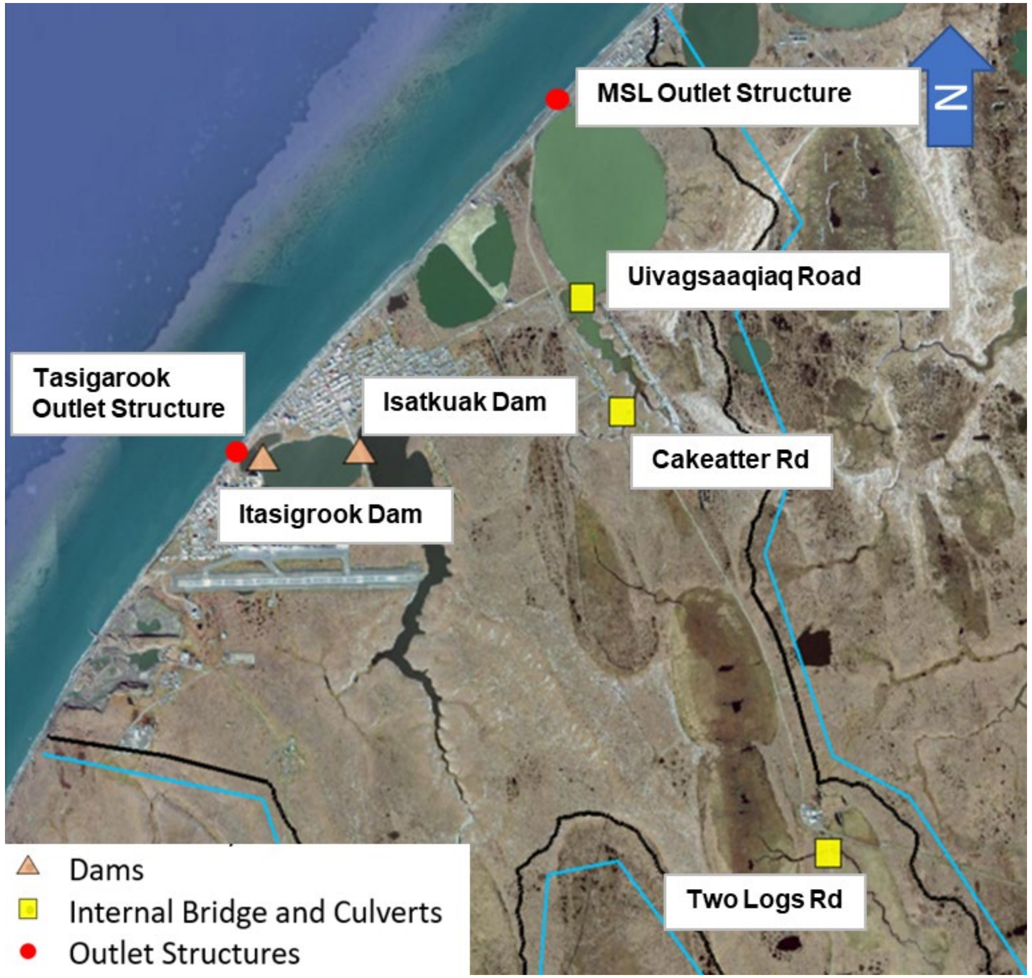
Middle Salt Lagoon outlet structure

Tasigarook Lagoon outlet structure



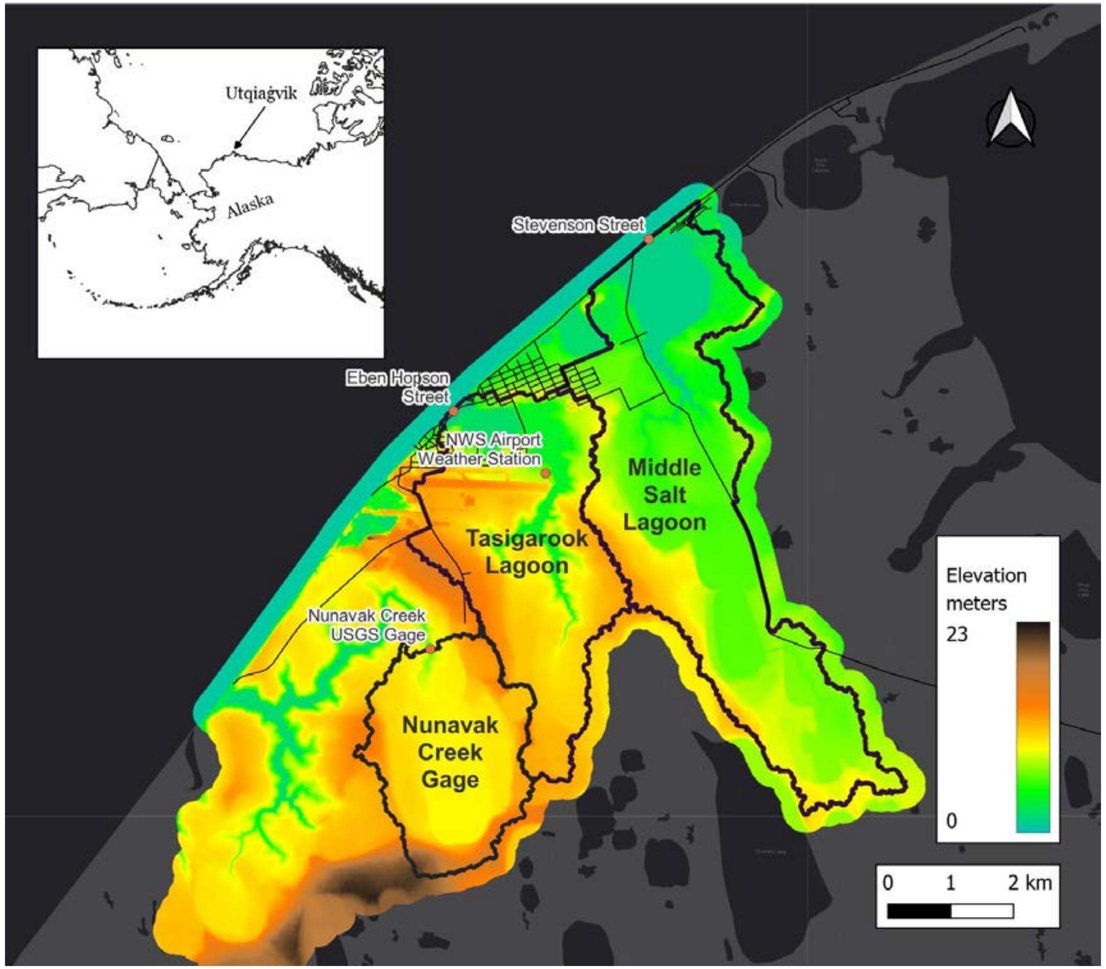
Study Location

- Lagoons located at upstream of outlets which discharge to the Arctic Ocean
- Watersheds contain hydraulic structures
  - Dams
  - Culverts
  - Outlets



Approach

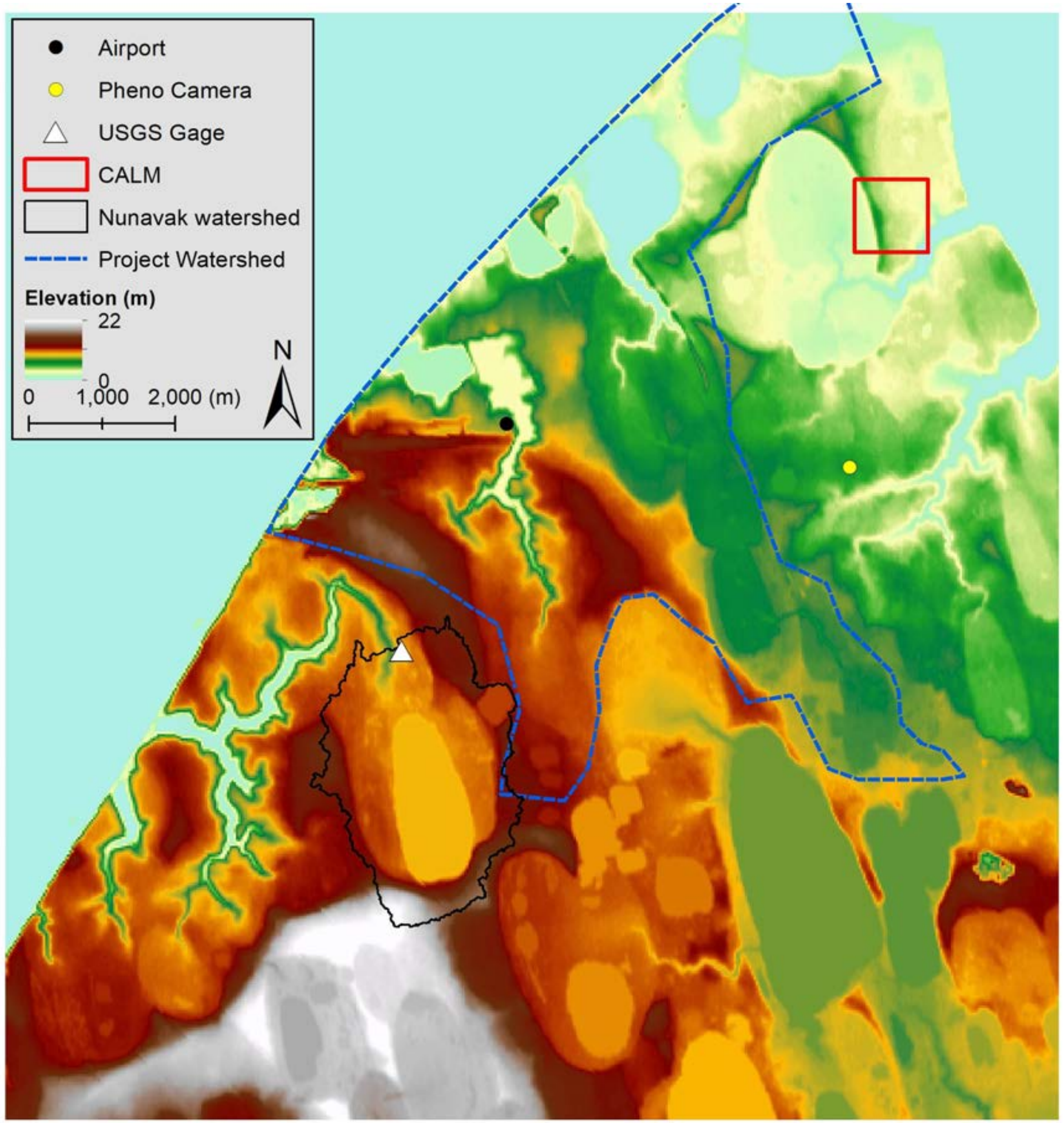
- **Modeling snow distribution and runoff (SnowModel)**
  - **Air temperature**
  - **Wind speed**
  - **Wind direction**
  - **Relative humidity**
  - **Precipitation**
- **Snowmelt runoff analysis (HEC-RAS and HEC-HMS)**
  - **Runoff from SnowModel**
- **Historical peak lagoon stage frequency**
- **Quantification of peak lagoon stage frequency uncertainty using a Monte Carlo simulation (HEC-WAT)**



HEC: Hydrologic Engineering Center; RAS: River Analysis Tool
HMS: Hydrologic Modeling System; WAT: Watershed Analysis Tool
CALM: Circumpolar Active Layer Monitoring

Snow modeling

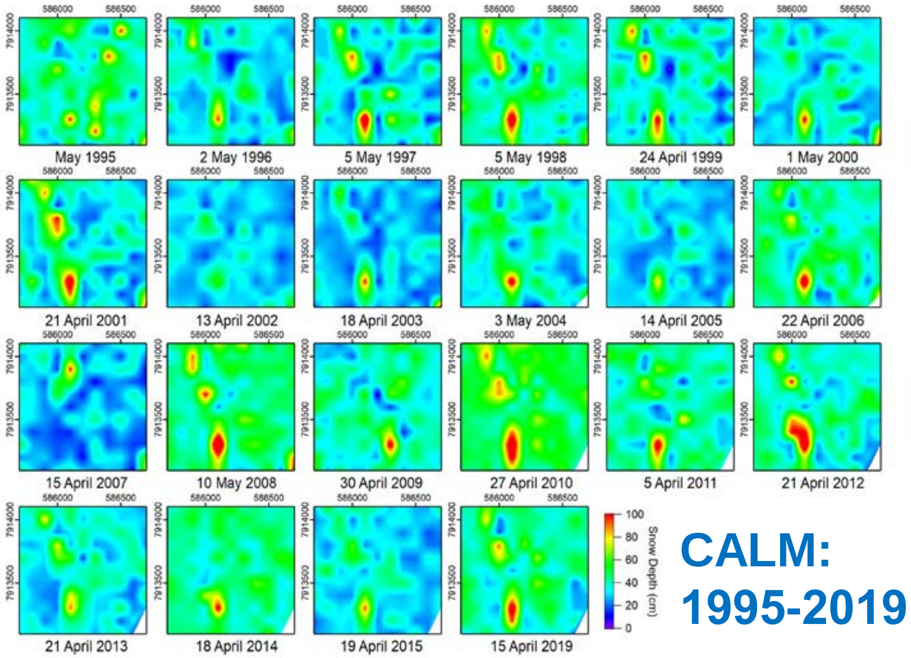
- **WY1982 - 2021**
- **Validation datasets**
  - **Field campaign SWE measurements**
  - **MODIS**
  - **Time-lapse camera (Phenocam)**



SWE: Snow water equivalent; MODIS: Moderate Resolution Imaging Spectroradiometer

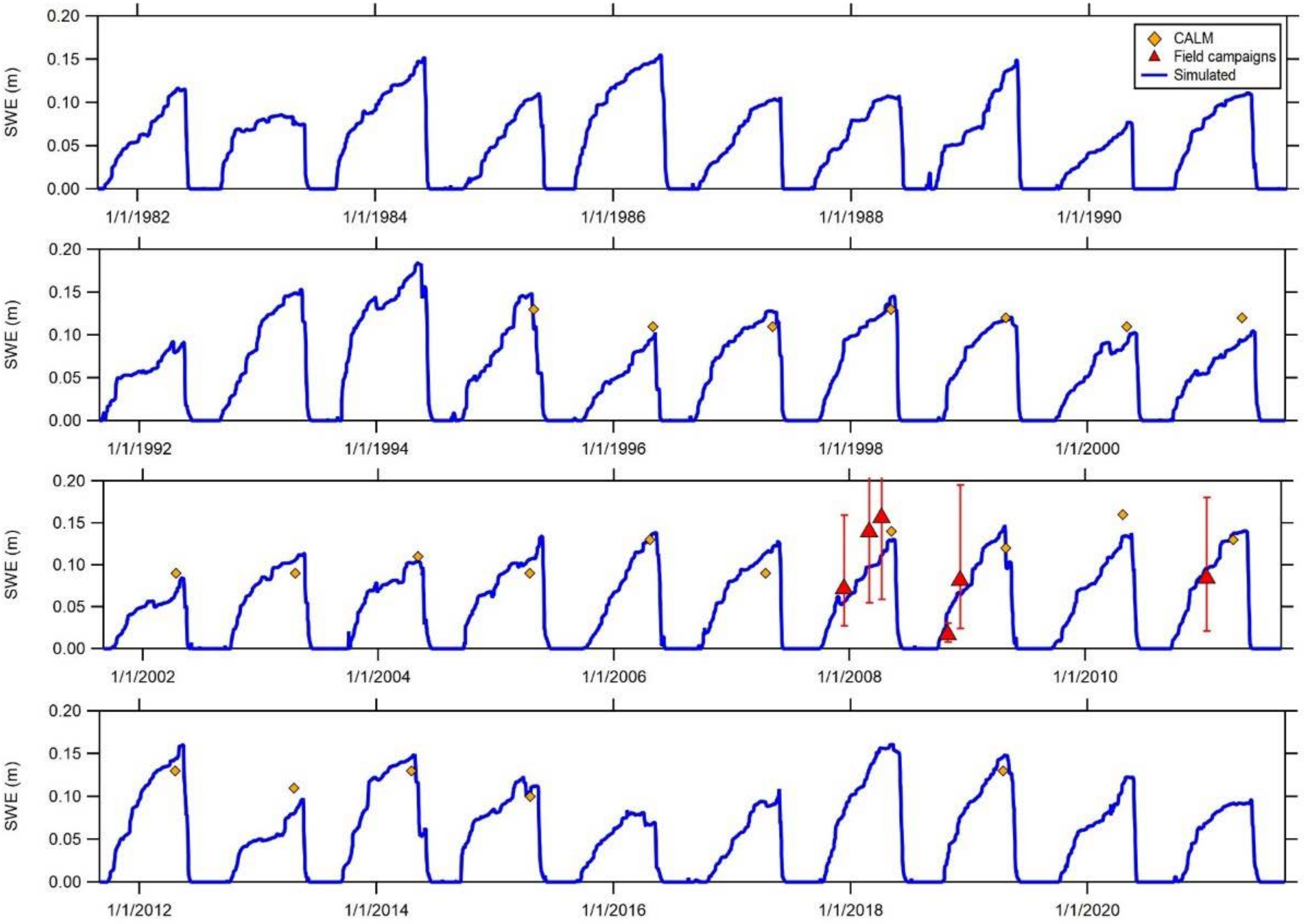
Snow modeling

- WY1982 - 2021
- Validation datasets
  - Field campaign SWE measurements
  - MODIS
  - Time-lapse camera (Phenocam)



CALM: 1995-2019

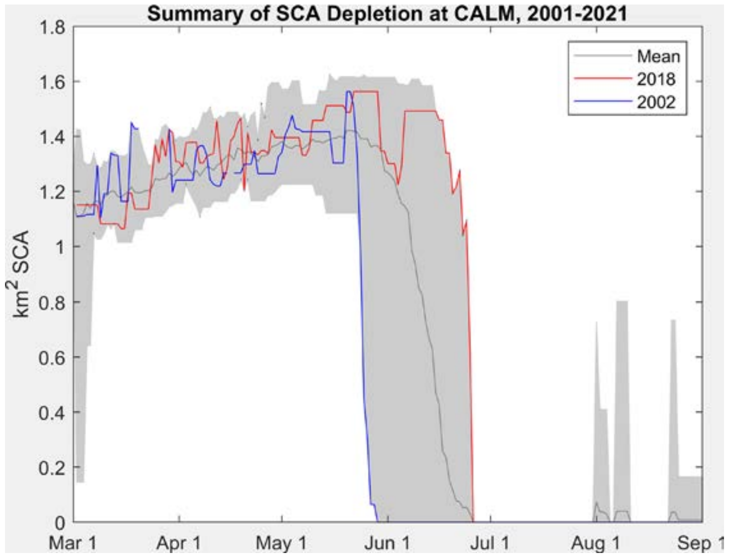
Snow model output – Field campaigns

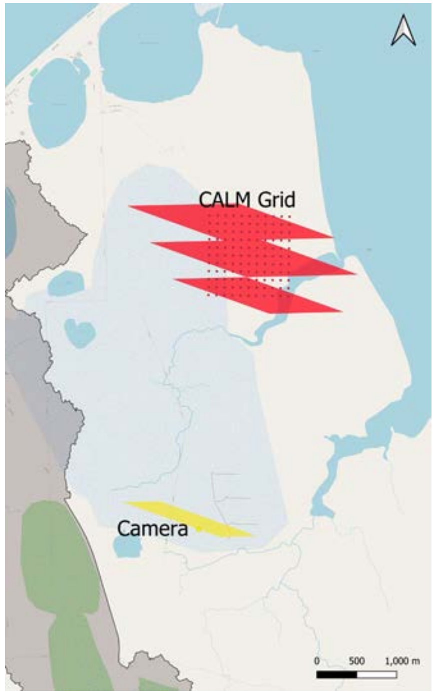


WY: Water year; SWE: Snow water equivalent; CALM: Circumpolar Active Layer Monitoring
MODIS: Moderate Resolution Imaging Spectroradiometer

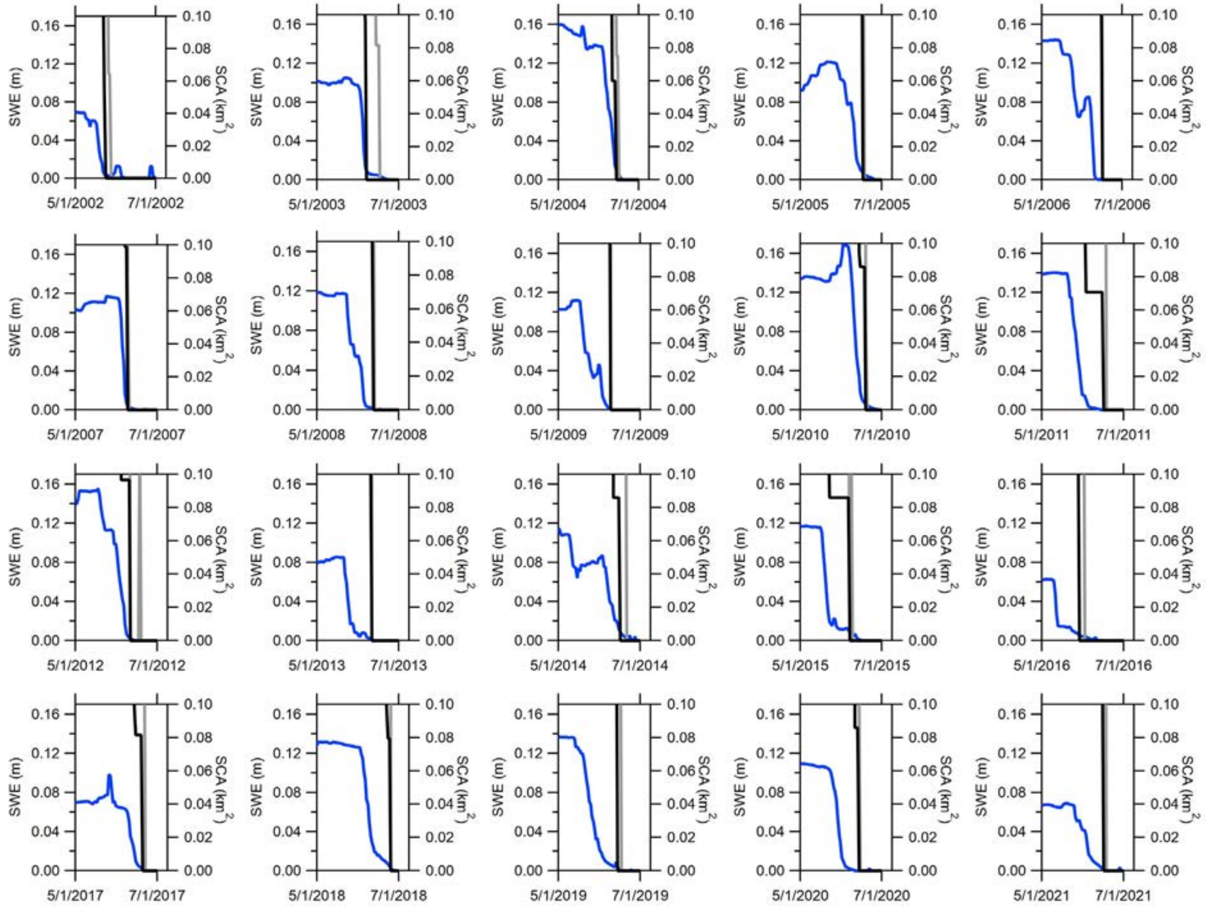
Snow modeling

- WY1982 - 2021
- Validation datasets
  - Field campaign SWE measurements
  - MODIS
  - Time-lapse camera (Phenocam)





MODIS



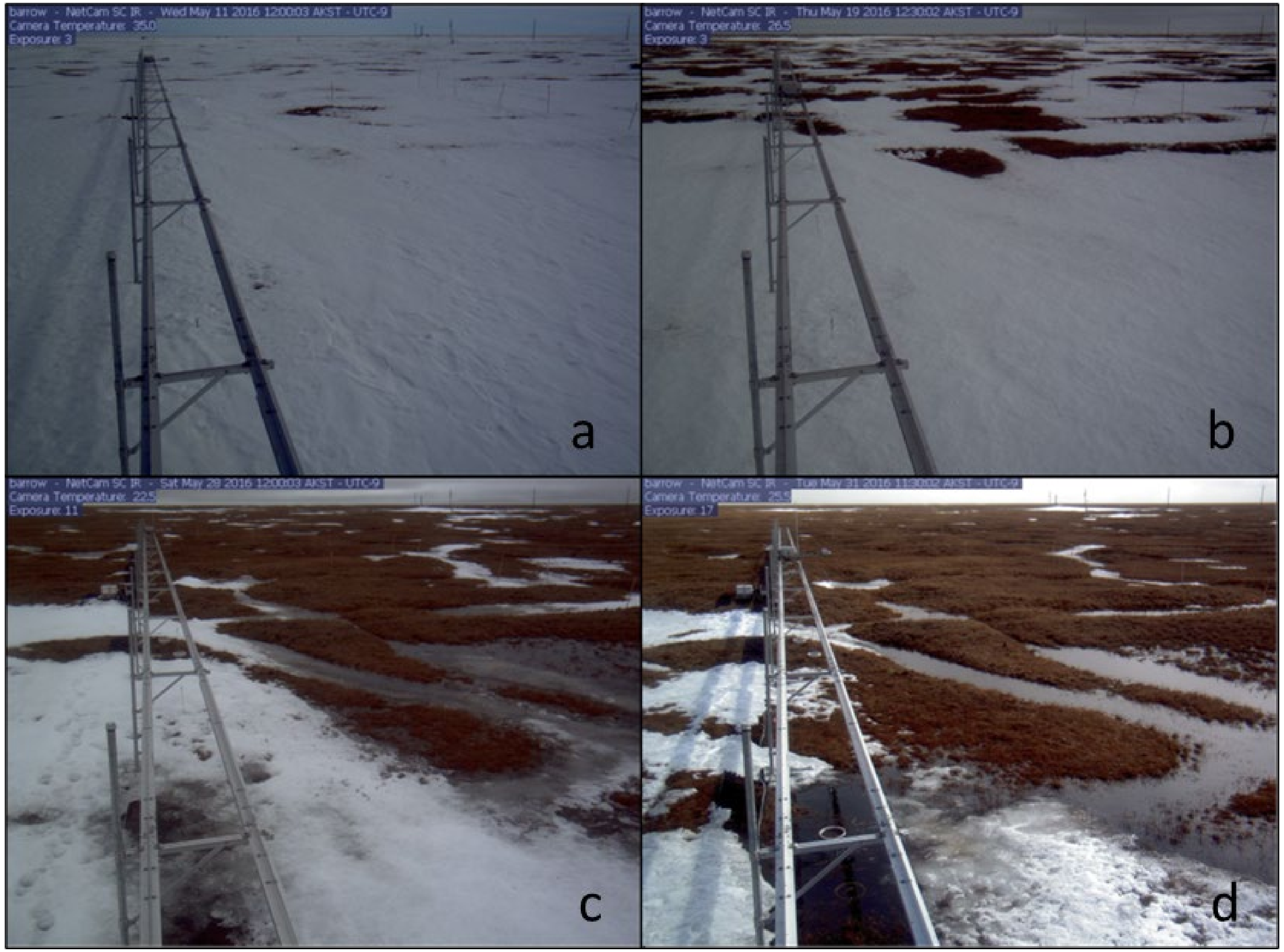
WY: Water year; SWE: Snow water equivalent; CALM: Circumpolar Active Layer Monitoring
MODIS: Moderate Resolution Imaging Spectroradiometer

Snow modeling

- **WY1982 - 2021**
- **Validation datasets**
  - **Field campaign SWE measurements**
  - **MODIS**
  - **Time-lapse camera (Phenocam)**

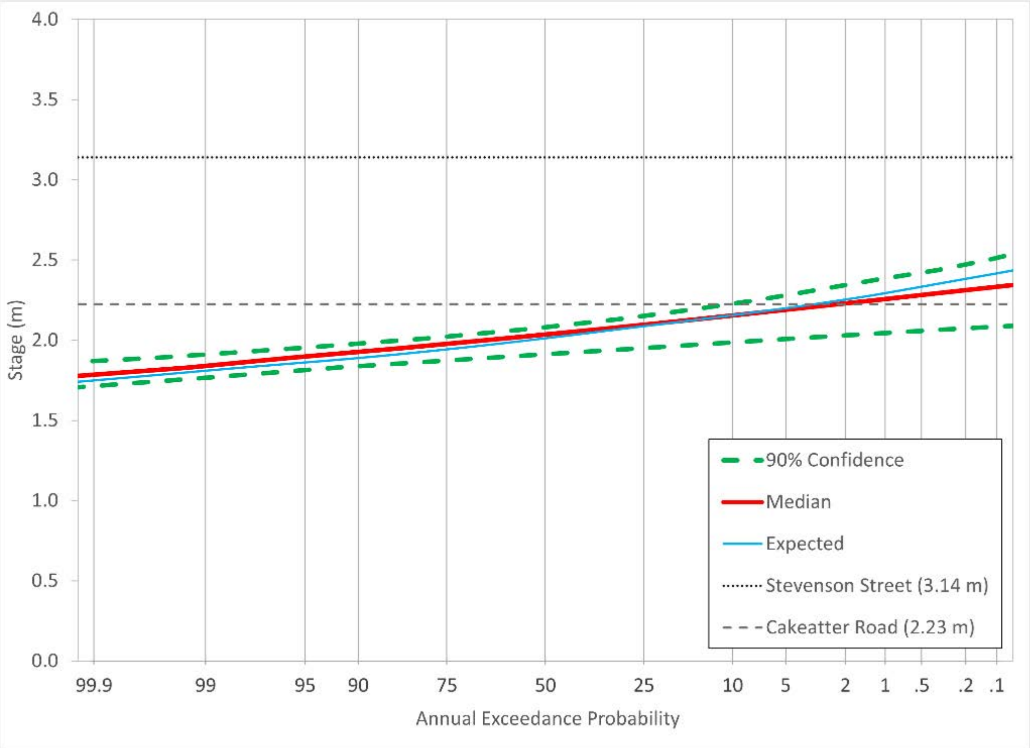
WY	Time-lapse camera snowmelt onset to snow free dates	Simulated snow free date
2015	18 May – 10 June	12 June
2016	11 May – 7 June	6 June
2017	1 June – 22 June	18 June
2018	7 June – 29 June	1 July
2019	1 June – 19 June	17 June

Time-lapse camera (Phenocam)

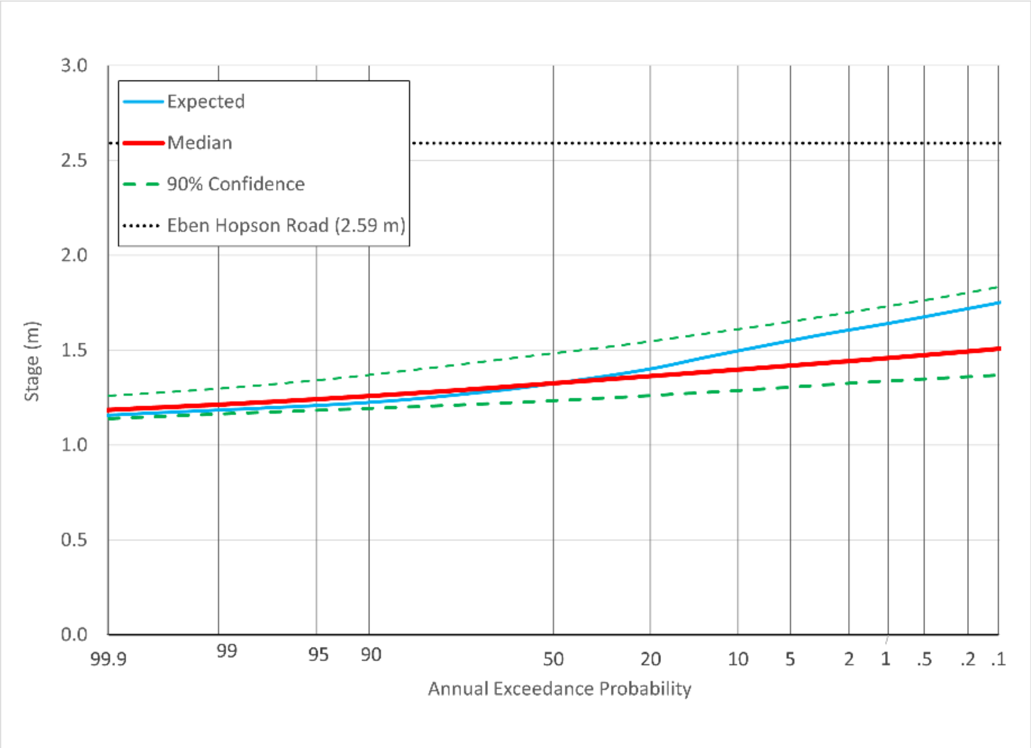


https://phenocam.nau.edu/webcam/sites/barrow/
WY: Water year; SWE: Snow water equivalent; CALM: Circumpolar Active Layer Monitoring
MODIS: Moderate Resolution Imaging Spectroradiometer

Results – Stage-frequency curves for both basins



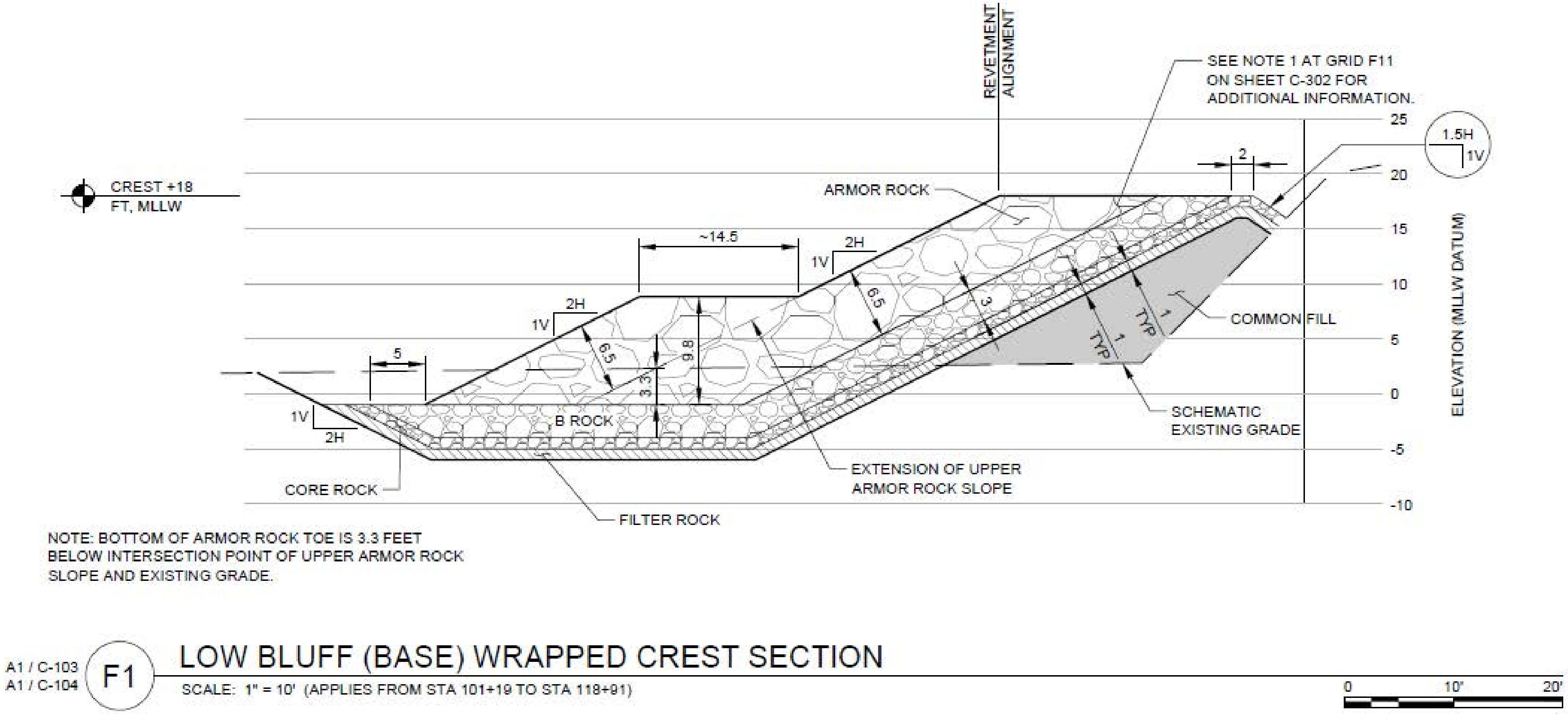
Middle Salt Lagoon



Tasigarook Lagoon

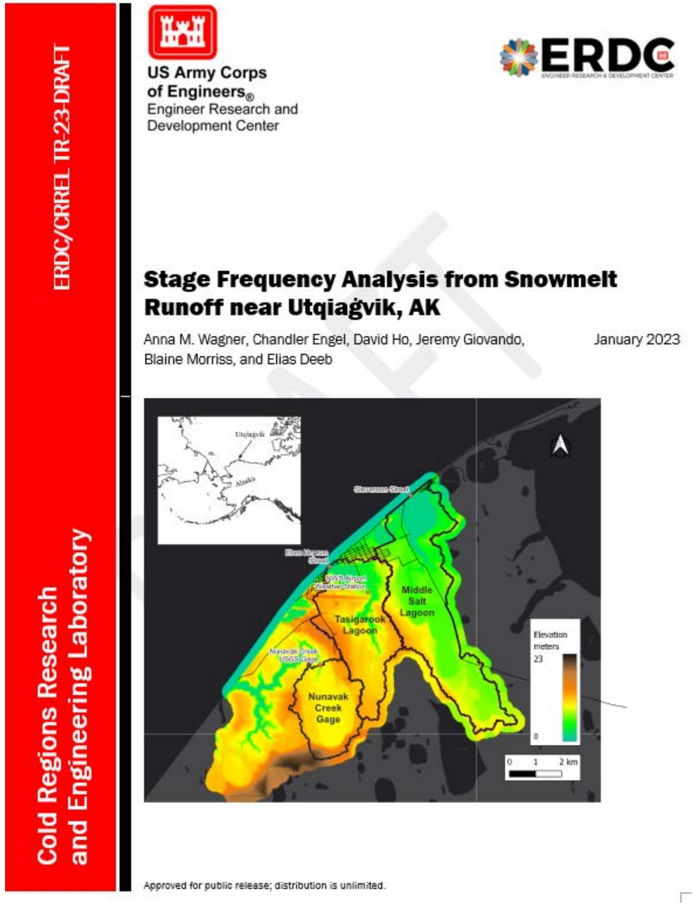
Revetment Status

- SATOC awarded to Brice Civil Consultants on 14 MAY 2024
- Task Order 1 included in the SATOC award provides for construction along the bluff sections of the coastline.
- Design of the outlet works for the lagoons and drainage system is underway and will be incorporated into future task orders.



Summary

- Challenging study
- Very little in-situ data for calibration/validation
- Arctic hydrology is hard
    - Low gradient terrain
    - Complex interactions between snow and runoff
- Method presents a way to indirectly capture uncertainty in runoff rates, and resulting lagoon stages
- Allows for design of hydraulic structures in a risk-based framework



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water MDPI

Article

Estimating Stage-Frequency Curves for Engineering Design in Small Ungauged Arctic Watersheds

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2 US Army Hydrologic and Engineering Center, Davis, CA 95616, USA; david.ho@usace.army.mil
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Abstract: The design of hydraulic structures in the Arctic is complicated by shallow relief, which cause unique runoff processes that promote snow-damming and refreeze of runoff. We discuss the challenges encountered in modeling snowmelt runoff into two coastal freshwater lagoons in Utqiagvik, Alaska. Stage-frequency curves with quantified uncertainty were required to design two new discharge gates that would allow snowmelt runoff flows through a proposed coastal revetment. To estimate runoff hydrographs arriving at the lagoons, we modeled snowpack accumulation and ablation using SnowModel which in turn was used to force a physically-based hydraulic runoff model (HEC-RAS). Our results demonstrate the successful development of stage-frequency curves by incorporating a Monte Carlo simulation approach that quantifies the variability in runoff timing and volume. Our process highlights the complexities of Arctic hydrology by incorporating significant delays in runoff onset due to localized snow accumulation and melting processes. This methodology not only addresses the uncertainty in snow-damming and refreeze processes which affect the arrival time of snowmelt inflow peaks, but is also adaptable for application in other challenging environments where secondary runoff processes are predominant.

Keywords: Arctic hydrology; snowmelt; ungauged watersheds; stage-frequency

check for updates

Citation: Engel, C.; Wagner, A.; Giovando, J.; Ho, D.; Morriss, B.; Deeb, E. Estimating Stage-Frequency Curves for Engineering Design in Small Ungauged Arctic Watersheds. *Water* **2024**, *16*, 1321. https://doi.org/10.3390/w16101321

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1. Introduction

Snowmelt runoff can be delayed by small-scale processes like snow-damming, meltwater storage in snowpacks, and refreezes. Although these processes are common in many regions that experience snowmelt, they are amplified in low gradient, extremely cold Arctic regions [1–3]. Common hydrologic modeling approaches used elsewhere typically ignore these processes with limited consequence. However, in the Arctic, snow-damming resulting from runoff collecting in snow-filled channels can delay runoff onset on the order of days and weeks [1].

Schramm et al. [1] applied TopoFlow to the Imnavait Creek watershed in Alaska and found that the onset of simulated discharge occurred 7 days earlier than measured discharge. They attributed this in part due to snow damming, which was not incorporated into the model due to a poor understanding of the process. Previously, Hinzman and Kane [4] also struggled with the complexities of snow dams when applying the Swedish Hydrologiska Byråns Vattenbalansavdelning (HBV) model to the same watershed. They applied an empirical calibration parameter (MAXBAS) between 1 and 5 days to account for the delay. Pohl et al. [2] used WATCLASS, a water and energy model [5], to simulate snowmelt runoff in Trail Valley Creek, located in a small Arctic watershed in Canada. They also noted the model predicted early runoff inception, which they attributed to meltwater storage and percolation through snow and snow damming in the streams. A review by Biu et al. [6] discusses the key hydrologic models used for surface Arctic hydrology, namely Topoflow, HBV, Soil and Water Assessment tool (SWAT), Ecological Model for

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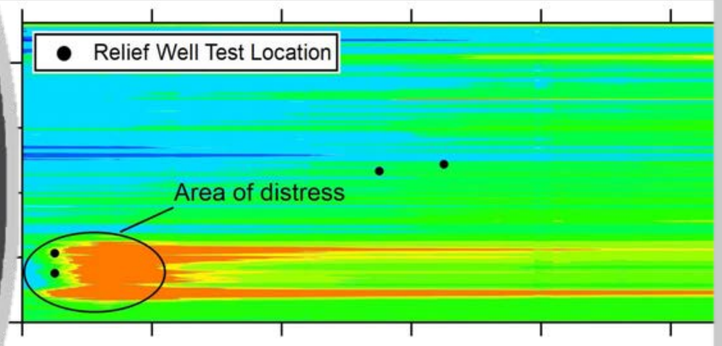
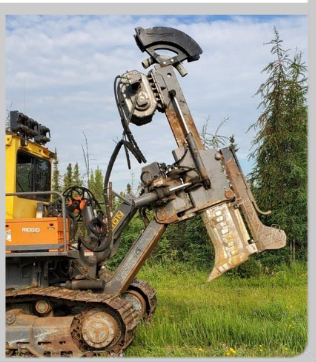
MONITORING OF MOOSE CREEK DAM, NORTH POLE, AK

Anna Wagner, Research Environmental Engineer – CRREL
Nathan Epps, Civil Engineer, AK District





US Army Corps of Engineers

Fairbanks – 1967 Flooding

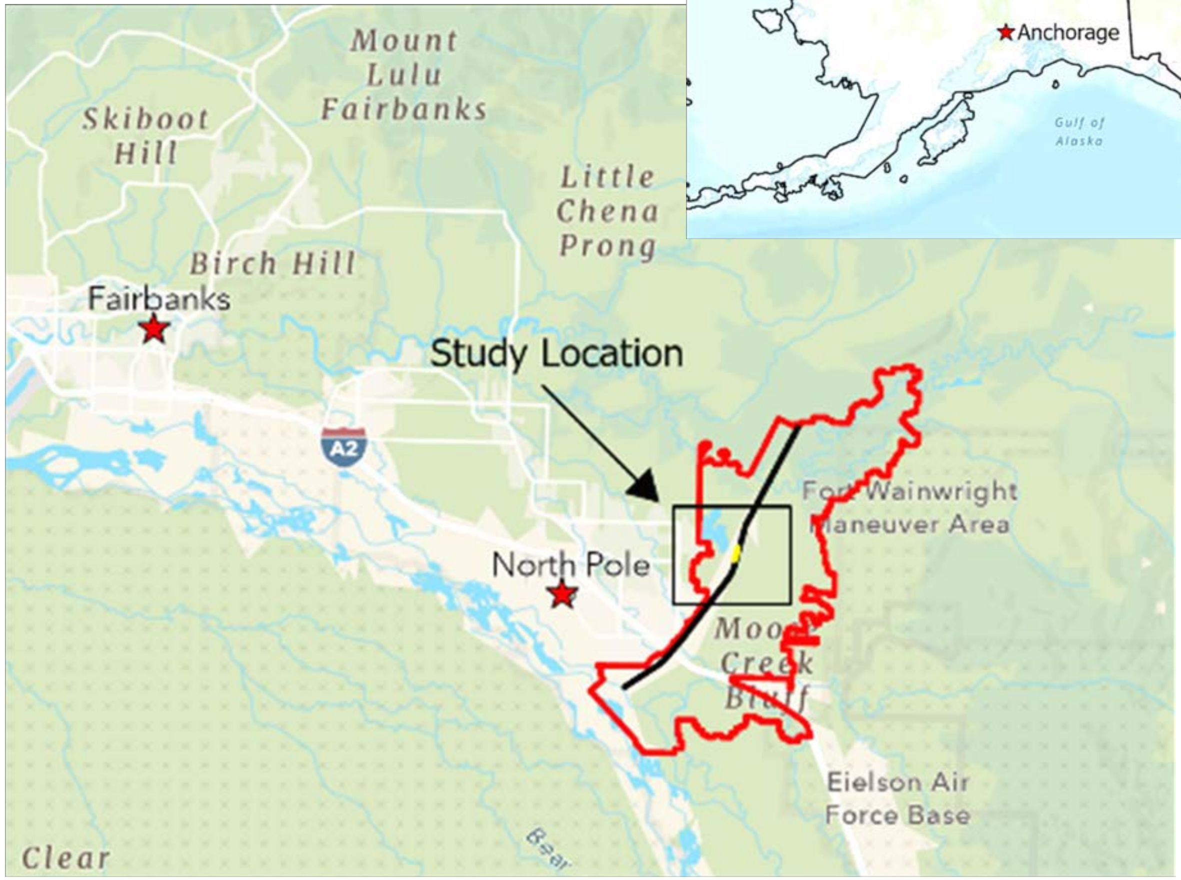
Chena River – Fairbanks

Ladd Field – Fort Wainwright

- 95% of Fairbanks flooded
- 12,000 people evacuated
- $170 Million in damage
- ~6,000 homes damaged

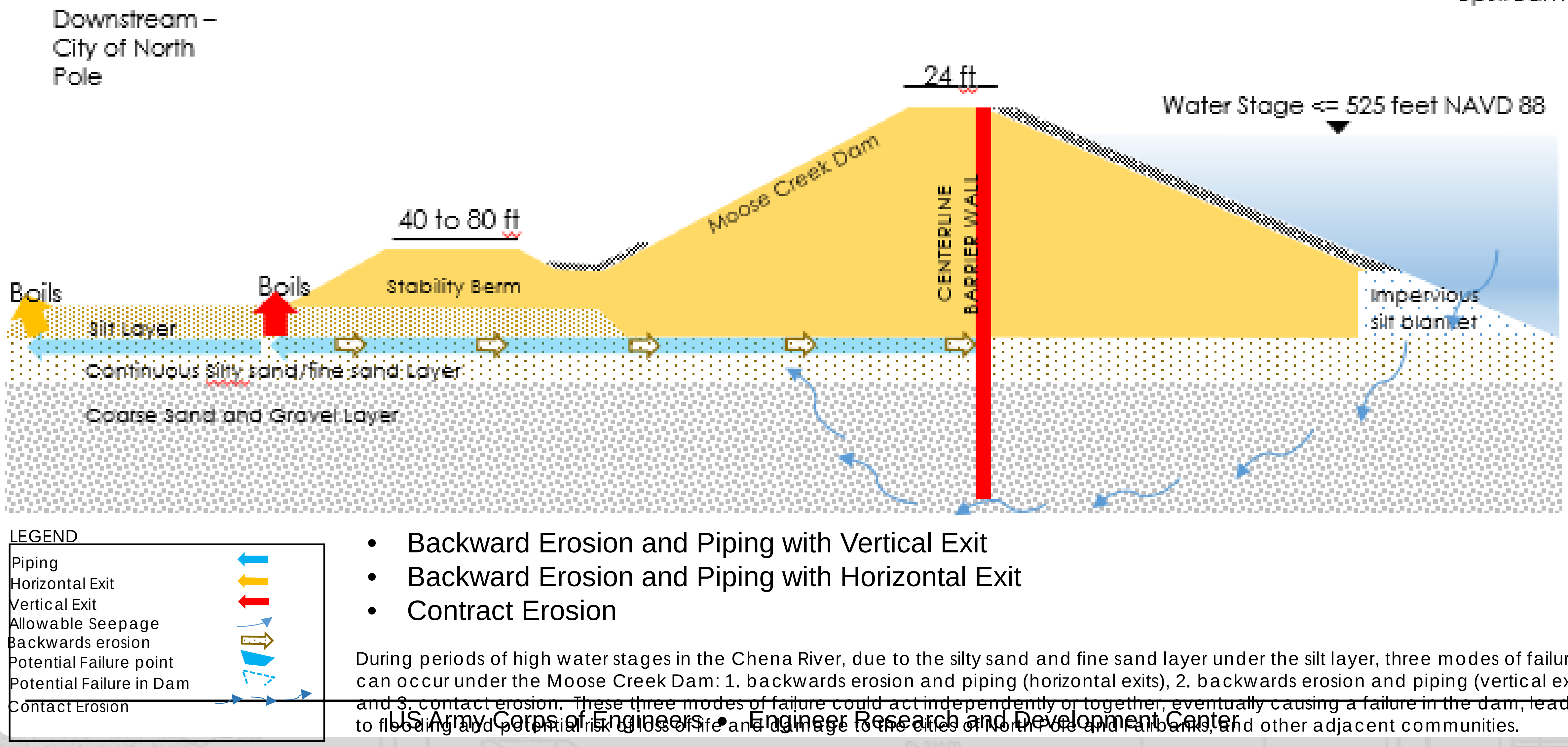
Moose Creek Dam (MCD)

- Built after the 1967 flood
- 12 km long earthen Dam
- 150 piezometers
- Measured manually once a day
- Time-consuming effort and
- Does not capture the fluctuations of the water table during a flood event



Potential Failure modes

*Allowable seepage will still occur and will be maintained and monitored as it currently is.



- Backward Erosion and Piping with Vertical Exit
- Backward Erosion and Piping with Horizontal Exit
- Contract Erosion

During periods of high water stages in the Chena River, due to the silty sand and fine sand layer under the silt layer, three modes of failure can occur under the Moose Creek Dam: 1. backwards erosion and piping (horizontal exits), 2. backwards erosion and piping (vertical exits) and 3. contact erosion. These three modes of failure could act independently or together, eventually causing a failure in the dam, leading to flooding and potential risk of loss of life and damage to the cities of North Pole and Fairbanks, and other adjacent communities.

Internal Erosion – Sand Boils

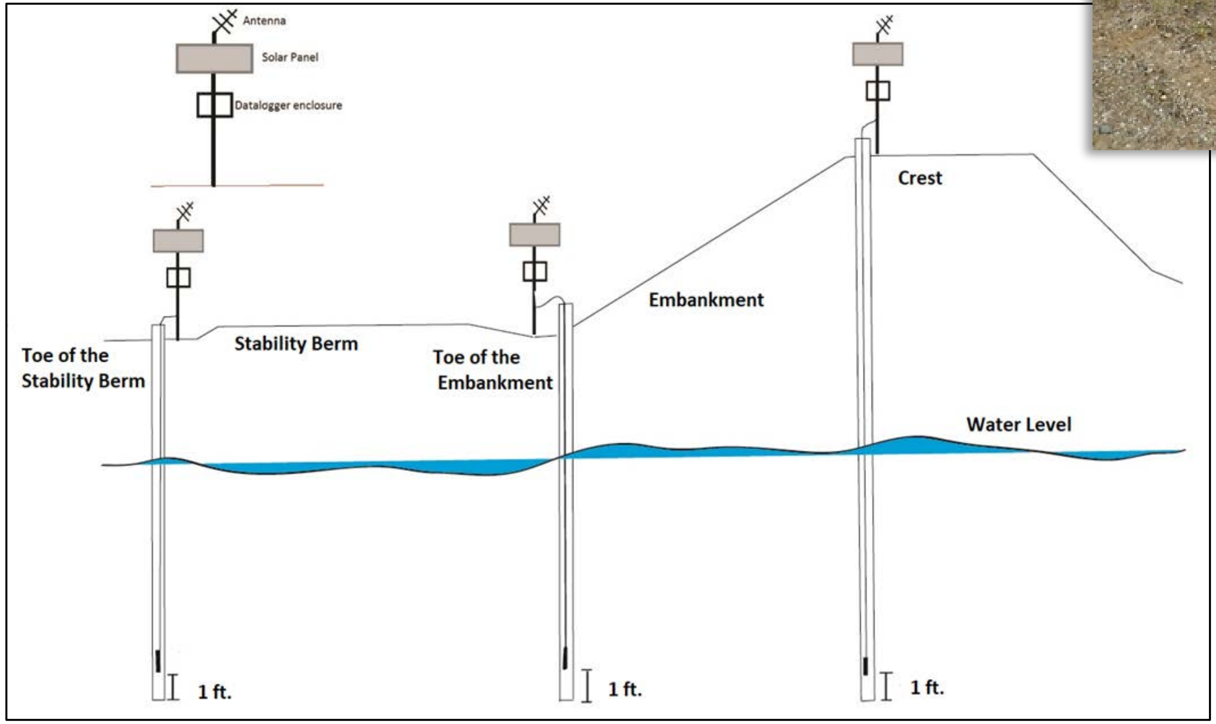
- Not a reliable early warning indicator
- No documented timeline until a failure might occur
- Spaced too far apart to serve as a seepage monitoring system
- Distress seen in 2014 (minor floods)
- 1,000+ sand boils detected

Boil classification	Silt Cone Size Range (Feet)	Typical Throat Size (Inches)
Small/Pin	0.0 to 0.5	0.25 to 1.0
Medium	0.5 to 2.0	1.0 to 2.0
Large	2.0 to 4.0	1.0 to 9.0
Extra Large	4.0 to 10.0 or larger	4.0 to 12.0

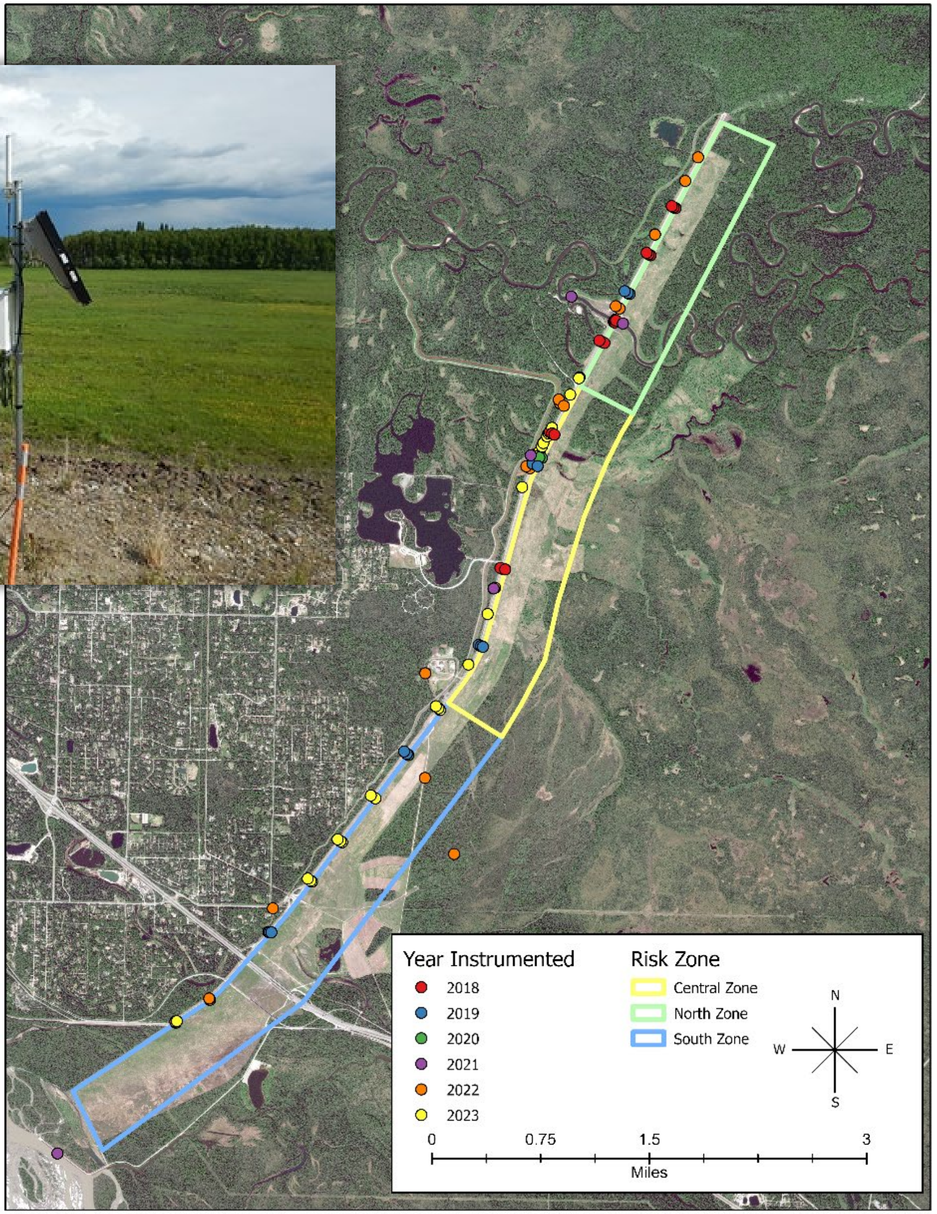
The height of boils ranged from an inch to one foot and was typically equalized with tail water level.

Automatic Monitoring – Groundwater levels

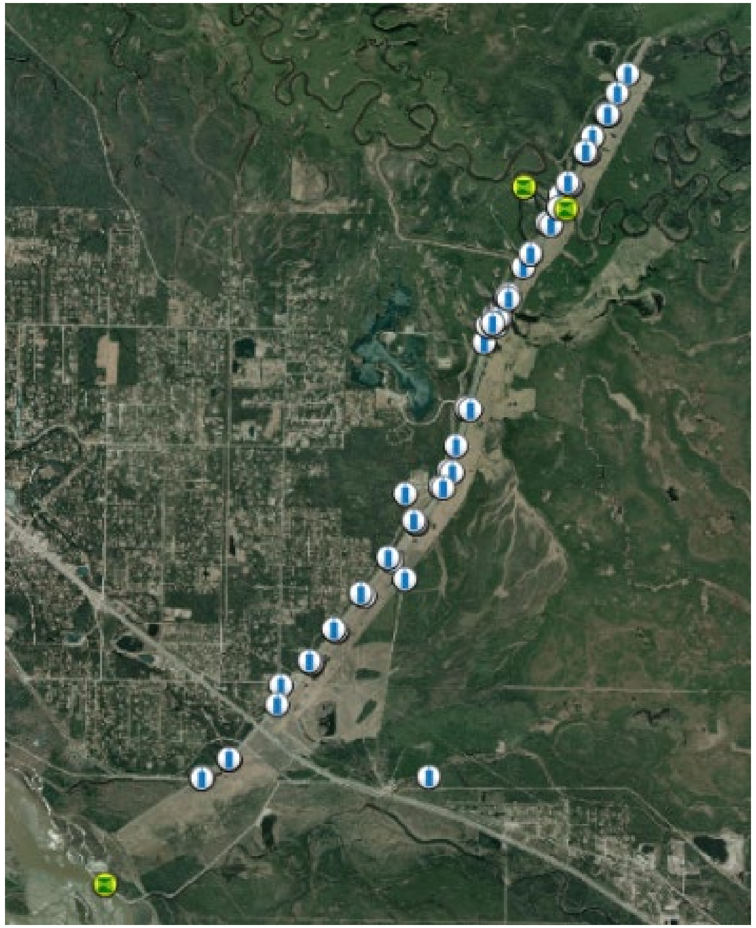
- **104 automated piezometers**
- **5 pool elevation sites**

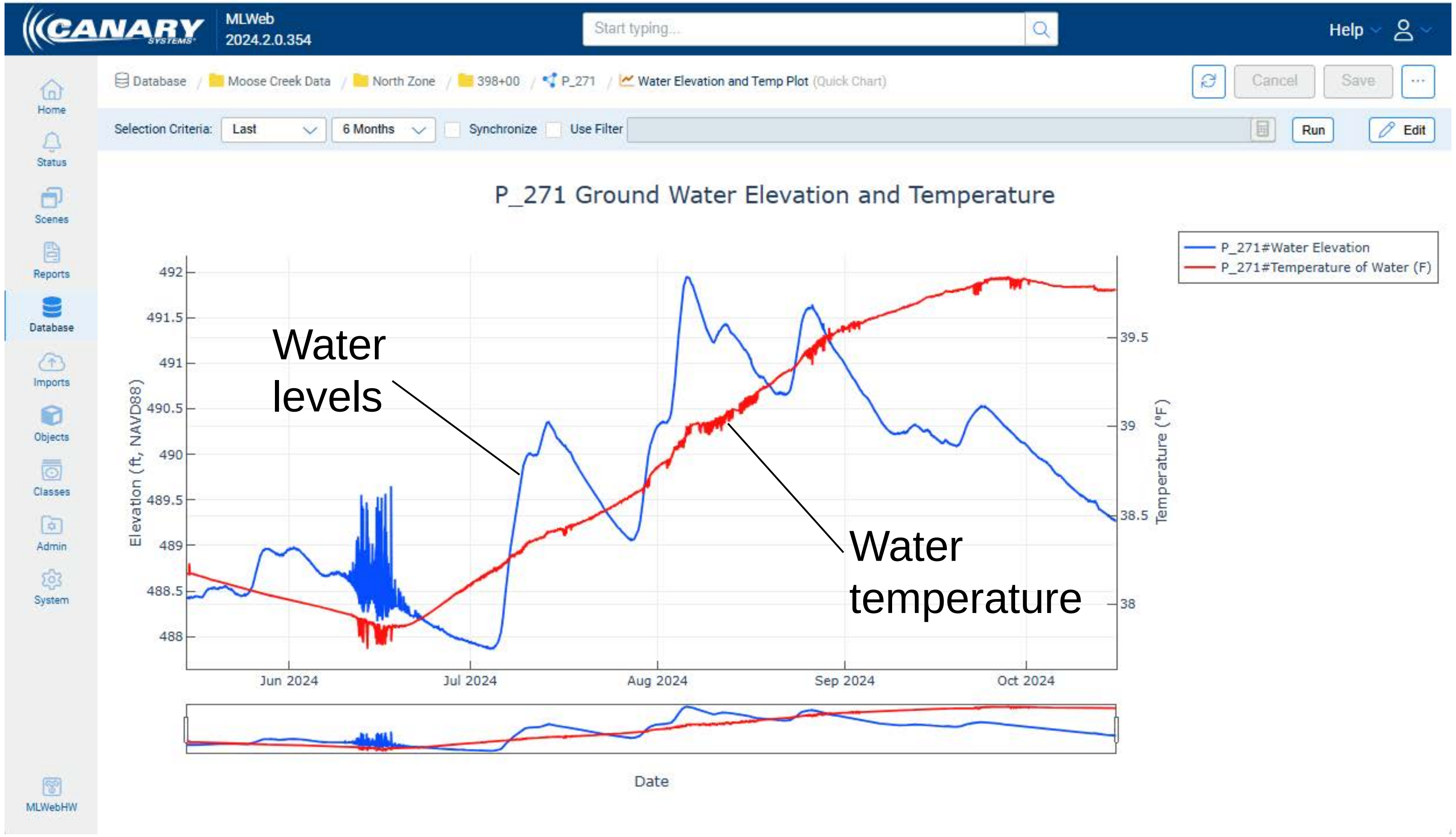


Position of piezometers located along the embankment berm.

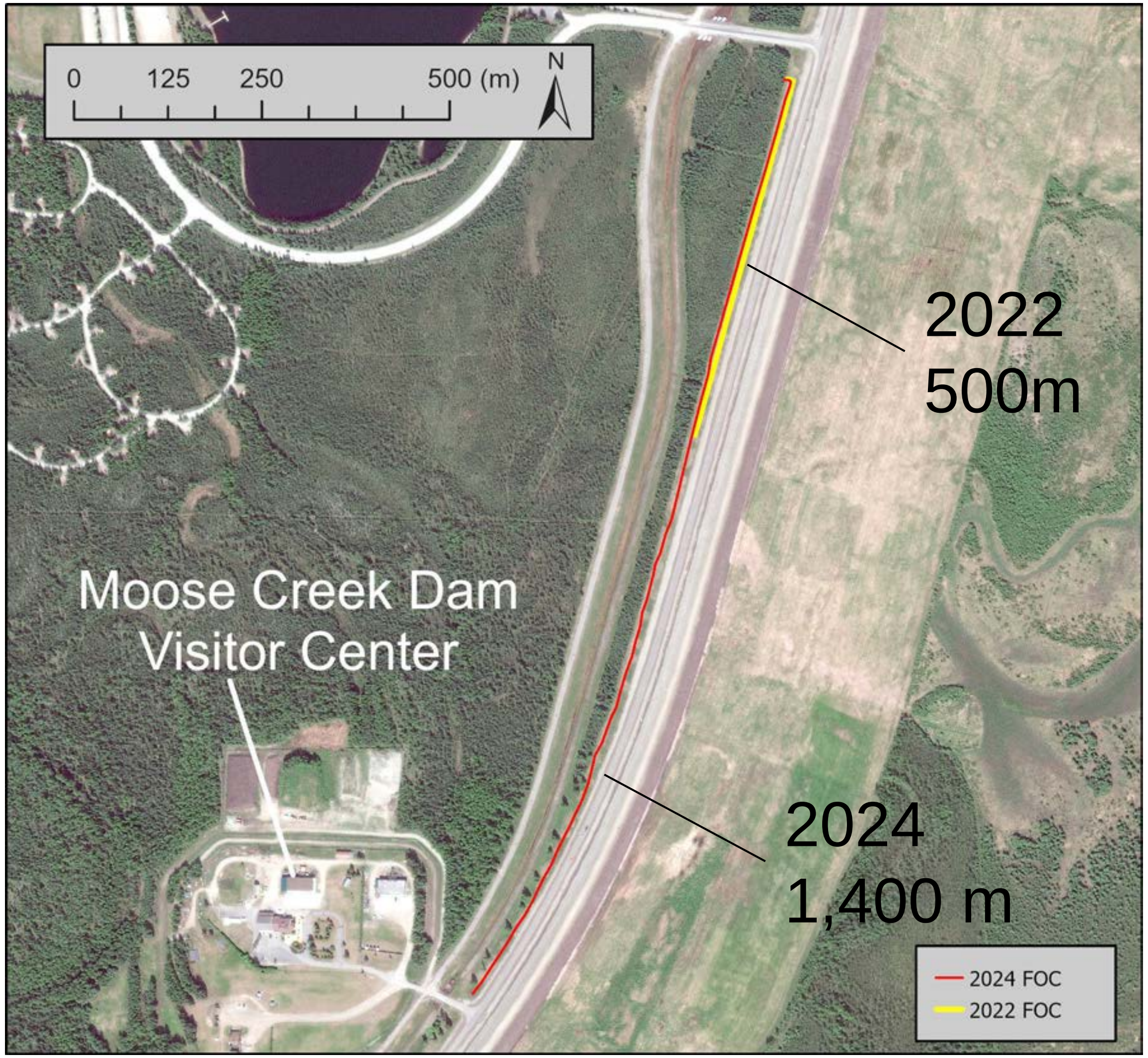


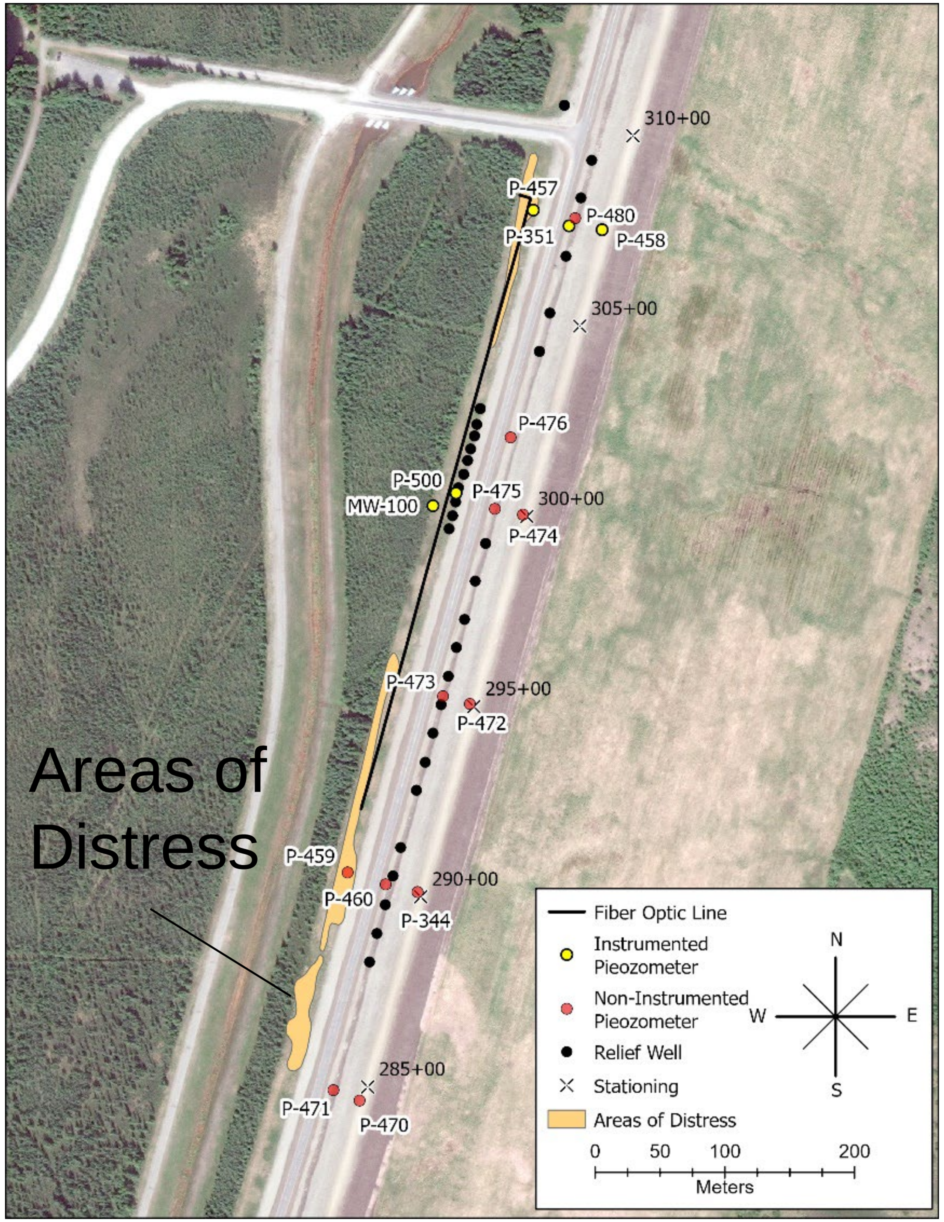
Online Platform – Groundwater Levels





Fiber optic monitoring – Temperature





Distributed Fiber-Optic Sensing

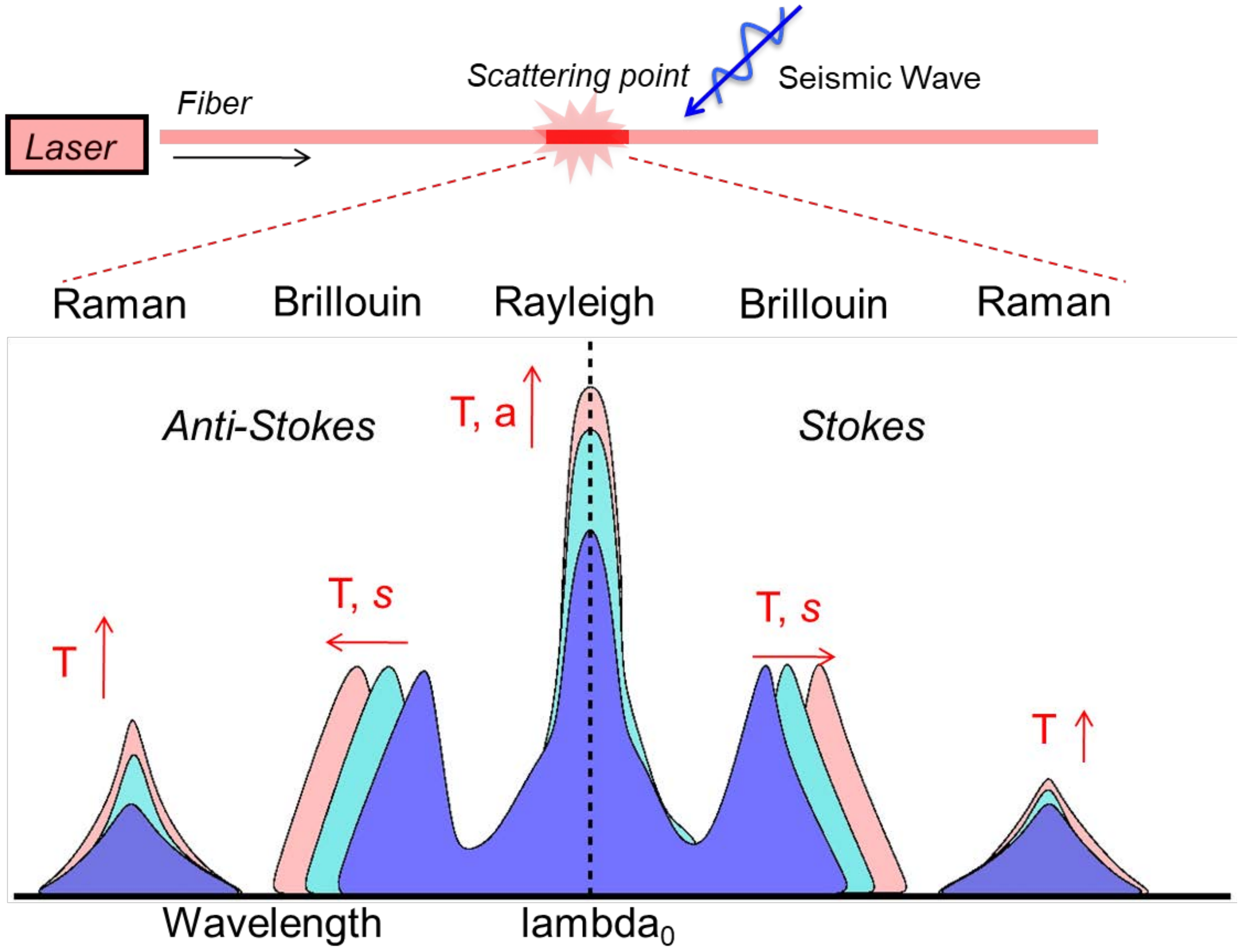
Concept :
Measure scattering from every point along a continuous fiber

Changes in fiber environment (T, strain, vibration) alter scattering.

Raman : (DTS)
Strong T dependence

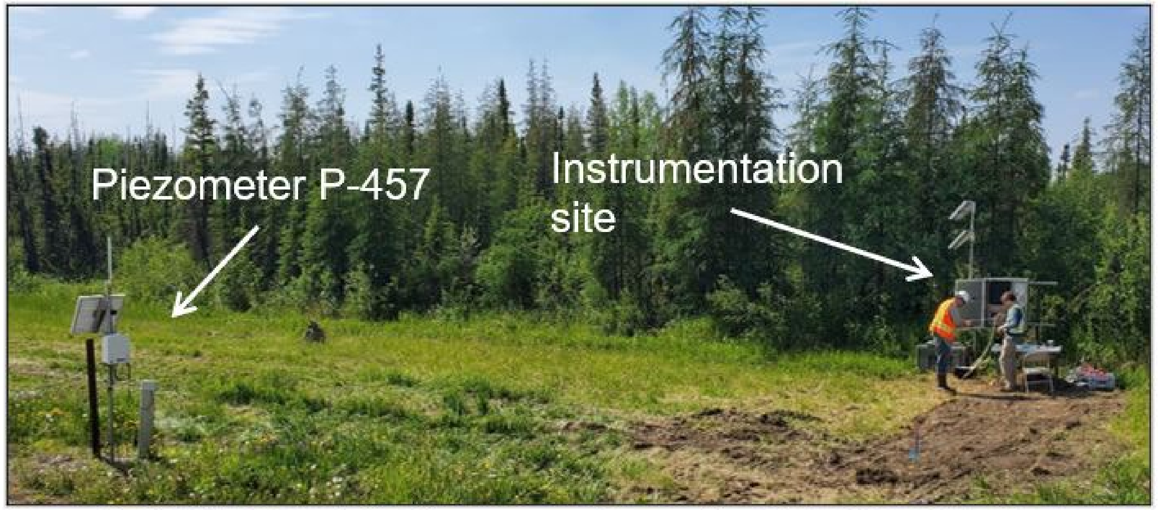
Brillouin : (DTS, DSS)
Wavelength shift during strain and T variation

Rayleigh : (DAS)
Amplitude variation induced by vibration, also T.



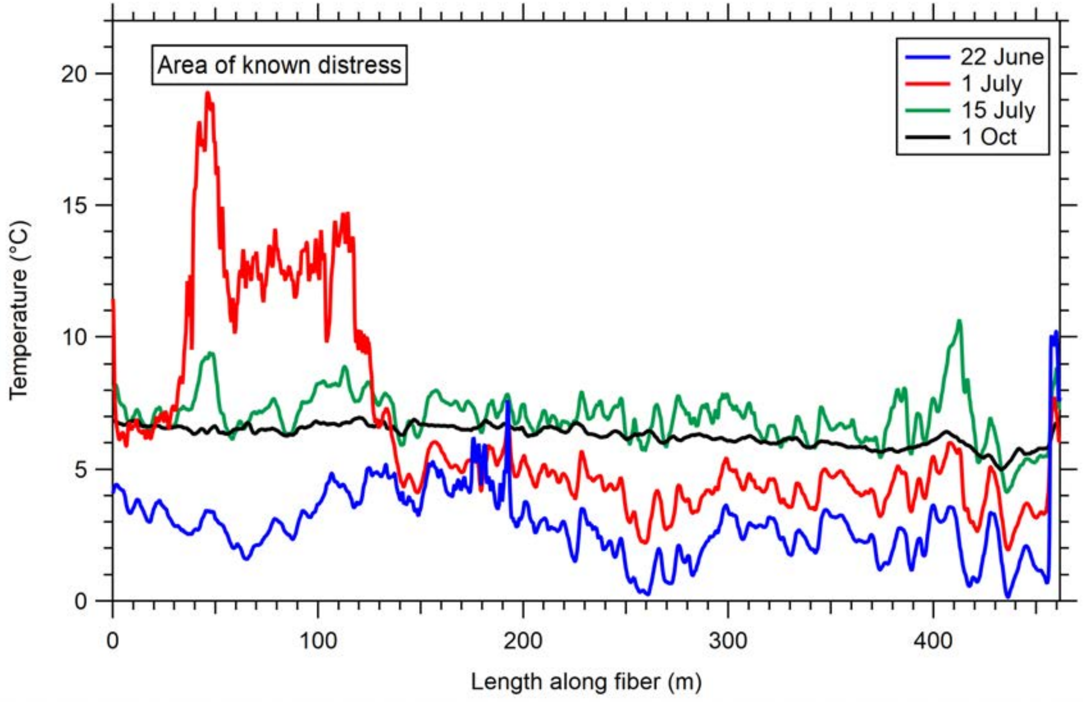
DTS: Distributed Temperature Sensing; DSS: Distributed Strain Sensing; DAS: Distributed Acoustic Sensing

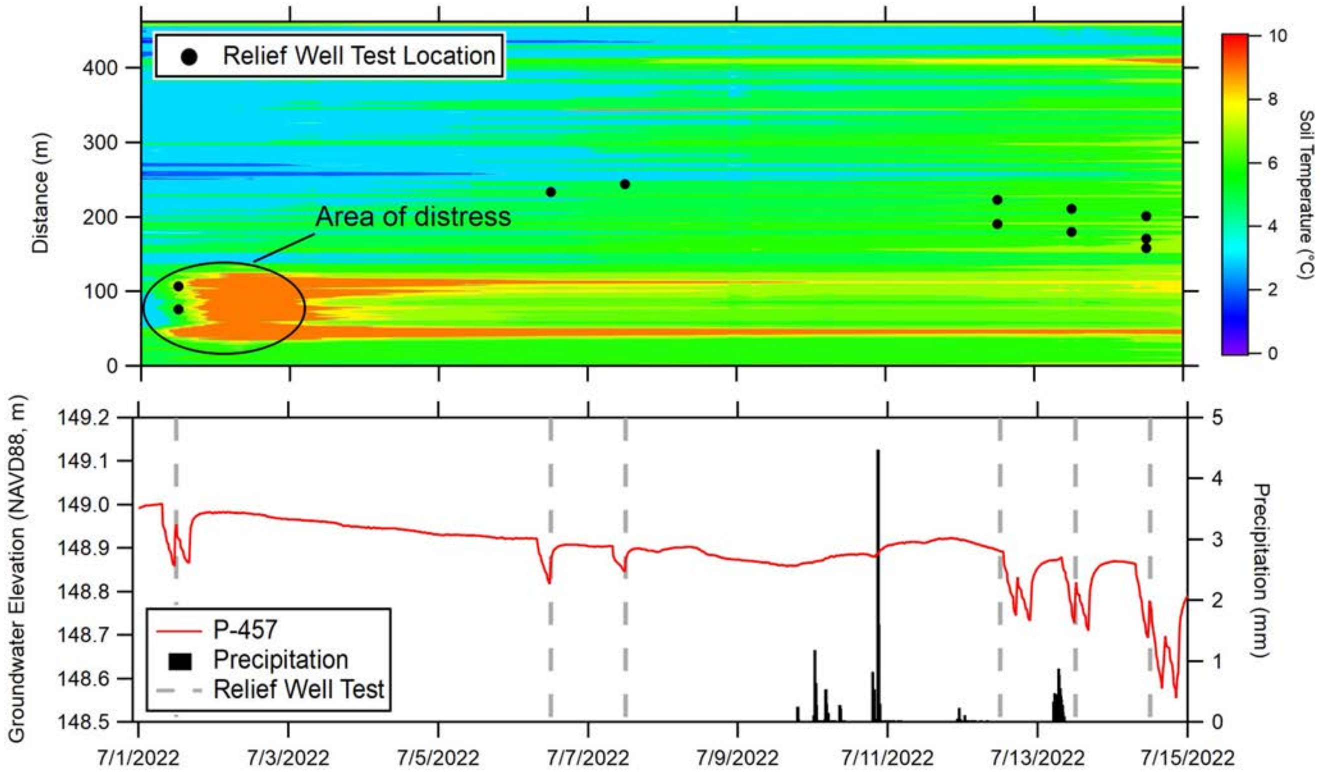
Fiber optic installation



DTS: Distributed Temperature Sensing

Relief well testing 2022

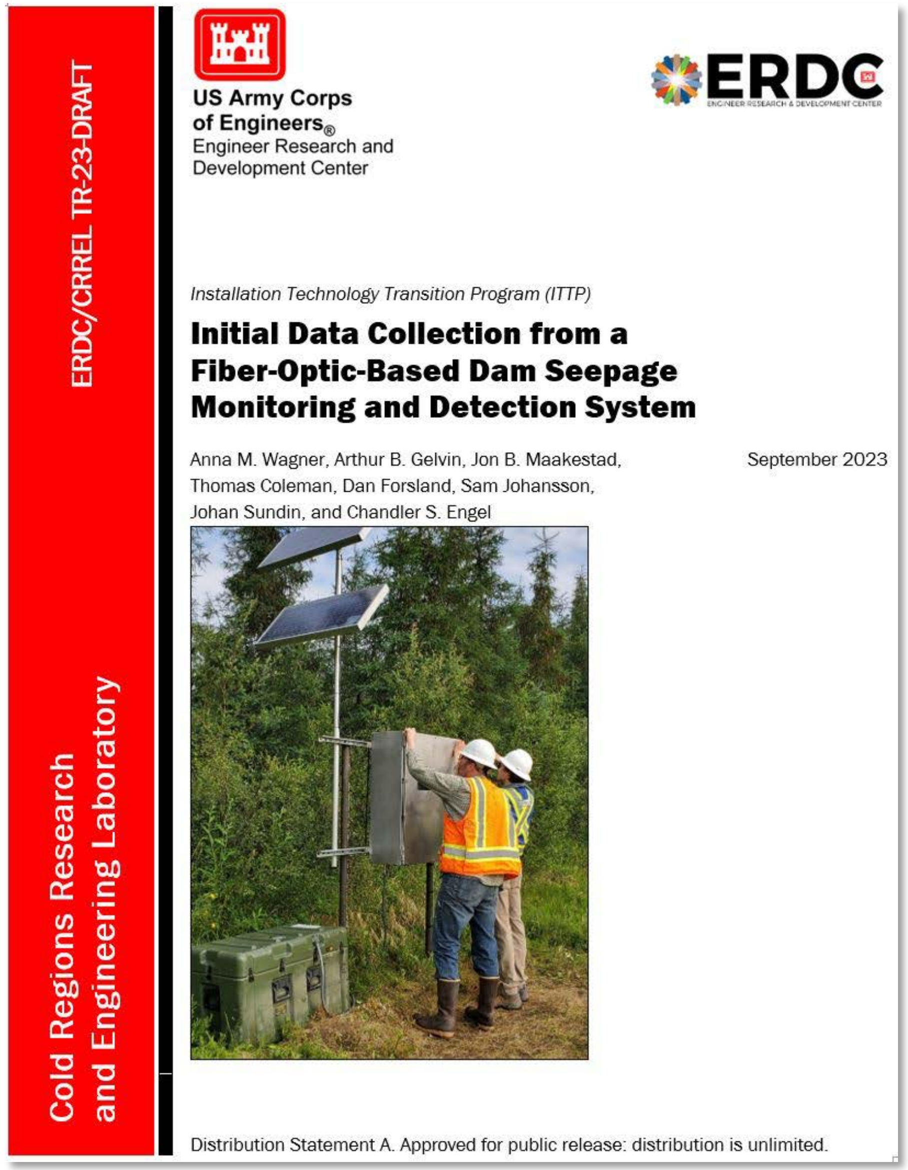




Summary

- **Automatic monitoring of groundwater levels**
  - **104 piezometers**
  - **5 pool elevation sites**

- **Fiber optic temperature monitoring**
  - **Pilot installation 2022 – 500 m**
  - **Installation 2024 – 1,400 m**



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Installation Technology Transition Program (ITTP)

Initial Data Collection from a Fiber-Optic-Based Dam Seepage Monitoring and Detection System

Anna M. Wagner, Arthur B. Gelvin, Jon B. Maakestad, Thomas Coleman, Dan Forsland, Sam Johansson, Johan Sundin, and Chandler S. Engel

September 2023

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Questions?

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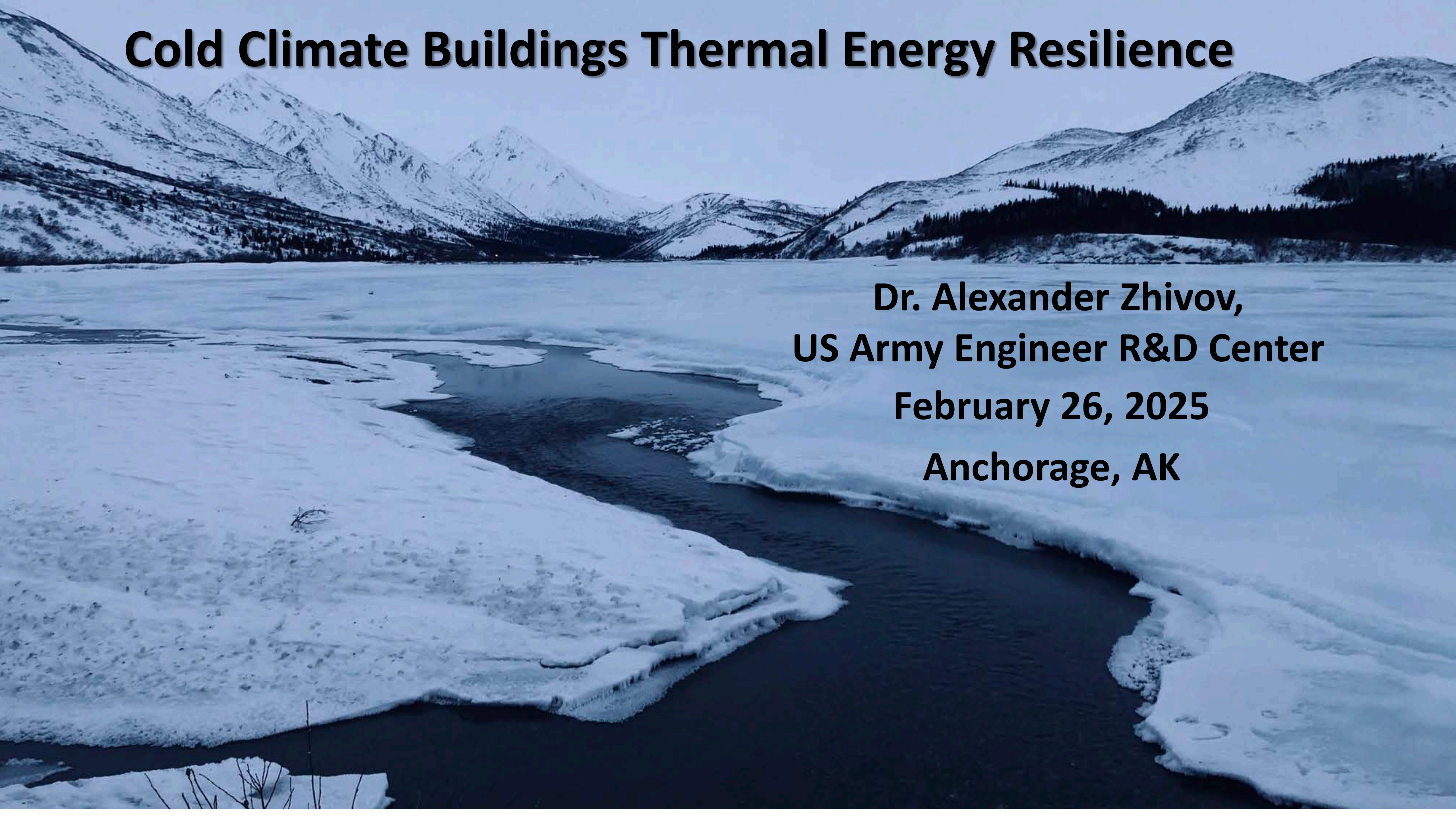
Cold Climate Buildings Thermal Energy Resilience

Dr. Alexander Zhivov,

US Army Engineer R&D Center

February 26, 2025

Anchorage, AK



Background

- International Energy Agency Annex 93 “Energy Resilience of Buildings in Remote Cold Regions”
- USACE “Cold Climate Thermal Resilience Criteria Project”
- ESTCP EW22-7473 project supplement “Moisture Analysis in Walls in Cold Climates”
- DOE BTO Support to the IEA Annex 93

Collaborative Project includes Participants from 10 countries)

- **Norway**
  - SINTEF, Norway
  - Norwegian University of Science and Technology (NTNU), Norway
  - UIT The Arctic University of Norway
  - Norwegian Defence Estates Agency (NDEA)
- **Denmark**
  - DTU, Denmark
  - University of Southern Denmark, Denmark
  - Ministry of Defence, Denmark
  - COWI A/S
  - Aalborg University
- **USA**
  - **US Army, USA (ERDC, USACE)**
  - **NREL**
  - **University of Alaska**
  - **National Personal Protective Technology Laboratory (NPPTL)/NIOSH/CDC,**
  - **ASHRAE**
  - **RDH Building Inc**
  - **ZAE**
  - **Design Alaska Inc**
  - **LBNL**
  - **Alaska Thermal Imaging**
  - **U.S. Air Force**
  - **Danfoss**
- **China**
  - Tsinghua University
- **Finland**
  - VTT, Finland
  - Arctic Construction Cluster Finland
- **Sweden**
  - Lund University, Sweden
  - Linköping University, Sweden
  - University of Gavle, Sweden
  - KTH, Sweden
  - Luleå University
  - LTU Business
  - Tekniska verken
- **Canada**
  - University of Toronto
  - RDH building science
  - ASHRAE
  - Carleton University, Canada
  - Concordia University, Canada
  - HDA Engineering, Canada
  - Natural resources Canada
  - University of Ottawa
- **Japan**
  - Tokyo City University, Japan
  - Hokkaido University, Japan
- **UK**
  - Imperial College
- **Iceland**
  - Reykjavik University

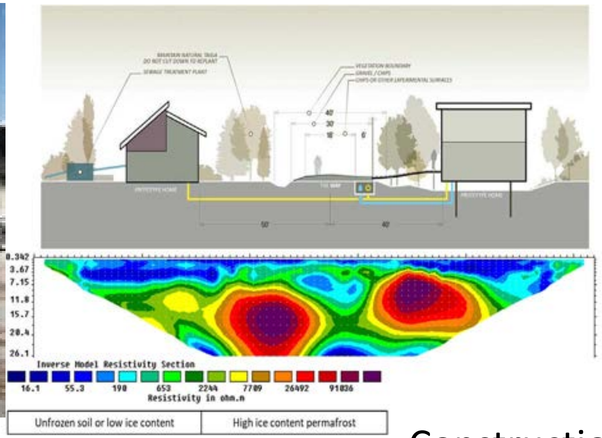
Major Deliverables

- Guide for Resilient Thermal Energy Systems Design in Cold and Remote Locations (2nd Edition)
- Inputs into Unified Facilities Criteria and other agencies’ guidance and standards
- Peer–reviewed technical papers, conference presentations
- Organization and participation in international forums

Challenges in cold and sub-Arctic regions

Remoteness, shortage of resources (e.g. fuel)

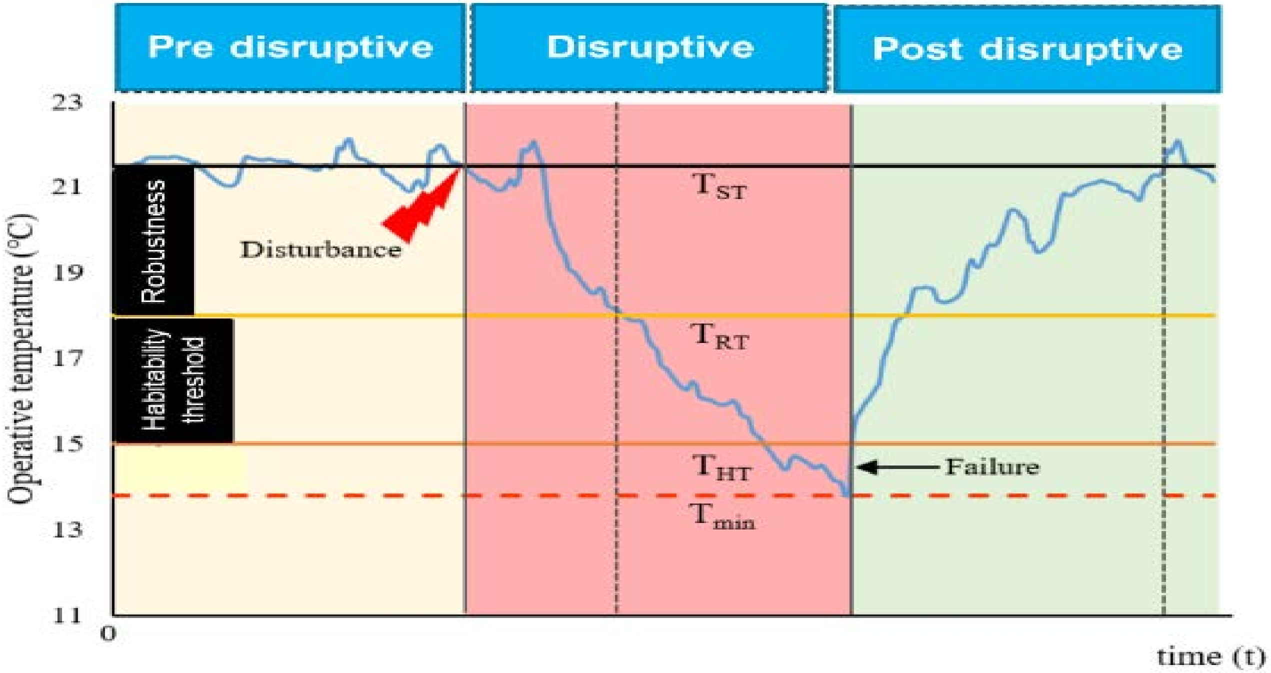
Cold wave



Construction challenges (permafrost)

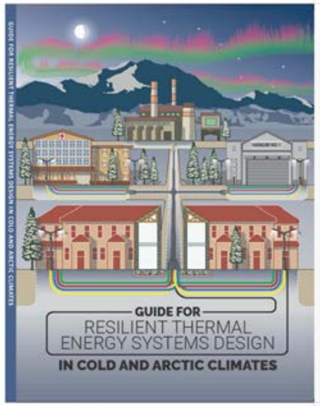
Shortage of parts and limited maintenance, high costs, accessibility, delivery issues

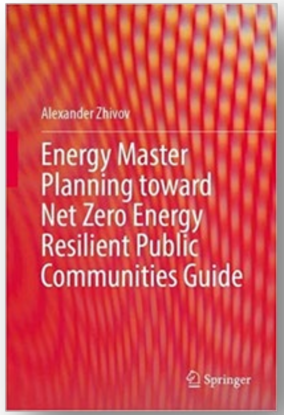
Mold and other sustainability issues), Dry air during cold time of the year

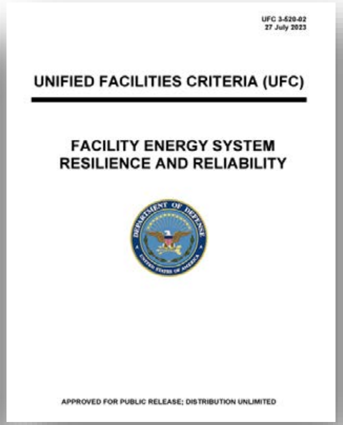


Energy systems resilience: risks to missions, health and buildings sustainability

Background: IEA EBC Annex 73 Research Results







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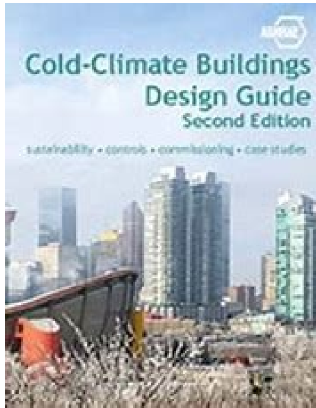


Scope

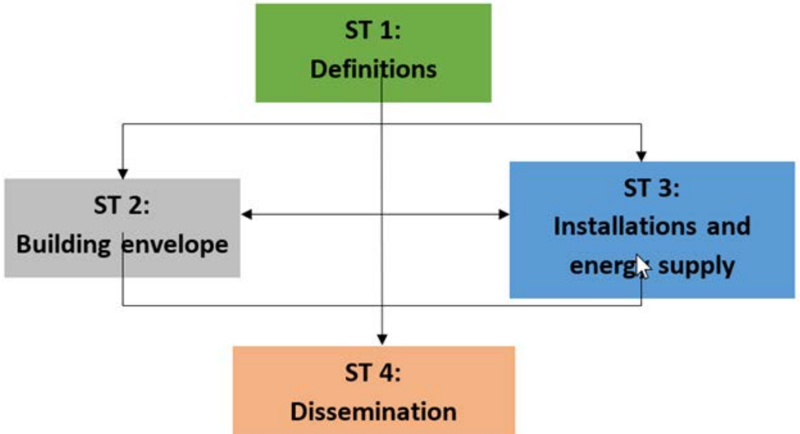
- Climates: cold, very cold, subarctic climate zones (U.S. DOE climate zone 6-8 classification).
- Scale: building clusters (residential and/or share common spaces).
- Remoteness: variously defined, e.g., related to power supply (e.g., a facility not connected to the grid), or related to physical isolation (a facility that is logistically challenging to reach), etc.

Intended target audience

- **Building owners and facility managers:** Annex deliverables will provide independent guidelines, case studies and other knowledge sharing resources to help reduce risks, improve information and encourage participation.
- **Building designers, HVAC consultants, suppliers:** The building designers/suppliers struggles to convince the building owners to buy their energy efficient and resilient solutions due to the higher cost, costly logistics and complexity. They need optimized, novel materials, smarter HVAC systems and methods for improved building resilience in cold regions.
- **Energy companies and logistic companies:** The annex will deliver framework that helps to establish suitable, localized and carbon neutral energy supply/storage markets integrated with building clusters in cold regions that may provide new revenue streams for their services.
- **Policy, regulatory and standards bodies:** Through Annex they will benefit from raising awareness and create guidelines, standards and regulation based on scientific based inputs. This will support in planning and developing resilient buildings, logistics and maintenance.
- **Researchers and professionals:** will gain important knowledge on interdisciplinary research on developing, improving, and using novel methods for energy-efficient and resilient built environment in cold regions. New methods, material and smart systems will be created.

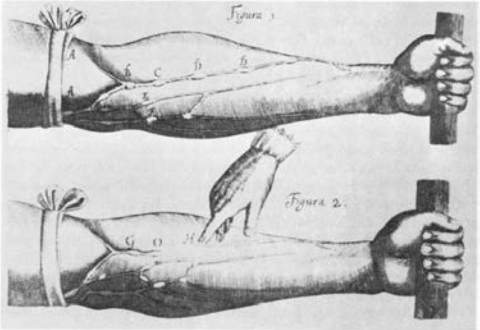
Structure

- Subtask 1: Establishing Energy Resilience Definition, Framework and Challenges for the Building Clusters in Cold Climate
- Subtask 2: Investigate Specifics of Buildings and Their Construction in Remote Cold Regions
- Subtask 3: Investigate Resilient Building and Building Clusters' Energy Systems, Renewable Energy Sources, and Systems Integration
- Subtask 4: Develop Guidelines and Disseminate Knowledge



Subtask 1

- Review the state-of-the-art concepts, definitions and matrices relevant to:
  - Energy efficiency in cold regions
  - Building and systems resilience,
  - Energy supply security and logistics specific to cold and remote regions
  - Policies, best practices
  - Case studies
- Identity the factors that contribute to human resilience and thresholds for thermal conditions (temperature and RH) and environmental quality during black skies (emergency) situations. These thresholds will support other Subtasks 2 and 3 in regard to requirements to the building envelop and energy systems.



Subtask 1. Requirements for Building Thermal Conditions under Normal and Emergency Operations (Contribution to the Informative Appendix of ASHRAE Std 55)

Three scenarios can be considered under normal (blue sky) operating conditions:

- Building/space is occupied,
- Building is temporarily (2-5 days) unoccupied, and
- Building is long-term unoccupied (e.g., when a building is hibernated).

Maintaining thermal parameters is necessary to achieve one or several purposes:

- Perform the required work in a building safely and efficiently,
- Support processes housed in the building, and
- Provide conditions required for the long-term integrity of the building and its materials.

Recommended and Allowable Conditions for Data and Electronic Equipment Centers

Conditions	ClassA1/ClassA2 (ASHRAE 2019a)		NEBS (ASHRAE 2005)	
	Allowable level	Recommended level	Allowable level	Recommended level
Temperature control range		64 °F-80 °F (18 °C–27 °C)	41 °F-104 °F (5 °C–40 °C)	65 °F-80 °F (18 °C–27 °C)
A1	51 °F - 89 °F (11 °C – 32 °C)			
A2	51 °F - 91 °F (11 °C - 33 °C)			
Maximum temperature rate of change	9 °F/hr (31 °F/hr)[1] (5 °C/hr [2 °C/hr])		2.9 °F/hr (1.6 °C/hr)	
RH control range		15 °F - 51 °F dewpoint (-9 °C - 11 °C) dewpoint and 60% RH	5%-85% 82 °F (28 °C) Max dewpoint	Max 55%
A1	10 °F (-12 °C) dewpoint and 8% RH to 62 °F (17 °C) dewpoint and 80%RH			
A2	10 °F (-11 °C) dewpoint and 8% RH to 69 °F(21 °C) dewpoint and 80%RH			

[1] 9 °F/hr (5 °C/hr) for tape storage, 31 °F/hr (2 °C/hr) for all other IT equipment and not more than 9 °F (5 °C) in any 15 min period.

Thermal environment requirements for selected spaces in medical facilities.

Space	T °F	T °C	RH, %
Class B and C operating rooms	68-75	20-24	30 to 60
Operating/surgical cystoscopy rooms	68-75	20-24	30 to 60
Delivery room	68-75	20-24	30 to 60
Critical and intensive care	70-75	21-24	30 to 60
Wound intensive care (burn unit)	70-75	21-24	40 to 60
Radiology	70-75	21-24	Max 60
Class A operating/procedure room	70-75	21-24	20 to 60
X-ray (surgery/critical care and catheterization)	70-75	21-24	Max 60
Pharmacy	70-72	21-22	Max 60

Some Results: Recommended thermal conditions for buildings located in cold/Arctic climate – Emergency operations (Black skies)

Scenario Type of Requirement	Emergency (Black Skies) Space Occupancy					
	Mission-Critical Operation		Tertiary Space (Non-Mission-Critical Bordering Mission-Critical Space)		Hibernated: Can Be Unoccupied for Extended Period of Time (from Days to Weeks) Building Freezing/ Not Freezing	
	DP	Minimum Dry Bulb Temp	Humidity Not To Exceed	Minimum Dry Bulb Temp	Humidity Not to Exceed	Minimum Dry Bulb Temp
Human Comfort	< 63 °F (17.2 °C) [1]	**> 60 °F (16 °C) [5]**	N/A		N/A	
Process Driven	Process specific – see examples in Tables D-1 & D-2		N/A		N/A	
	Humidity not to exceed	Minimum Dry Bulb Temp	Humidity not to exceed	Minimum Dry Bulb Temp		
Building Sustainment	80%[3]	**40 °F (4.4 °C)[2]**	80%[3]	**40 °F (4.4 °C)[2] 55 °F (12.7 °C)[4]**	80%[3]	N/A **40 °F (4.4 °C)[2] or N/A if drained**

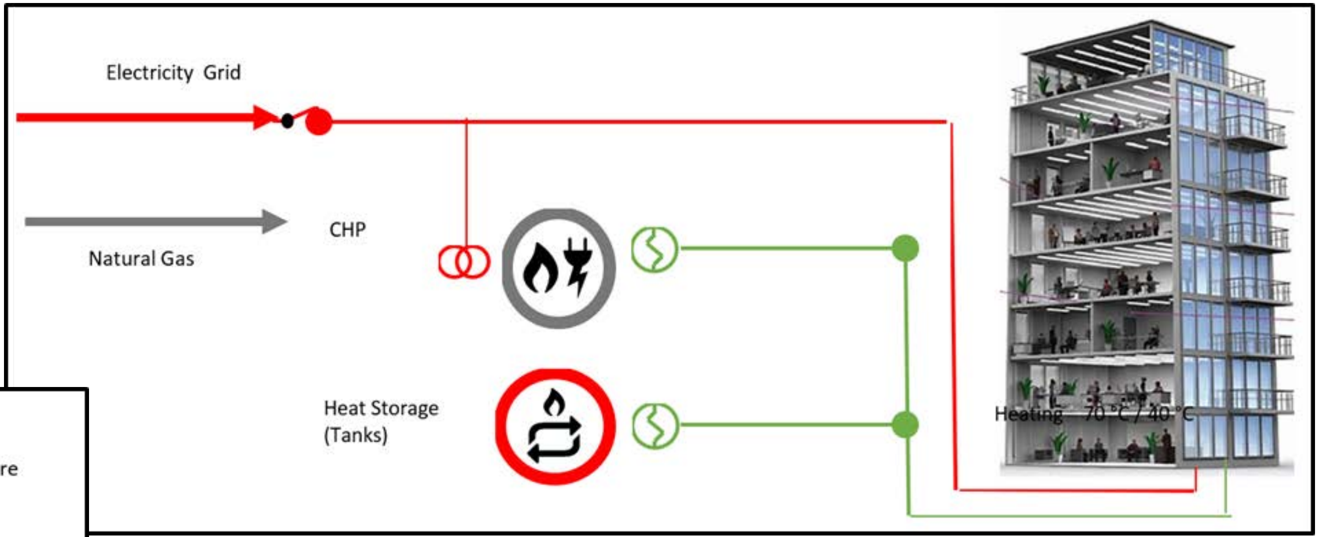
Relative Humidity

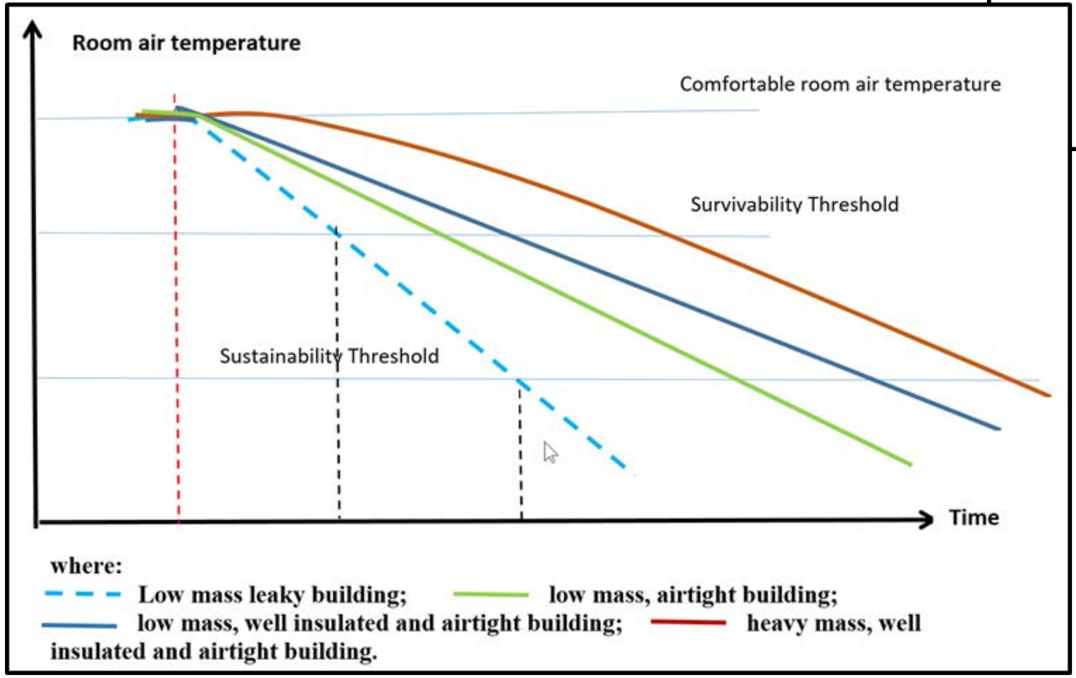
- Buildings in cold climates are typically not humidified and have very low relative humidity (<20%), which negatively impacts occupant health, comfort and productivity.
- Buildings with higher humidity (30-40%) in cold climates, which are actively humidified, often develop mold on and in the building envelope, which leads to many health concerns.
- The risk of mold can be minimized by applying continuous vapor barrier on inside surfaces, improving building air tightness (e.g., <0.15 cfm/ft2 at 75Pa), reducing thermal bridges and installing continuous thermal barrier on external surfaces (walls, attic)

Reduced Ventilation Rates during Emergencies

- Adequate ventilation in a building increases productivity and reduces sick leave. The amount of ventilation air that should be supplied into the building is regulated by national and international codes, e.g., by ASHRAE Standard 62.
- In cold climates, outside air brought into the building requires more energy to heat it from the outside air temperature to the room air temperature, than is required for heating of the building. With the shortage of energy/fuel available during emergency situations, it may be safe to reduce outdoor air rates and to use filtration of the return air, to maintain indoor air quality to the **habitable level** sufficient for the tenant's alertness required for mission fulfillment.
- The main contaminant of submarine air is CO2. In ordinary buildings 500 - 1000 ppm is usually considered as a maximum concentration. This value is not based on health effects but on the typical rate of ventilation. In submarines and space stations, higher CO2 concentrations are permitted, usually 5000-7000 ppm.

Subtask 1. Thermal Energy Systems Resilience Metrics – Maximum Time to Repair



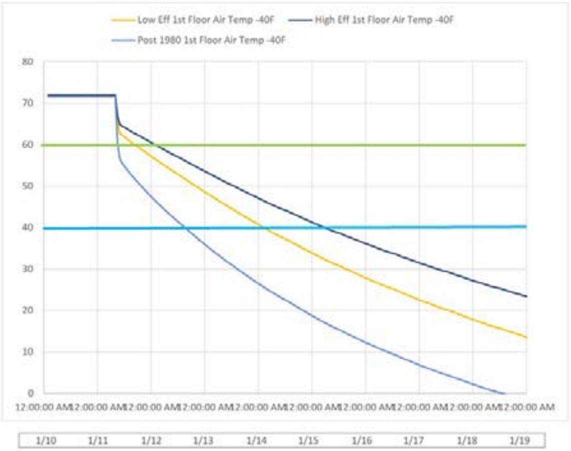


Notional example of temperature decay rate for different types of building envelope.

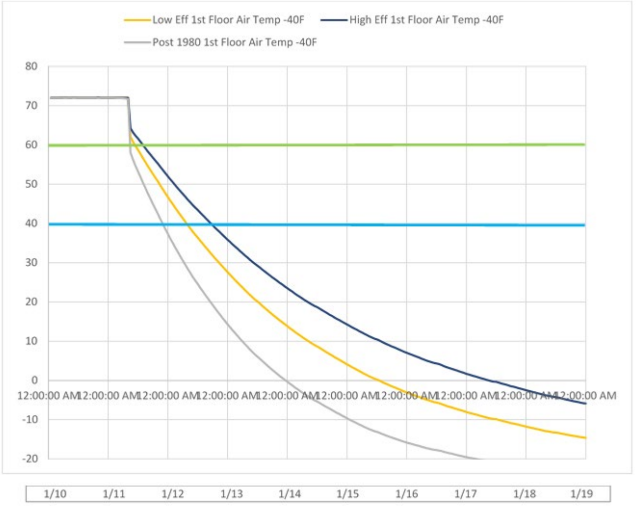
Example: Maximum Time Available for Repair

Building Parameters	Temp ODB	Mass Building			Frame Building		
		Typical/Post 1980	Low Efficiency	High Efficiency	Typical/Post 1980	Low Efficiency	High Efficiency
Walls (R-Value IP)		20.5	40	50	20.5	40	50
Roof (R-value IP)		31.5	45	60	31.5	45	60
Air Leakage cfm/ft^2		0.4	0.25	0.15	0.4	0.25	0.15
Window (R-Value / U value)		Double Pane; R= 1.78 / U=.56	Double Pane; R= 3.34 / U=.3	Triple Pane; R= 5.25 / U=.19	Double Pane; R= 1.78 / U=.56	Double Pane; R= 3.34 / U=.3	Triple Pane; R= 5.25 / U=.19
MTTR Hab. (60F)	-60 F	< 1 hours	2 hours	5 hours	<< 1 hour	1 hours	2 hours
MTTR Sust. (40F)	-60 F	9 hours	28 hours	41 hours	4 hours	14 hours	21 hours
MTTR Hab. (60F)	-40 F	1 hours	3 hours	10 hours	< 1 hour	2 hours	4 hours
MTTR Sust. (40F)	-40 F	20 hours	36 hours	51 hours	10 hours	18 hours	24 hours
MTTR Hab. (60F)	-20 F	2 hours	6 hours	15 hours	1 hour	3 hours	6 hours
MTTR Sust. (40F)	-20 F	31 hours	46 hours	60 hours	15 hour	22 hours	28 hours
MTTR Hab. (60F)	0 F	3 hours	13 hours	29 hours	2 hours	5 hours	9 hours
MTTR Sust. (40F)	0 F	43 hours	59 hours	90 hours	21 hours	28 hours	33 hours
MTTR Hab. (60F)	20 F	10 hours	28 hours	45 hours	3 hour	8 hours	15 hours
MTTR Sust. (40F)	20 F	60 hours	78 hours	95 hours	28 hours	35 hours	40 hours
MTTR Hab. (60F)	40 F	29 hours	54 hours	72 hours	8 hour	17 hours	23 hours
MTTR Sust. (40F)	40 F	93 hours	112 hours	123 hours	41 hours	47 hours	50 hours

Mass Building:



Frame Building



Subtask 2. Building envelope in cold climates

- Normally:
    - Protect against outdoor climate and intruders
    - Ensure comfortable indoor climate
        - Save energy
        - Ensure healthy building
- In emergencies:
    - Protect against outdoor climate and intruders
    - Keep tolerable indoor climate as long as possible
        - Reduce energy loss

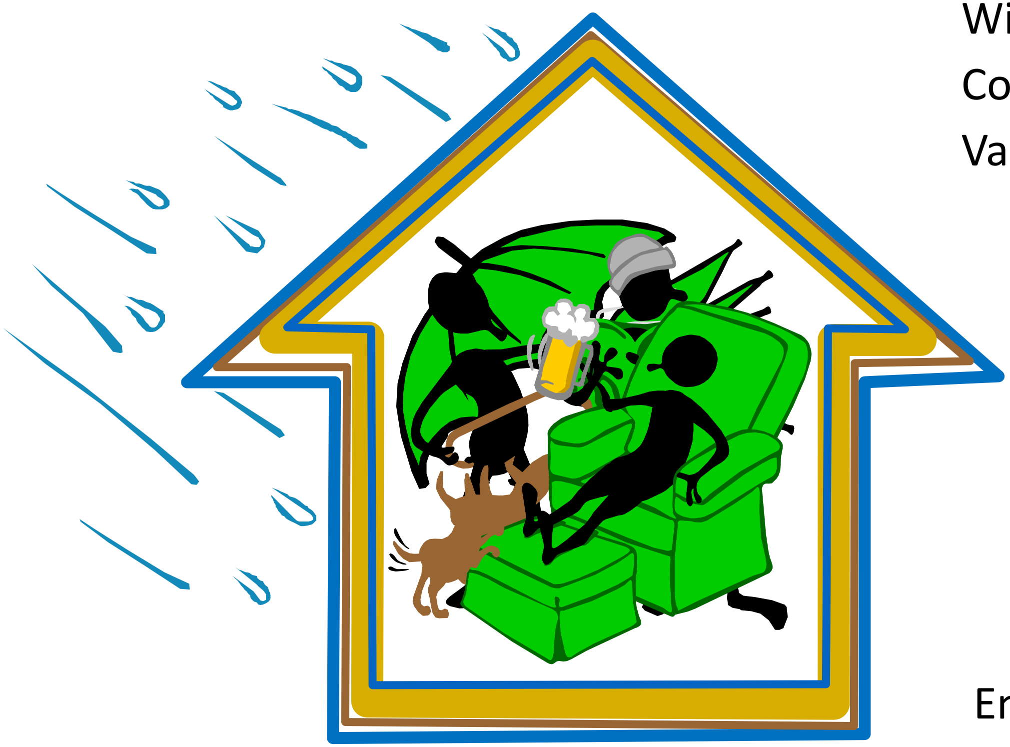
Barriers against:

Snow and rain

Wind

Cold

Vapor (from inside)



Ensure tightness

Subtask 2. Remote cold areas are not all alike

The building design depends on:

- Location
  - Climate
  - Remoteness
  - Culture
  - Traditions
  - Regulations
  - ….
- Resources
  - Local materials
  - Competences
  - ….

Subtask 2. Special attention:

- Ensure healthy and energy efficient buildings (blue sky)
  - Tightness
  - Good thermal insulation
  - Minimize thermal bridges
- Energy resilience (black sky)
  - New methods
  - Thermal mass
- Sustainability

Subtask 3 – Focus Areas

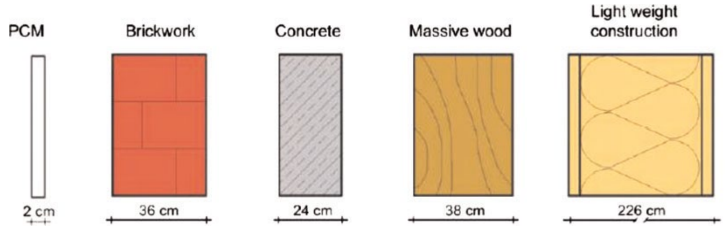
1. Energy Systems in Buildings in Cold Remote Regions
2. Electricity and heat generation and distribution mechanisms crucial for these buildings
3. Green, blue and transitional fuels

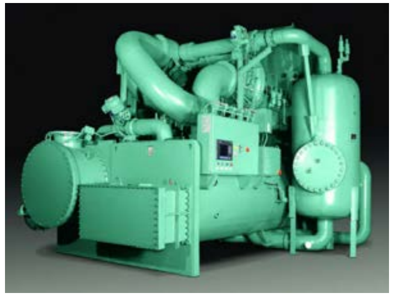
Subtask 3 (Cont.)

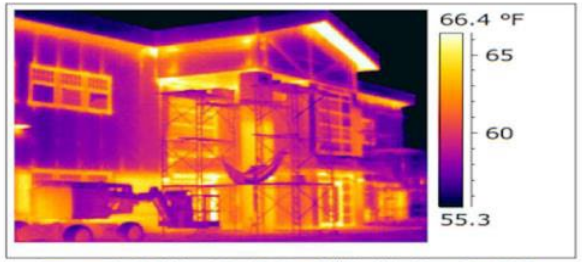
- **Investigating heating, cooling, electricity production, and distribution systems.**
- **Improving energy efficiency, increasing renewable energy usage, and enhancing supply security**
- **Developing solutions to optimize energy systems and increasing resilience of energy grids**
- **Tailoring solutions to local infrastructures, such as renewable energy sources, district heating, and integration strategies between sectors**
- **Mobile boilers, chillers, CHP.**

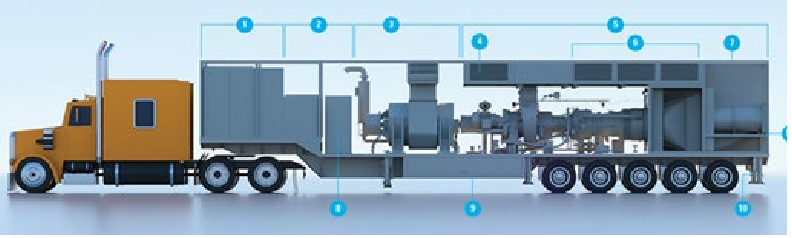
Examples of Technologies to be Considered

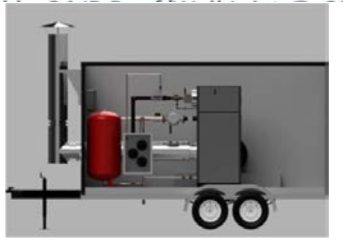
- Building envelope: insulation, air tightness, vapor barriers, PCM, carbon content
- HVAC systems: heating, cooling, humidification, controls, ASHP
- CHP, CCHP, Mobile emergency boilers,
- DH systems, WSHP, GSHP,
- TES: long and mid term
- Energy networks coupling
- RE sources,…

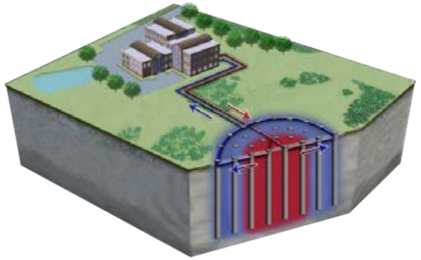


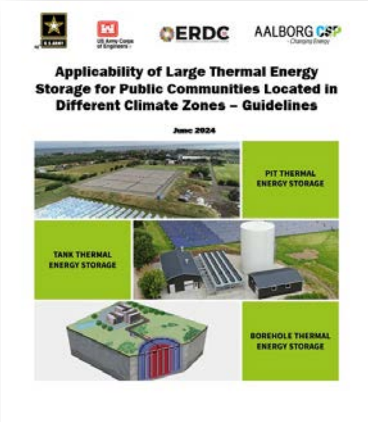











ERDC AALBORG CSP

Applicability of Large Thermal Energy Storage for Public Communities Located in Different Climate Zones – Guidelines

June 2024

PIT THERMAL ENERGY STORAGE

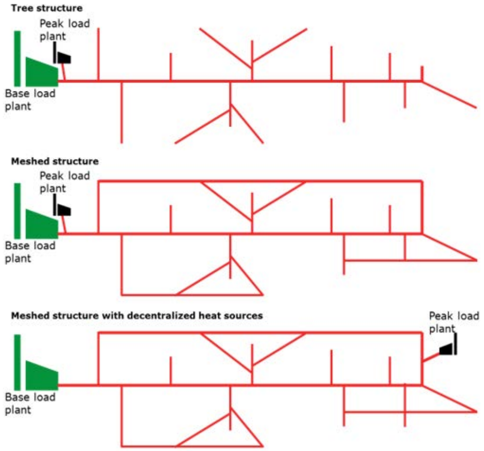
TANK THERMAL ENERGY STORAGE

BOREHOLE THERMAL ENERGY STORAGE


ERDC

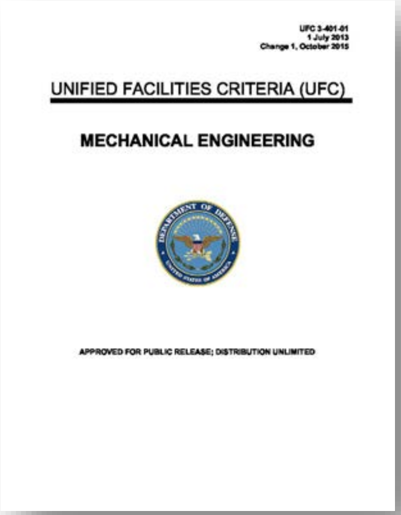
Analysis of Potential for Air-Source Heat Application for Renovation Projects of Public Buildings Located in Different Climate Zones

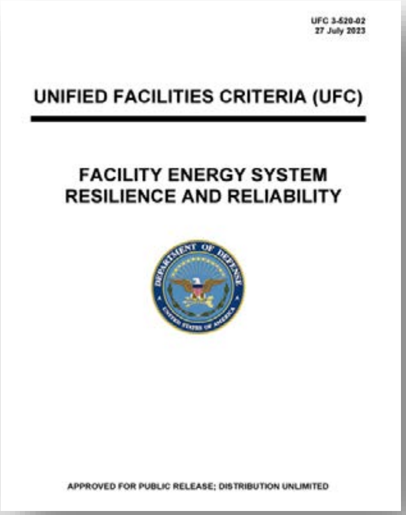
June 2024

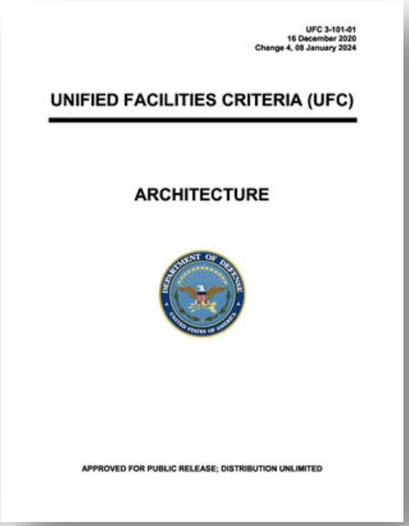


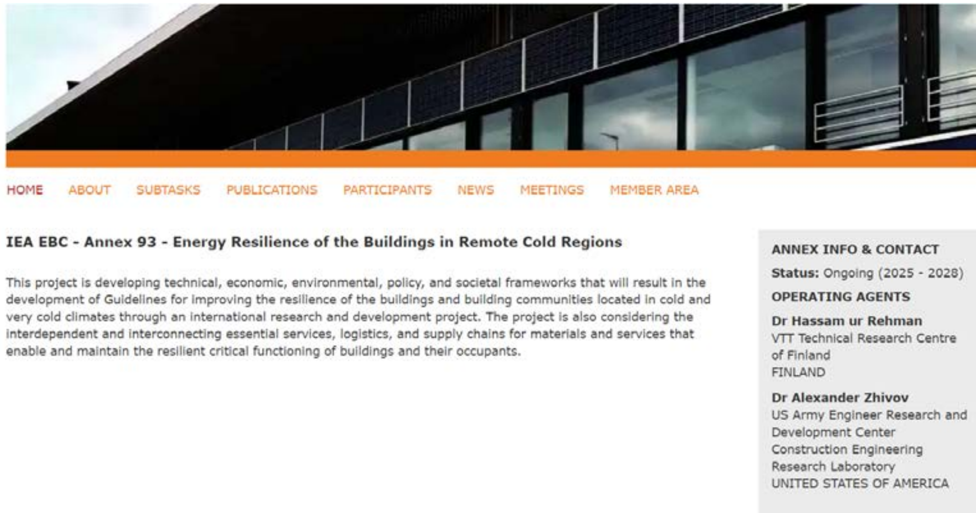
Subtask 4. Major Deliverables

- Guidelines (potentially to be published by ASHRAE)
- UFC, Standards and national Guidelines
- Peer–reviewed technical papers, conference presentations
- Organization and participation in international forums
- Inputs into agencies’, local, national and international guidance and standards









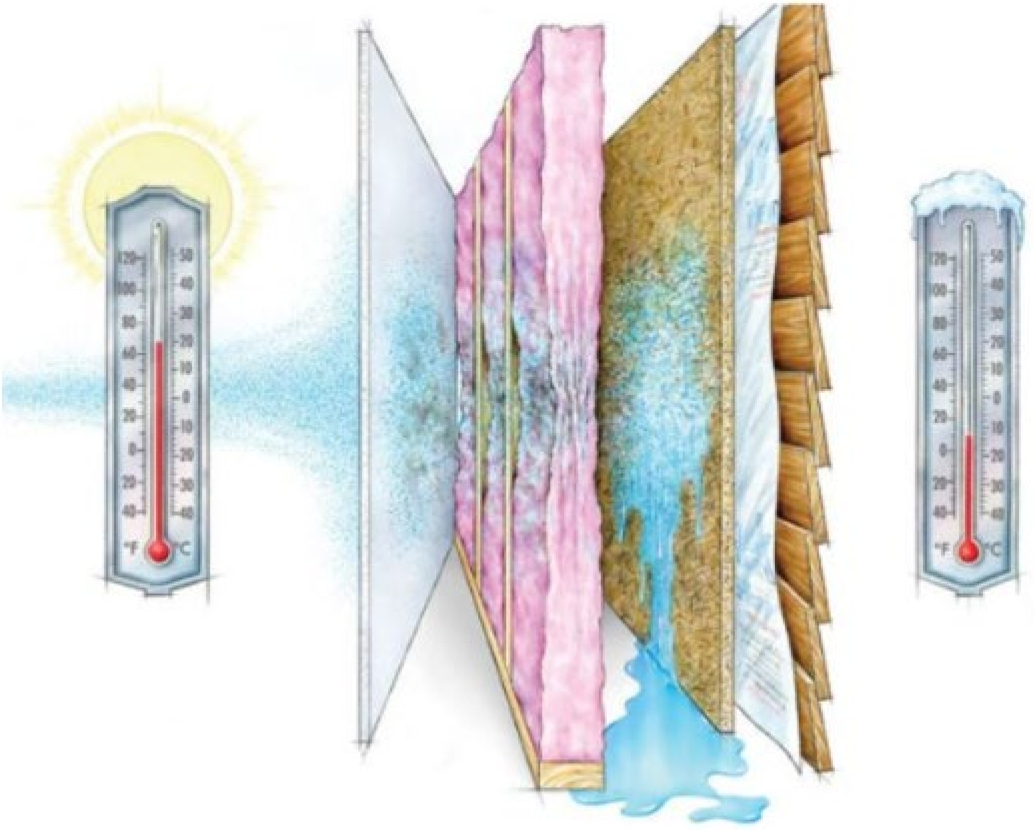
Infiltration… a Building Area Story

Clayton Harrison, AIA
USACE – Alaska District
Sustainable Engineering Program Manager

Part 1… The infiltrators

Interior vs Exterior

- Interior Characteristics
  - Higher temperatures
  - Higher Humidity
  - Lower density



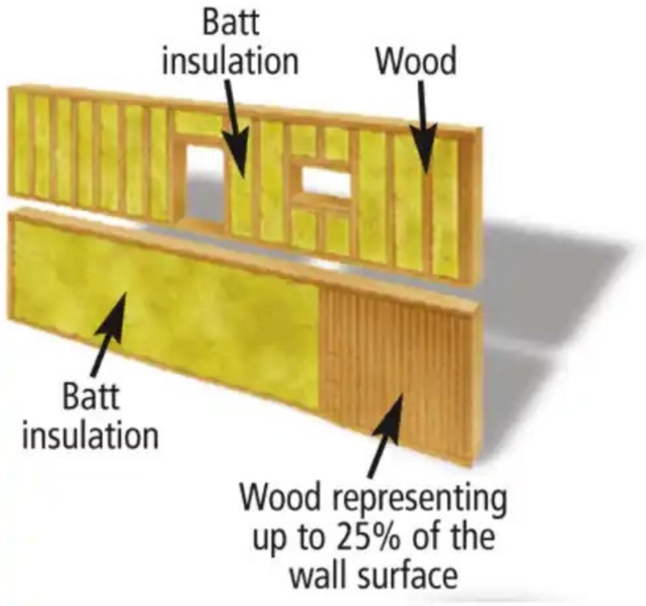
The basics of air and vapor drive in a wall assembly

- Exterior Characteristics
  - Lower temperatures
  - Lower Humidity
  - Higher density

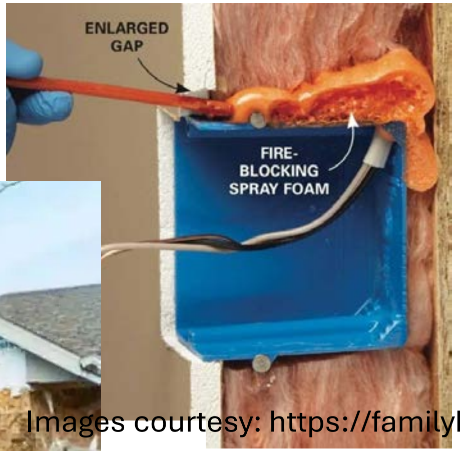
Vapor vs Liquid

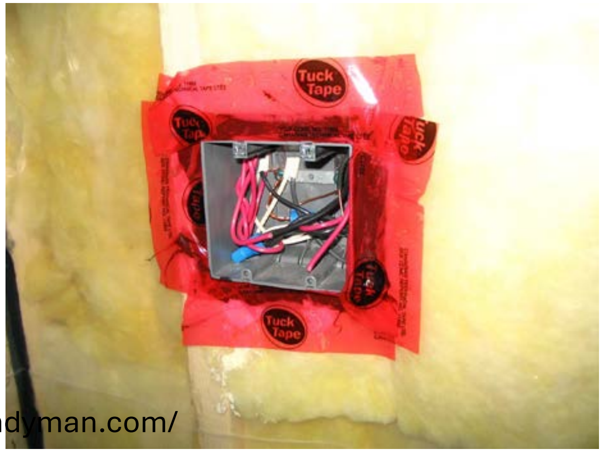
Images courtesy: https://havelockwool.com/vapor-barrier-info/

Movement of air, vapor and thermal energy



Images courtesy: rmax.com/





Images courtesy: https://familyhandyman.com/

Optimized Assemblies

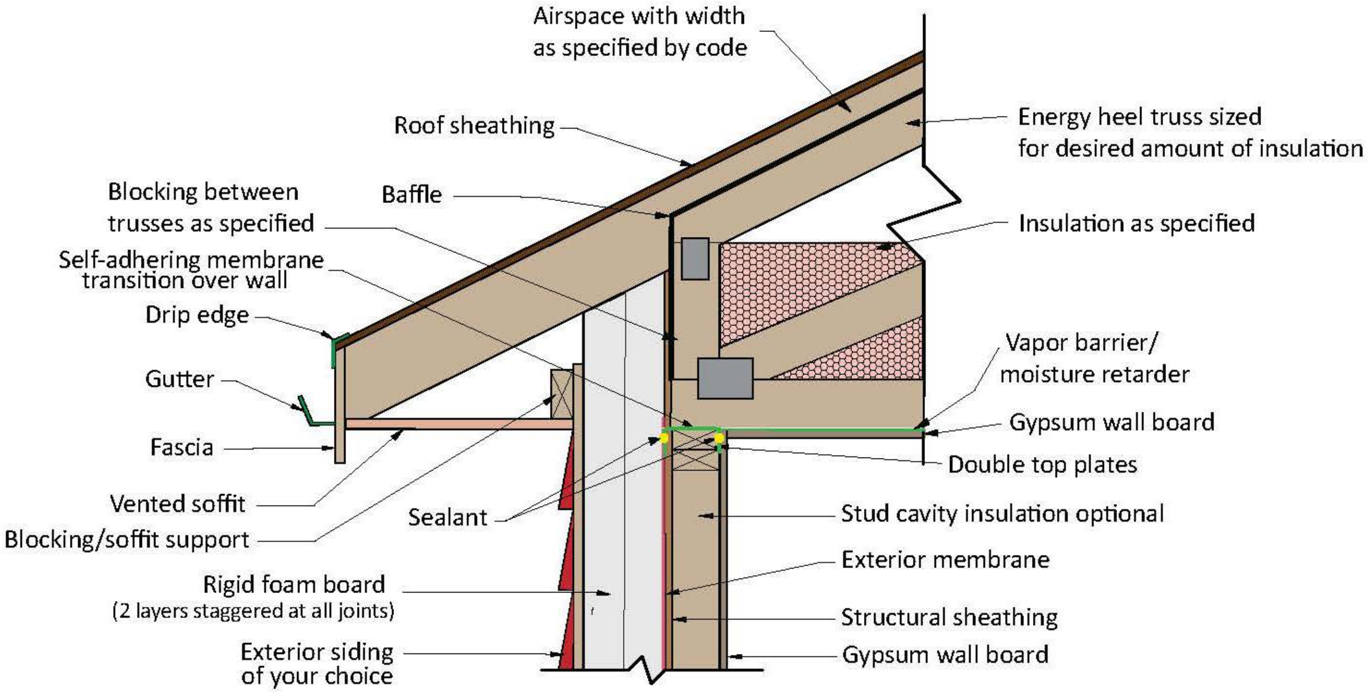
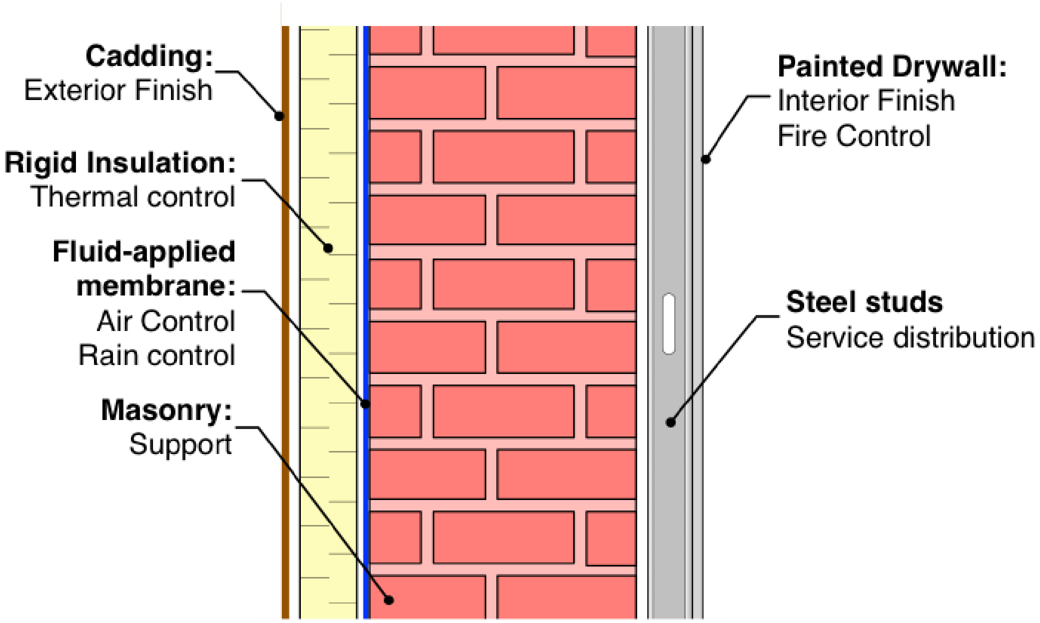


Figure 3. BRACING WITH ROOF INSULATION ABUTTING TOP CHORD, DEEPER ENERGY HEEL TRUSS

Images courtesy: cchrc.org



Images courtesy: buildingscience.com

Optimized for hot **AND** cold

Images courtesy: https://www.buildingenclosureonline.com/articles/86722-ceu-air-vapor-barrier-elements

Common Features of the Optimal wall

- **Thickness** : 16” – 24”
  - Membrane Sandwich = continuity and protection
  - Continuous insulation / thermally broken
  - Thermal Mass for resilience

Part 2… Area

Table 4-1 Gross Building Area

Type of Space	Definition
Enclosed Spaces	The total area of all floors measured from the exterior face of exterior walls or from centerline of walls separating adjoined buildings including: - mezzanines - basements - penthouses - enclosed spaces such as pre-engineered metal building's housing equipment. - enclosed stairwells, elevators, utility chases are included as part of the area of the floor that they occupy.

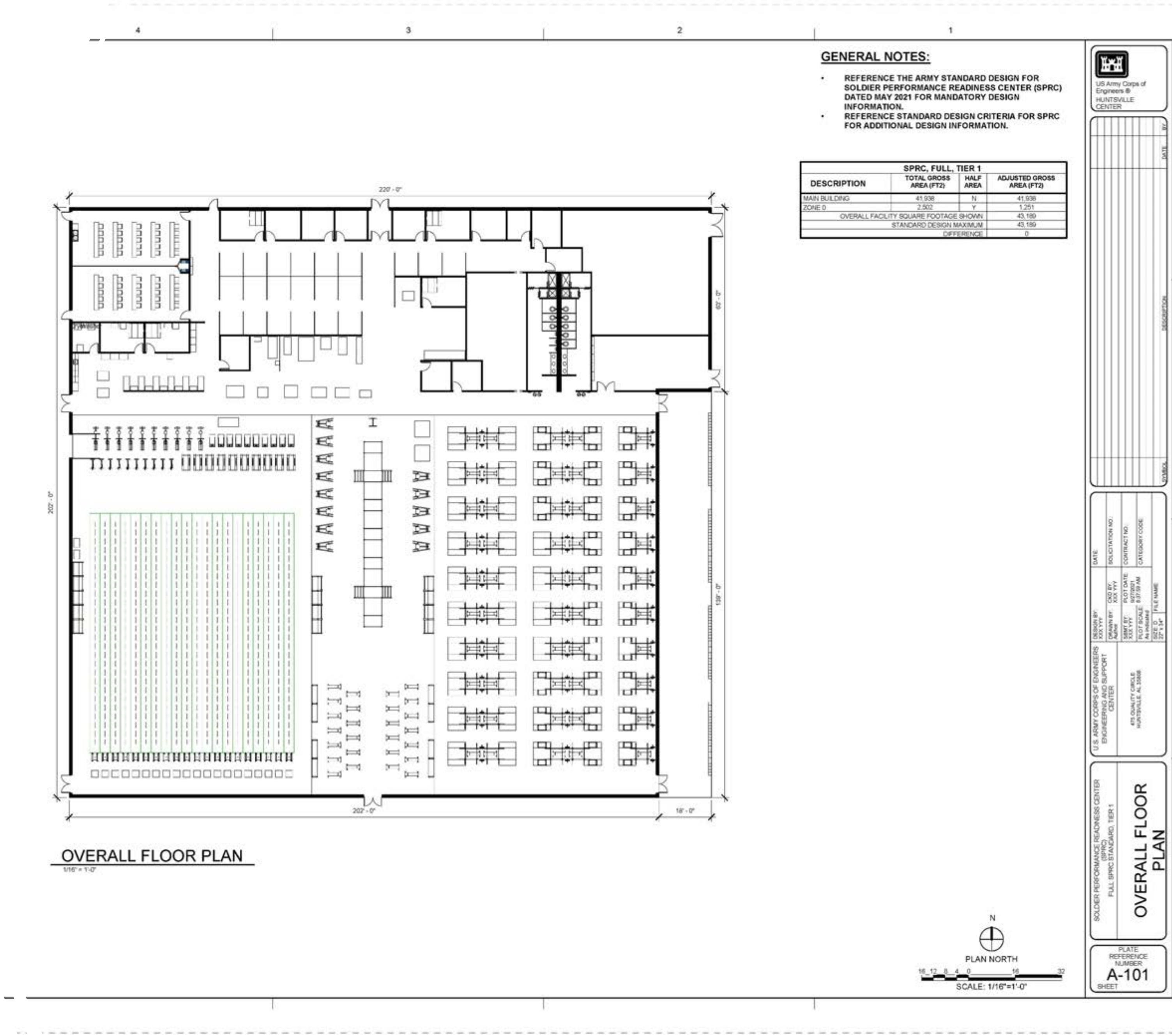
Ex. Problem

- Authorized Area Maximum
- Program area per UFC 3-100-01

- Example – Soldier Performance Readiness Center Design 43,189 GSF

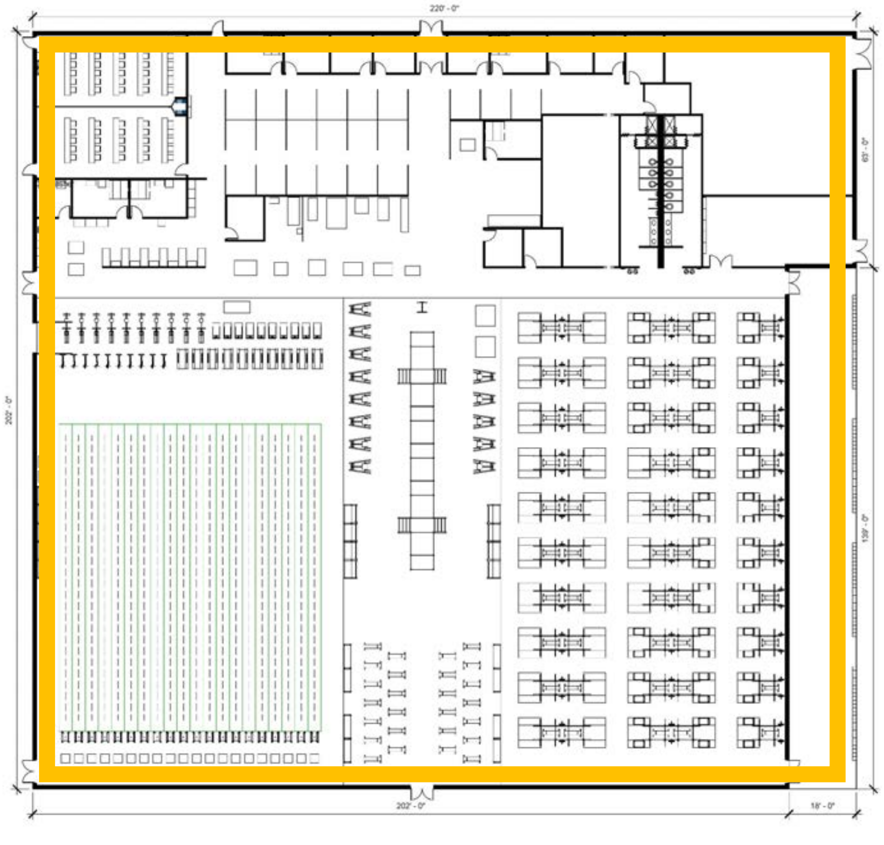
“Standard wall” : 12” wall thick
= 842sqft
“Ideal wall” : 20”-24” thick
= 1,684 sqft

842sqft delta = 100%



Solution(s)

- Cut Program Area....?
- Multitasking materials
  - Insulation & Finish combined
- Continuous Insulation
  - Thinner wall
  - Less building volume = $$$ savings $$$
- **CHANGE THE UFC?!**



OVERALL FLOOR PLAN

MECHANICAL / BUILDING ASSEMBLY

ARCTIC CONSIDERATIONS
Air Leakage Rate

US Army Corps of Engineers Mechanical Section

ERDC
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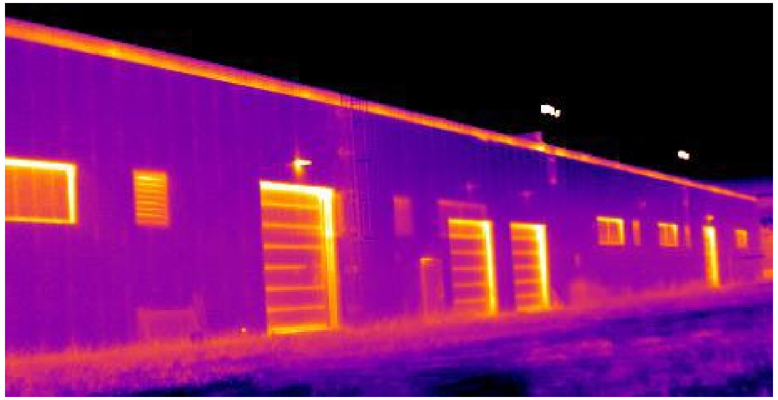
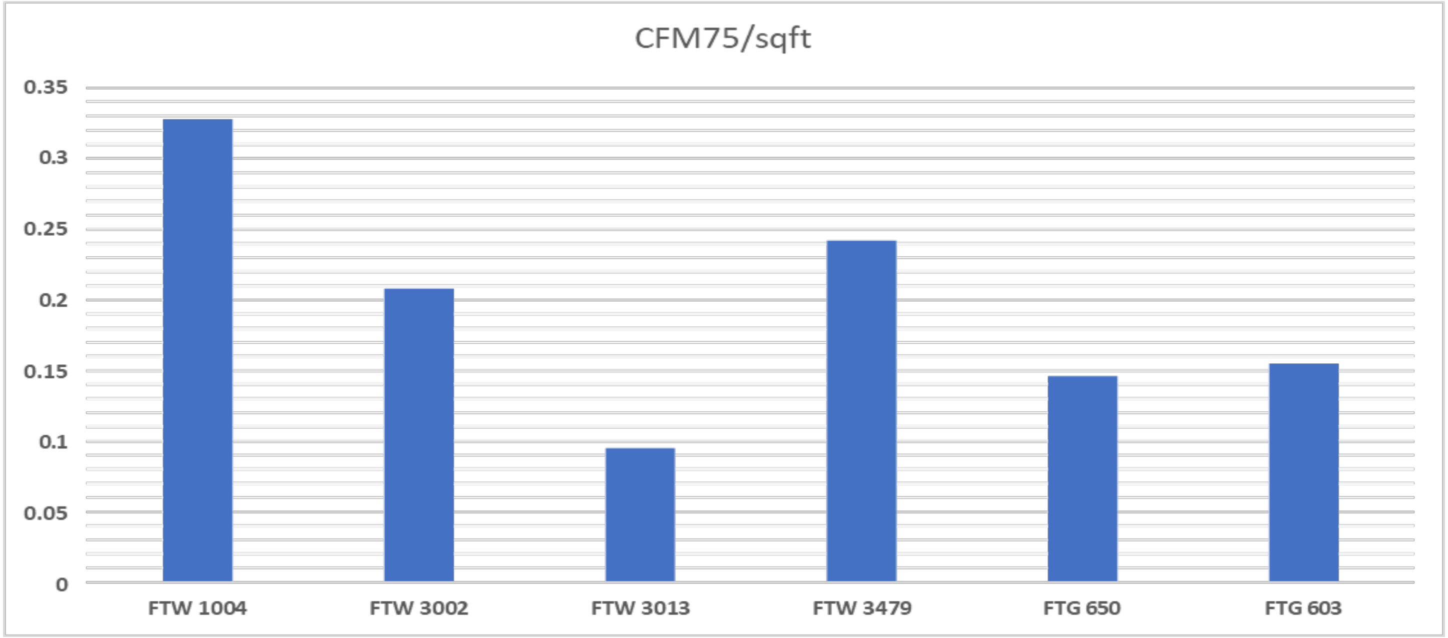
Allowed Air Leakage Rate

- Currently specified in UFGS 07 72 10 specification and UFC 3-101-01 as 0.25CFM/SqFt @ 75 Pa
  - Legacy building tests indicate that legacy buildings (40 years old) still meet this requirement.
  - There is little care required in constructing building exterior closure to meet this requirement.
  - There is a significant amount of outdoor pressurization air required to maintain building pressurization with this leakage rate.



Legacy Building Air Leakage Rate

FTG & FTW ABT-2019	Year of Const.	Bldg Const. Type	6 sided SA	CFM75/sqft	EqLA75
FTW 1004	1949	Concrete/CMU	34,442 sqft	0.328	7.6 sqft
FTW 3002	2016	Insulated Metal Panel	39,822 sqft	0.208	5.7 sqft
FTW 3013	1999	Wood Framed	8,488.8 sqft	0.095	.5 sqft
FTW 3479	1954	CMU Upgraded	66,012 sqft	0.242	10.6 sqft
FTG 650	1955	CMU/Concrete/EIFs	28,501.6 sqft	0.146	2.8 sqft
FTG 603	1955	CMU/Concrete/EIFs	32005.6 sqft	0.155	3.3 sqft



Allowed Air Leakage Rate

- Recommend altering specification / UFC guidance to 0.15CFM/SqFt @ 75 Pa
  - Requires 40% less (effectively lost to pressurization) outside air for pressurization
  - In interior Alaska generic 10,000 SF building saves 62,500 btu/h heat load
  - Minimal cost impact in constructing exterior closure (primary detailing and care in assembly)
  - Minimize moisture from humidified buildings migrating to building assemblies and associated degradation

Thank you for your attention.

Questions and Discussion?

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Proposed recommendations for UFCs:

- UFC 3-101-01 to **increase building airtightness** for cold climates (c.z. 6,7 and 8) by changing the requirement from **0.25 cfm/ft2 (at 75PA) to 0.15 cfm/ft2** (resulting in improved resilience, energy efficiency, CBR protection)
- UFC 3-410-01 update to include an **increase RH inside buildings to 30% in cold season** (with subsequent improvement in building envelop- airtightness, internal vapor barrier, external thermal barrier, reduced thermal bridging) – improves immune system, protects from airborne viral infection, reduces absenteeism, improves productivity;
- UFC 3-410-01 update to include **requirements for IAQ and thermal conditions inside buildings for emergency/Black skies operations**: $T > 60^oF$, $WBGT < 83^oF$, $TLV_{CO2} < 5000ppm$ (with shutting down or significantly reducing OA flow rate and scrubbing recirculated air): saves/extends the use of fuel available, improves resilience, improves CBR protection
- UFC 3-101-01 update Table 4-1 Gross Building Area… Enclosed Spaces: "The total area of all floors measured from the **INTERIOR** face of exterior walls…"
- UFC 3-520-02 to include **thermal energy system resilience**, addressing both **building systems** and **envelope**.