TETRA TECH EBA

Innovative Solutions for operating on Ice Covers in Northern Canada

Nunavut Mining Symposium 2014

April 08, 2014

Volker W. Neth

Corporate Overview

- EBA was founded in 1966 and today has more than 800 employees.
- In August 2010, EBA was acquired by Tetra Tech Inc.
- Our corporate name is as of January 1, 2014

Tetra Tech EBA Office Locations

What We Do…

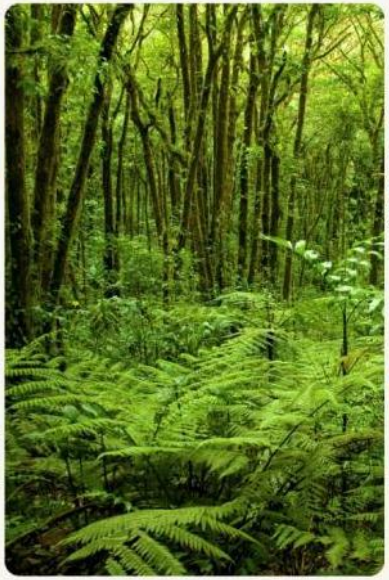
WATER

- Water Resources
- Drinking Water
- Groundwater
- Wet Weather Infrastructure/CSOs
- Wastewater Treatment
- Water and Agriculture

NATURAL RESOURCES

- Mining
- Industrial Process
- Oil and Gas

ENVIRONMENT



- Air Quality
- Environmental Compliance
- Environmental Management
- Environmental Response/Disaster Management
- Remediation
- Waste Management

INFRASTRUCTURE

- Transportation
- Dams, Locks, and Levees
- Buildings
- Ports, Harbors, and Waterfront
- Communications
- Information Technology
- Construction

ENERGY

- Wind
- Solar
- Hydropower
- Nuclear
- Emerging Renewables
- Transmission and Distribution
- Utilities/Market Analytics
- Energy Efficiency

Presentation Overview

- INNOVATION
  - Definition
  - Why innovative solutions?
- ICE COVER
  - Use as temporary work platform - Examples
  - Basics of ice…and snow
- INNOVATIVE SOLUTIONS
  - Improved construction methods
  - Advanced analytical models
  - Monitoring techniques
- SAFETY

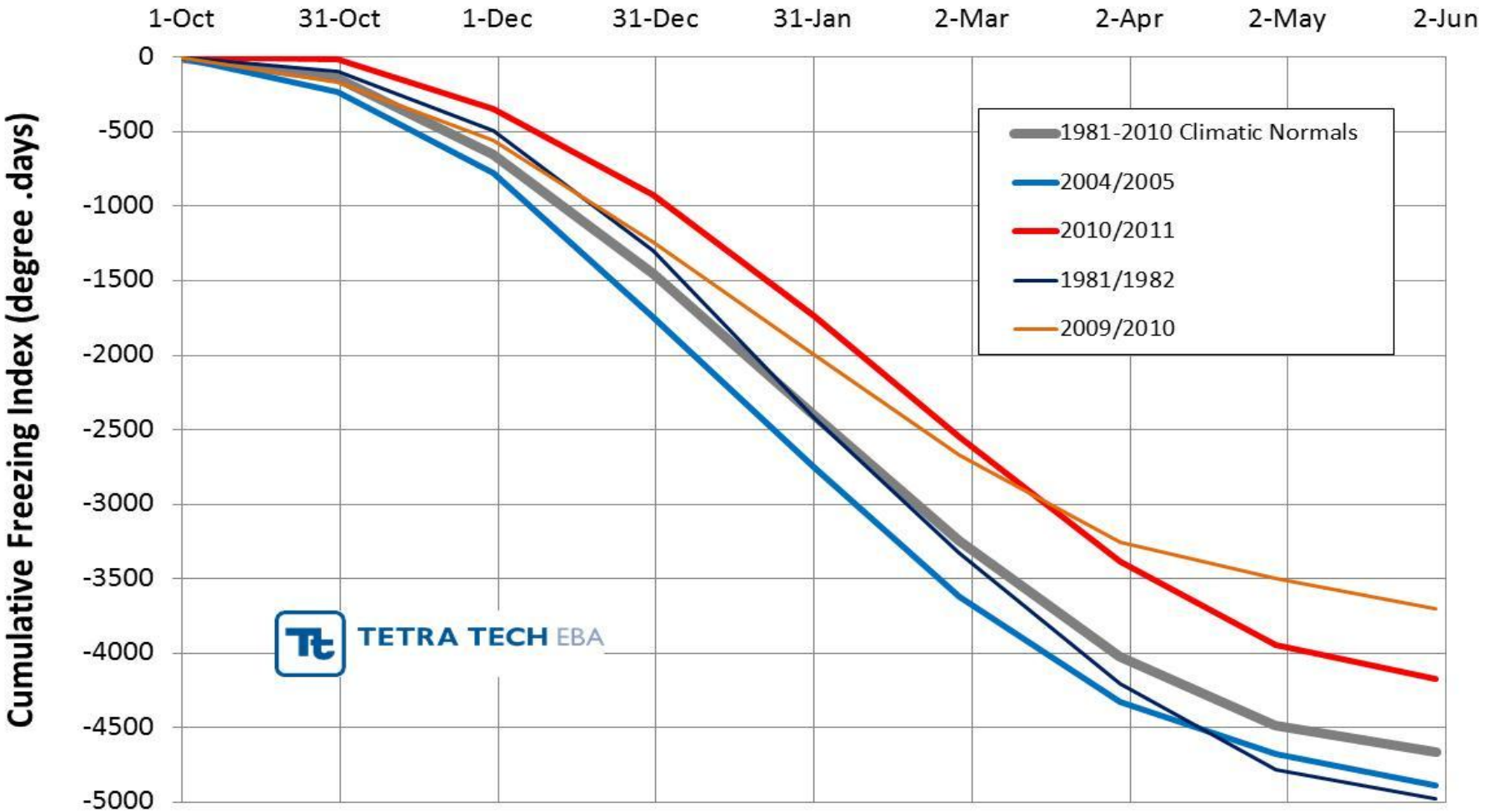
Message from our President

Innovation is letting you step out from the tried solution.

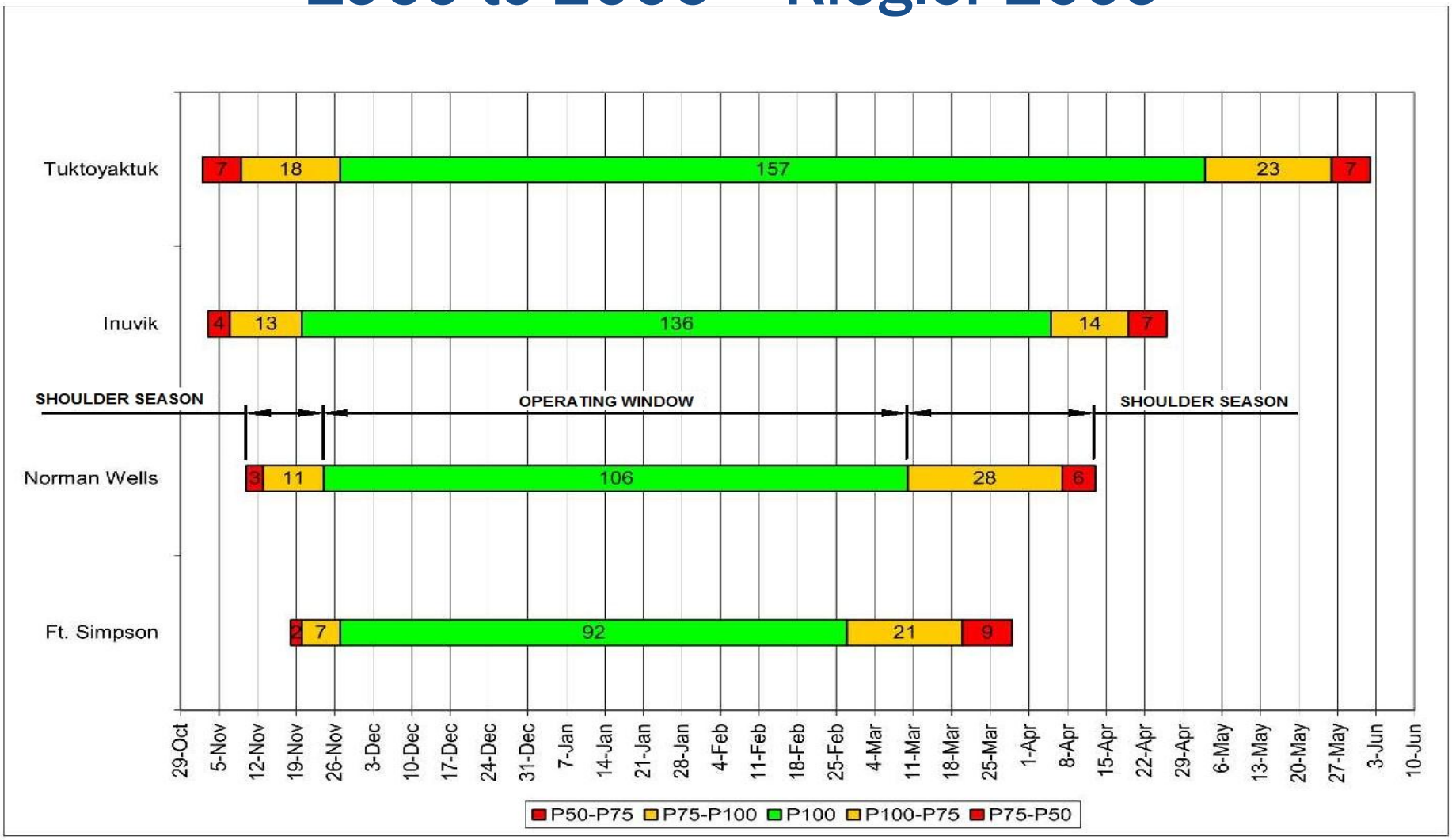
Why Innovative Solutions?

- Ice covers are temporary working platforms lasting only a couple of months. Their usefulness depends on:
  - Ambient temperatures
  - Planning efforts (analysis, monitoring, safety)
  - Construction methods

Rankin Inlet Freezing Index



Historical Winter Construction Windows 1960 to 2006 – Kiegler 2009

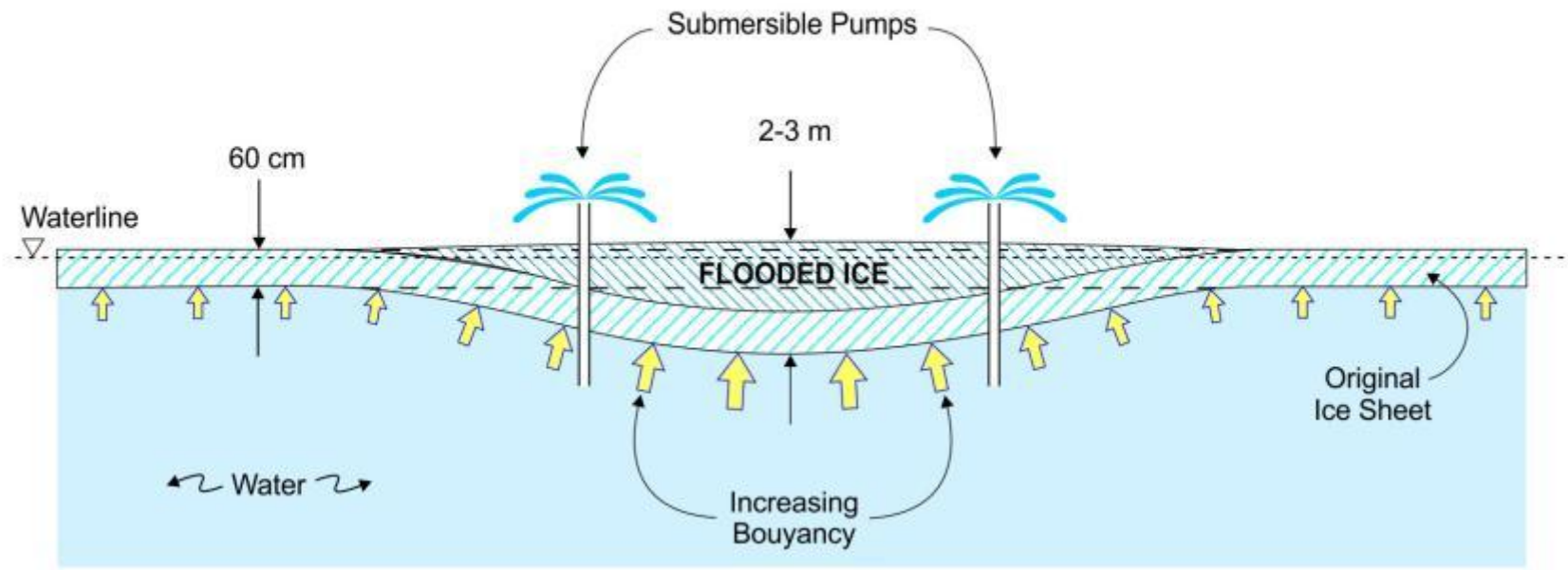


Ice as temporary work platform

- **ICE PADS**
- Offshore ice platforms N of Melville Island
  - 1,800t drill rigs for PanArctic
  - Thickened ice from 60 cm to 7 m
- **ICE RUNWAYS**
- Roche Bay
- Hope Bay
- **ICE ROADS/ICE BRIDGES**
- Tibbitt to Contwoyto Winter Road
- Ice road on a crater lake in Siberia


TERRITOIRE DU YUKON, TERRITOIRES DU NORD
ET NUNAVUT
NUNAVUT
NORTHWEST TERRITORIES
TERRITOIRES DU NORD-OUEST
BAFFIN BAY
BAIE DE BAFFIN
HUDSON BAY
VICTORIA ISLAND
BANKS ISLAND
BAFFIN ISLAND
ÎLE DE BAFFIN
QUEEN ELIZABETH ISLANDS
ÎLES DE LA REINE-ÉLISABETH
ARCTIC OCEAN
OCÉAN ARCTIQUE
CANADA BASIN
BASSIN CANADA
DAVIS STRAIT
DÉTROIT DE DAVIS
FOXE BASIN
FOXE
HUDSON STRAIT
DÉTROIT D'HUDSON

Ice Thickness and Buoyancy



Drilling a 200 mm hole

B-55 Flooding pump

Close-Up of Rock Shoal on Ice Cover

Rock Shoals falling through the Ice, May '07

2 km long On-Ice Air Strip at Roche Bay, NU

Doris Lake ice aerodrome at Hope Bay

Photo B-1: Runway under construction, December 12, 2011.

TCWR Ice Road

Ice Road with Markers in NE Russia

Basics of Ice – Mechanical Properties

- **Ice is a naturally grown (or man made) material**
  - with flaws (air bubbles, water inclusions, cracks)
- **Types of ice**:
  Fresh/salt water; snow ice; blue/white etc.
- **Mechanical properties**.:
  Strong in compression, weak in tension
- **Factors affecting ice strength**:
  Density, temperatures & salinity (not the color!)
- **Ice thickness**
  Most important variable in determining carrying capacity

Safety and ice thickness

Almost all on-ice operations involve SNOW!

Proper snow management determines whether an On-Ice project is a success or failure!

Snow on ice

Snow Characteristics

- Snow insulates and suppresses ice growth
- Snow increases weight on ice
- Snow cover hides cracks in ice
- Snow patches cover thin ice (danger!!)
- Weight of snow impacts operation

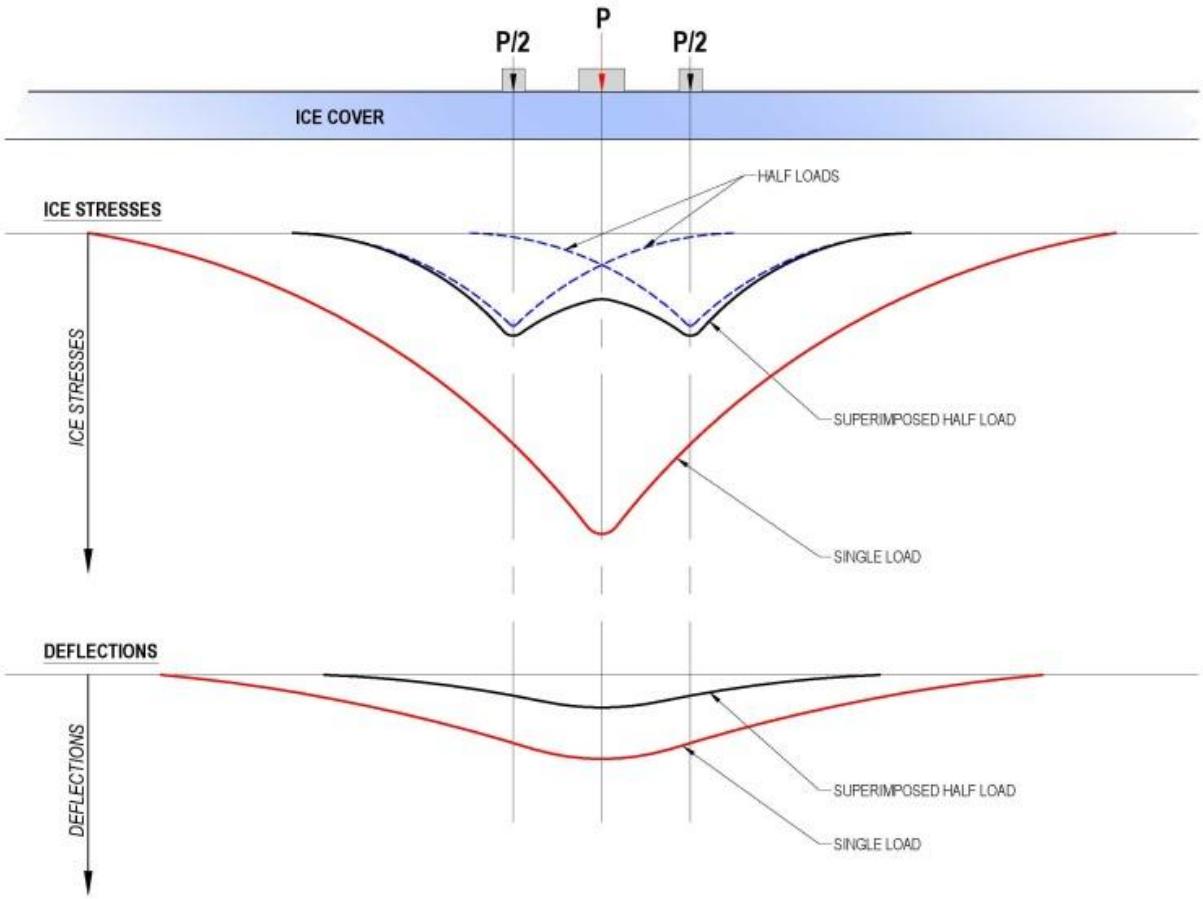
Innovative Solutions

- Improved construction methods
  - Early, proper snow management
  - Use spray techniques
- Advanced analytical models
  - To determine carrying capacity
    - Load distribution
    - Sort term/long term loading
- Monitoring techniques
  - Thickness, ice temperature, ice strength
  - To ensure the safety of the on-ice personnel

Flooding pump

Spray pump

Point load vs. distributed load



Monitoring Parameters & Monitoring Tools

- **Ice thickness & freeboard**
  - 50 mm ice auger & tools
  - GPR/GPS unit
- **Ice temperatures**
  - Thermistors
- **Ice strength**
  - Borehole Jack
- **Ice cracks**
  - Measuring tape & spray paint

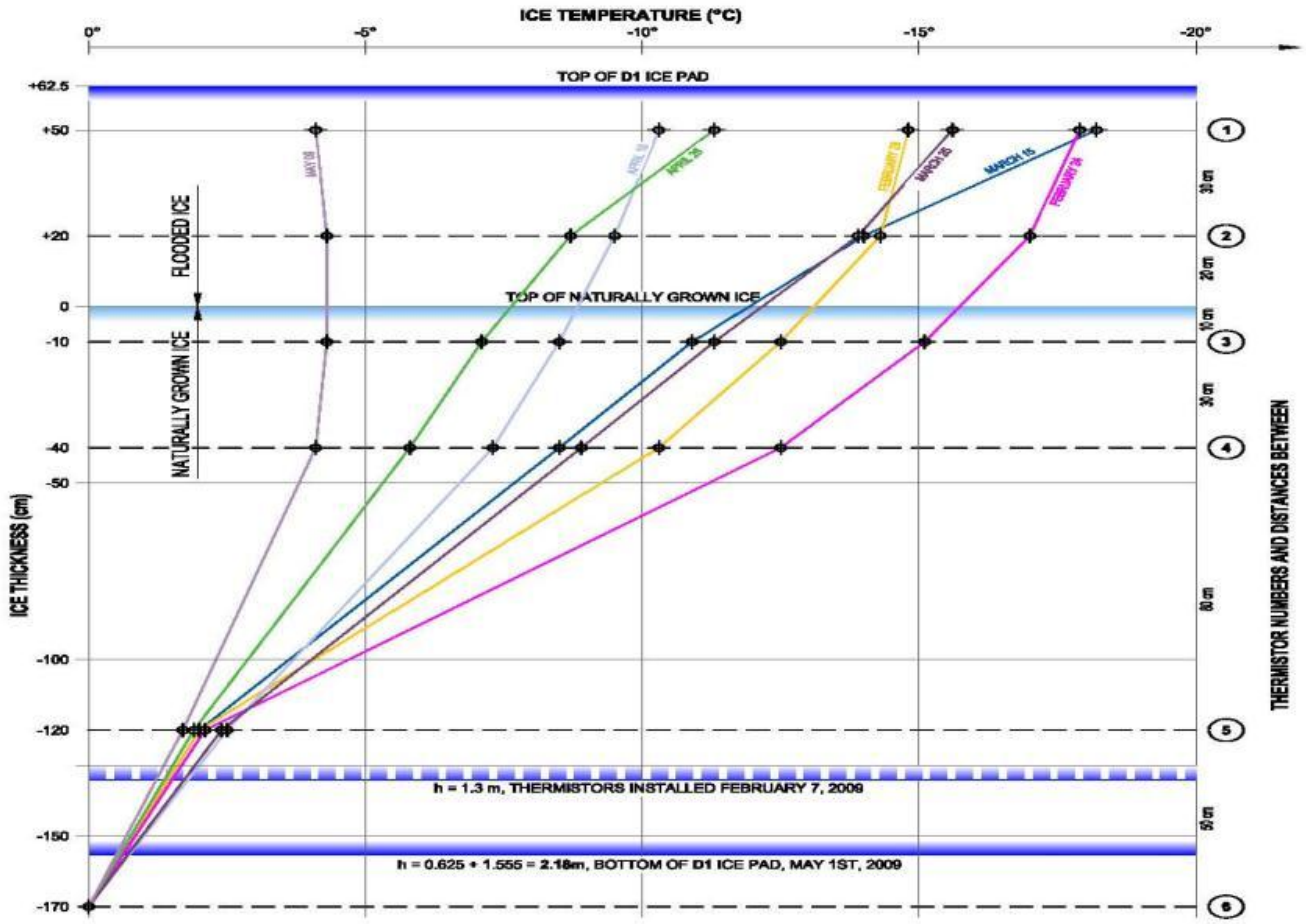
50 mm Ice auger

Volker drills a hole in Siberia in 2009

Thermistor bank assembled

Thermistor bank installed

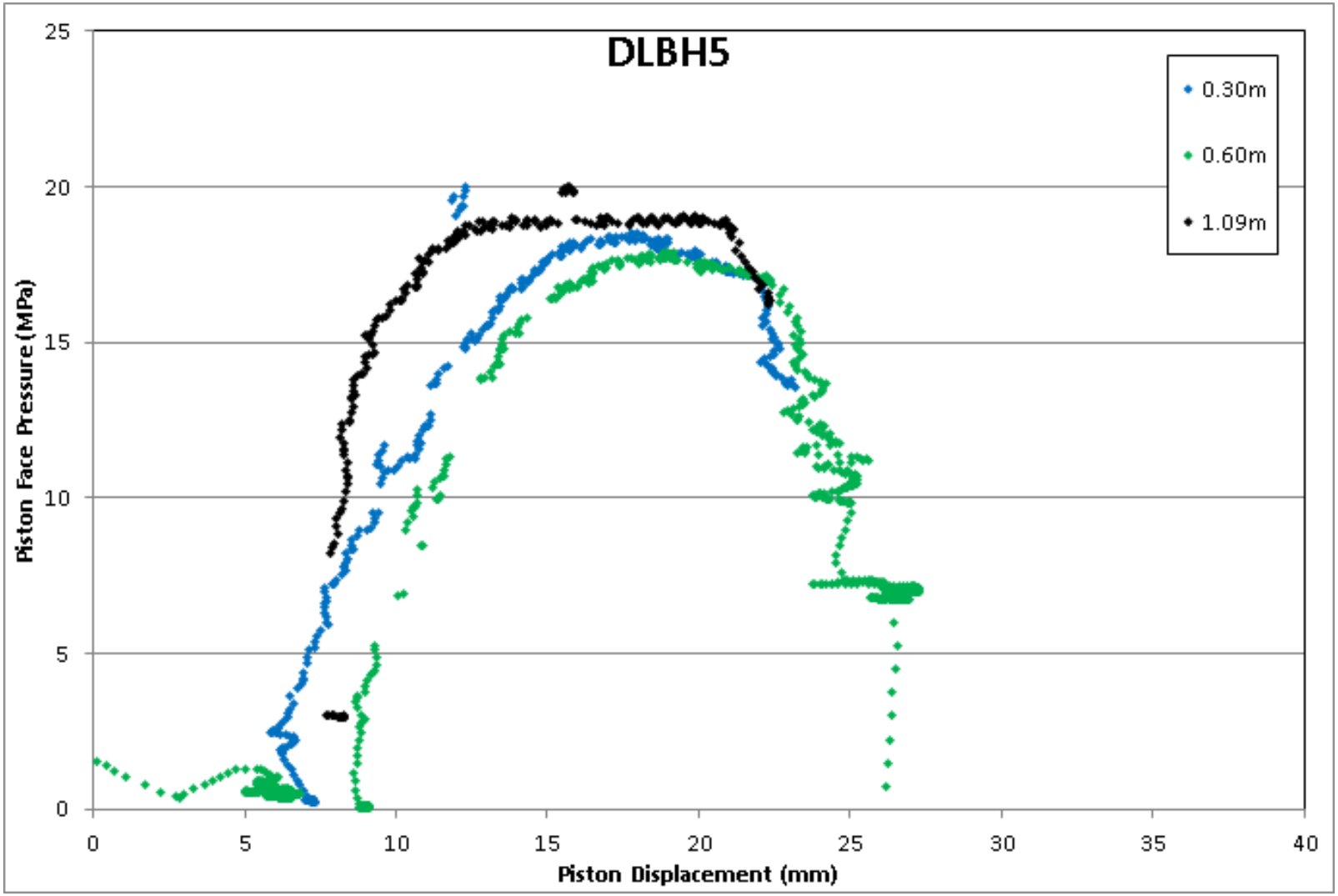
ICE TEMPERATURE MEASUREMENTS IN D1 ICE PAD



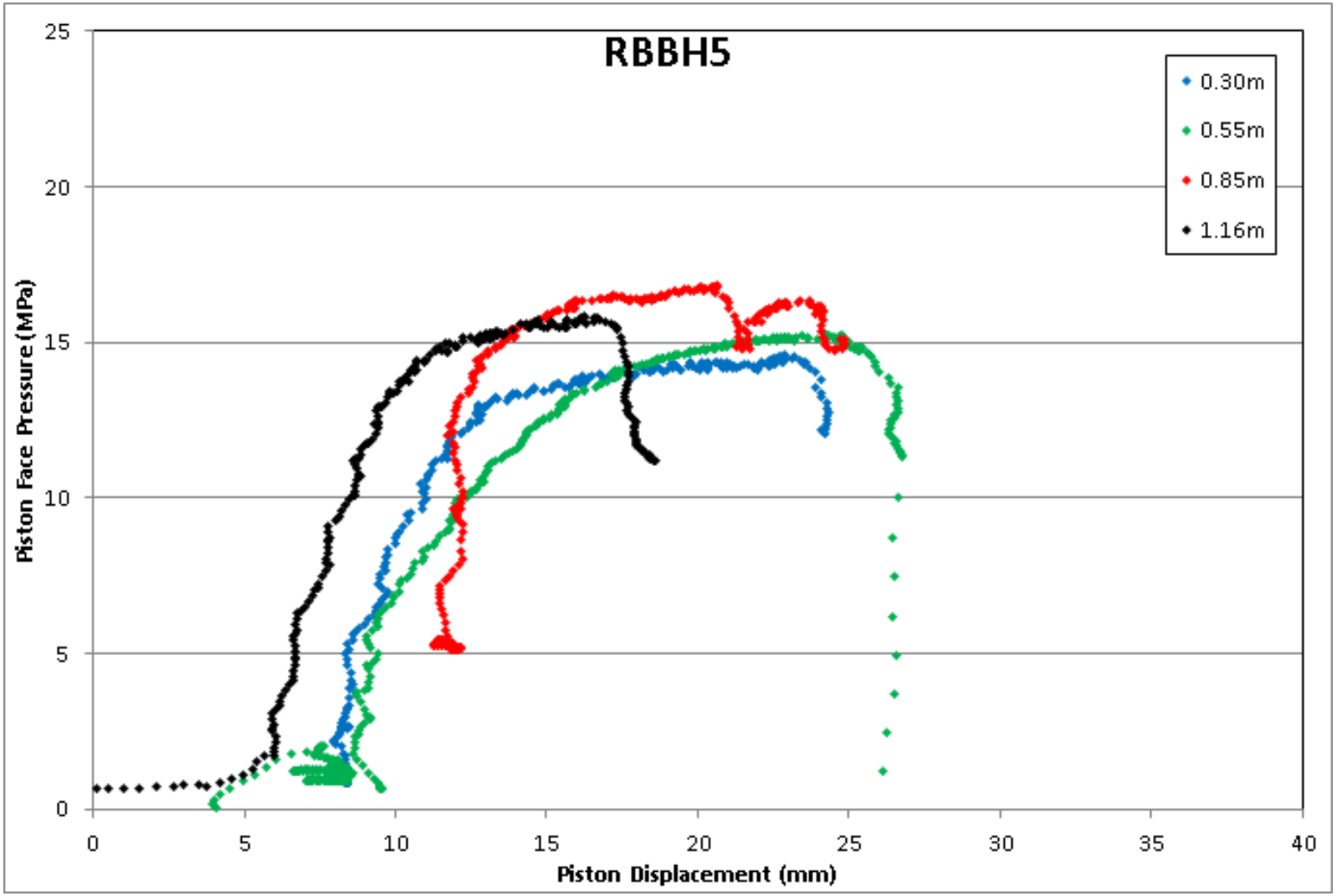
Borehole Jack

Borehole Jack in action

Ice strength: Fresh water ice, May 2011



Ice strength: Salt water ice, May 2011



ON-ICE SAFETY

Travelling & working on ice is risky!

Tetra Tech EBA considers Safety as an integral part and has the highest priority of any on-ice project.

Accidents on Floating Ice Covers

- Recreation related accidents:
  - Between 1996 and 2006 nearly 500 people died in Canada (Canadian Red Cross Society, 2006)

- 4 Examples of work related accidents:
  - Island Lake – MB (January 2002) – EBA as expert witness
  - Peace River – AB (January 7, 2005) – “Best Practice …
  - Opapimaskin Lake – ON (January 14, 2012) - loader retrieval
  - Near Ft. Nelson – BC (February 20, 2014) – excavator ..

Main Reasons for On-Ice Accidents

- Communication gap
- Don’t know the ice thickness
- Don’t know the load
- Wandering off the established road
- Placing and leaving loads on the ice
- Working alone

Peace River fatality, January 07, 2005

Jan.14, 2012 incident: break through hole

March 09, 2012 : Crane Set-Up

March 09, 2012: Hooking-up loader

March 09, 2012 : Loader Retrieval

Ice break-through of an excavator in Northern BC

Break through consequences

- Operator injury or death
- Survivor compensation
- Equipment loss
- Cost of equipment retrieval
- Cost of environmental clean-up
- Damage to reputation of company/industry

The cost of proper safety planning is minimal compared to the cost of an accident!

Summary

- Ice structures were and are vital for assessing remote communities and resources in the Territories.
- Increased ambient temperatures require innovative solutions to increase the on-ice working window.
- Several innovative solutions are suggested.
- On-ice work is risky; but risks can be managed.
- **Remember:**
  - Snow is your enemy!
  - Not knowing the ice thickness is dangerous!

Innovative Solutions for Operating on Ice Covers in Northern Canada

Have a safe stay in Iqaluit!

Thank You !