# Giant Mine Remediation Project– Arsenic Trioxide Management

Pan–Territorial Permafrost Workshop – November 5-7, 2013

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# Overview of Presentation

1. Background on the Giant Mine and the arsenic trioxide dust
2. Selection of the Frozen Block Method
3. Freeze Optimization Study

# Site Location

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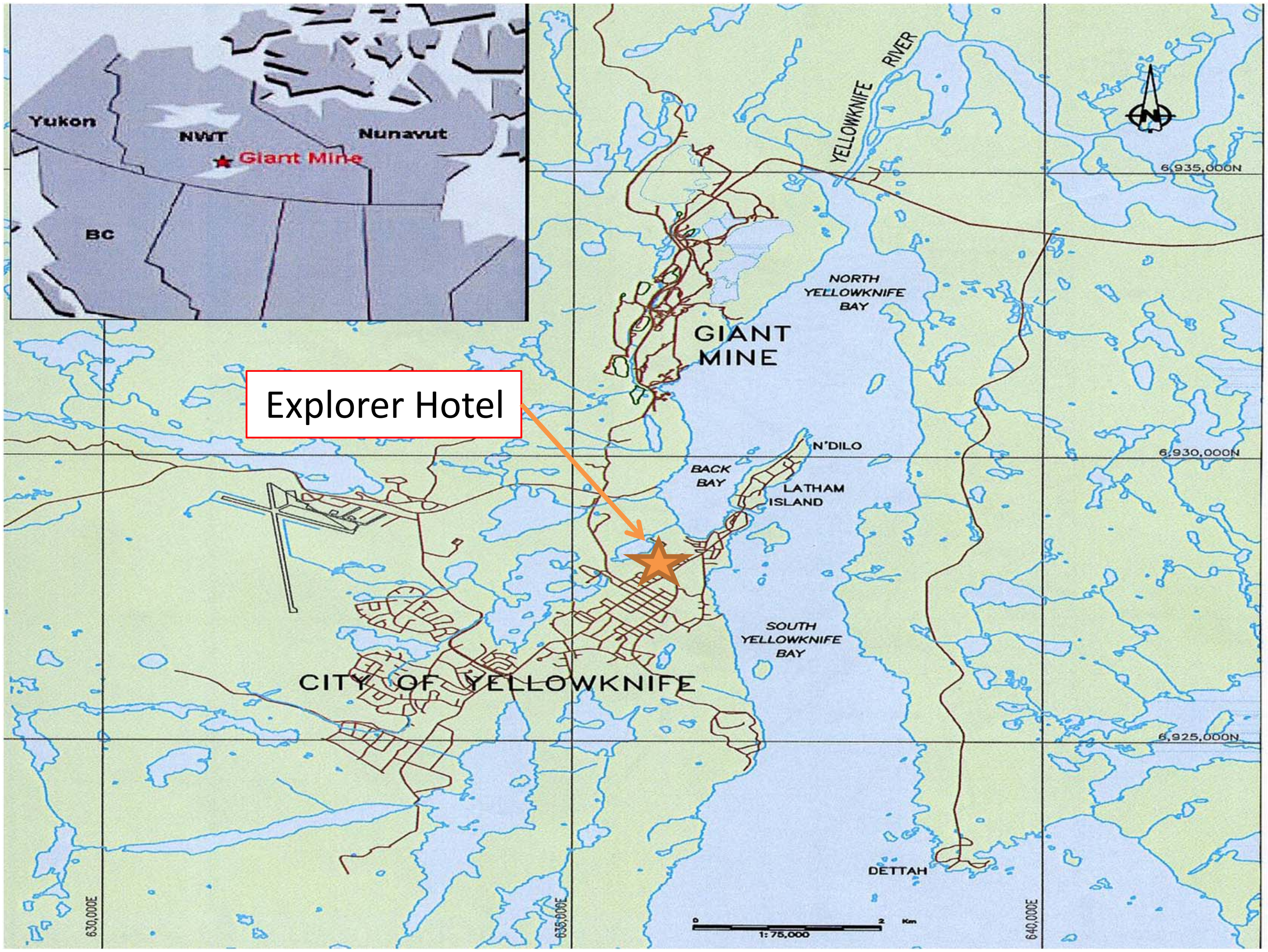
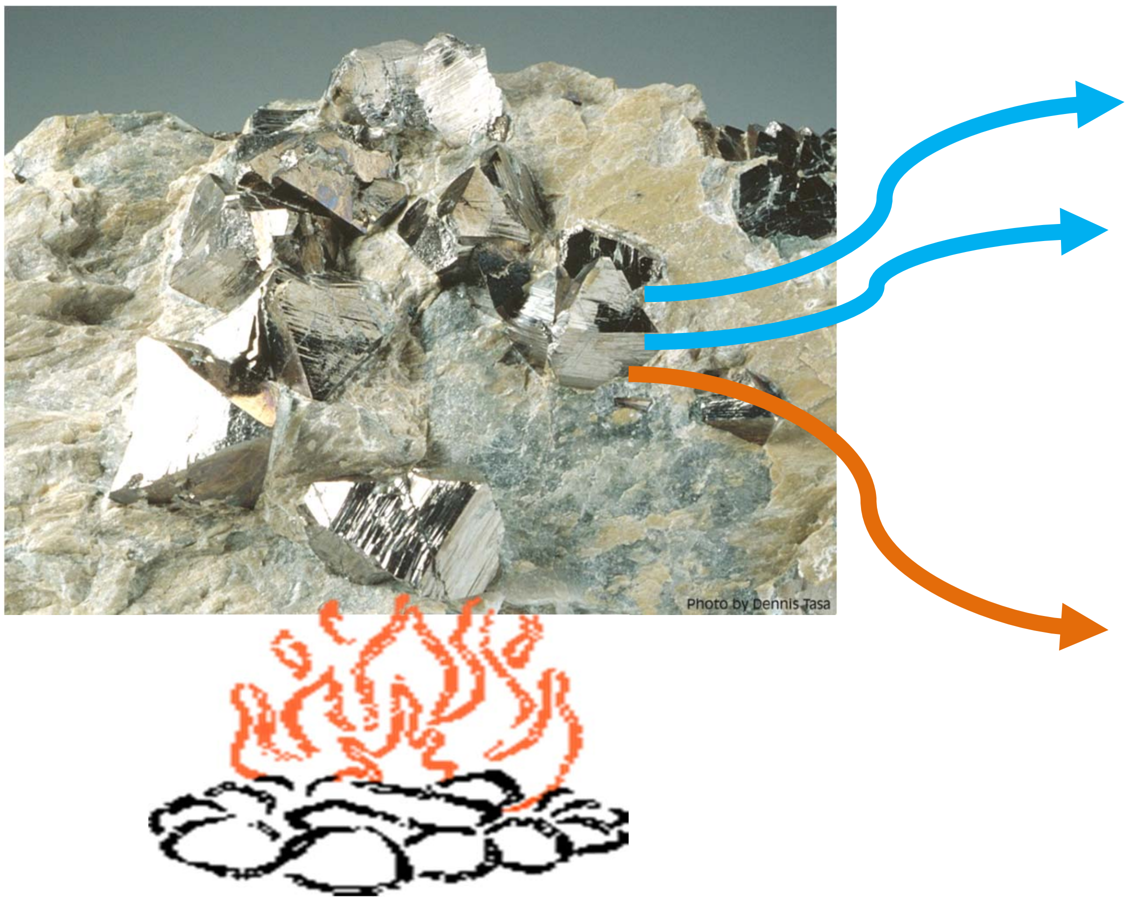


# Arsenic Dust Background

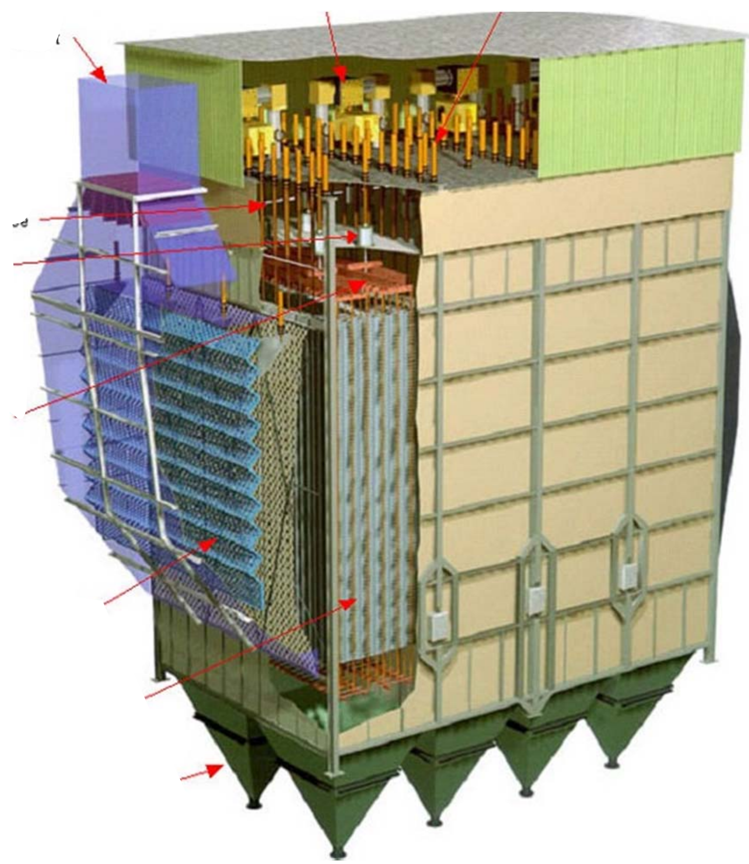
Gold at Giant Mine is associated with an arsenic mineral called arsenopyrite (FeAsS):



# Arsenic Dust Background

- 1949 - 1951
  - Arsenic vapour released into the air
  - Vapour cools to form arsenic trioxide dust

- 1950's
  – Construction and modification of electrostatic precipitator to capture arsenic vapour & dust
- 1963 - 1999
  – Continuing operation with two precipitators



# Arsenic Dust Background

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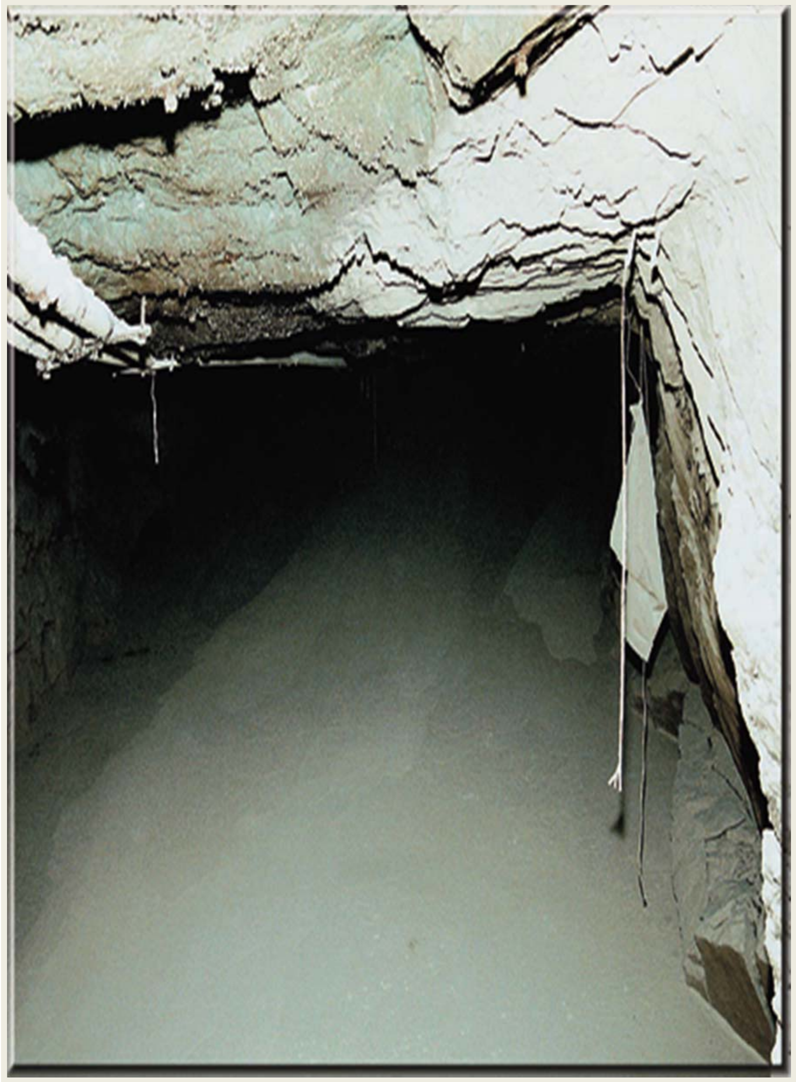
- Initially a dry powder
- Very small particles
- Like fine flour
- 60% arsenic
- Dissolves in water up to 9,000 mg/L



# Arsenic Dust Background

- Yellowknife is in area of discontinuous permafrost
- From 1950's to 1970's, all dust storage areas were in permafrost
- Later became clear that permafrost was degrading, probably due to warm ventilation air pumped through mine

# Arsenic Trioxide Dust Chambers and Stopes

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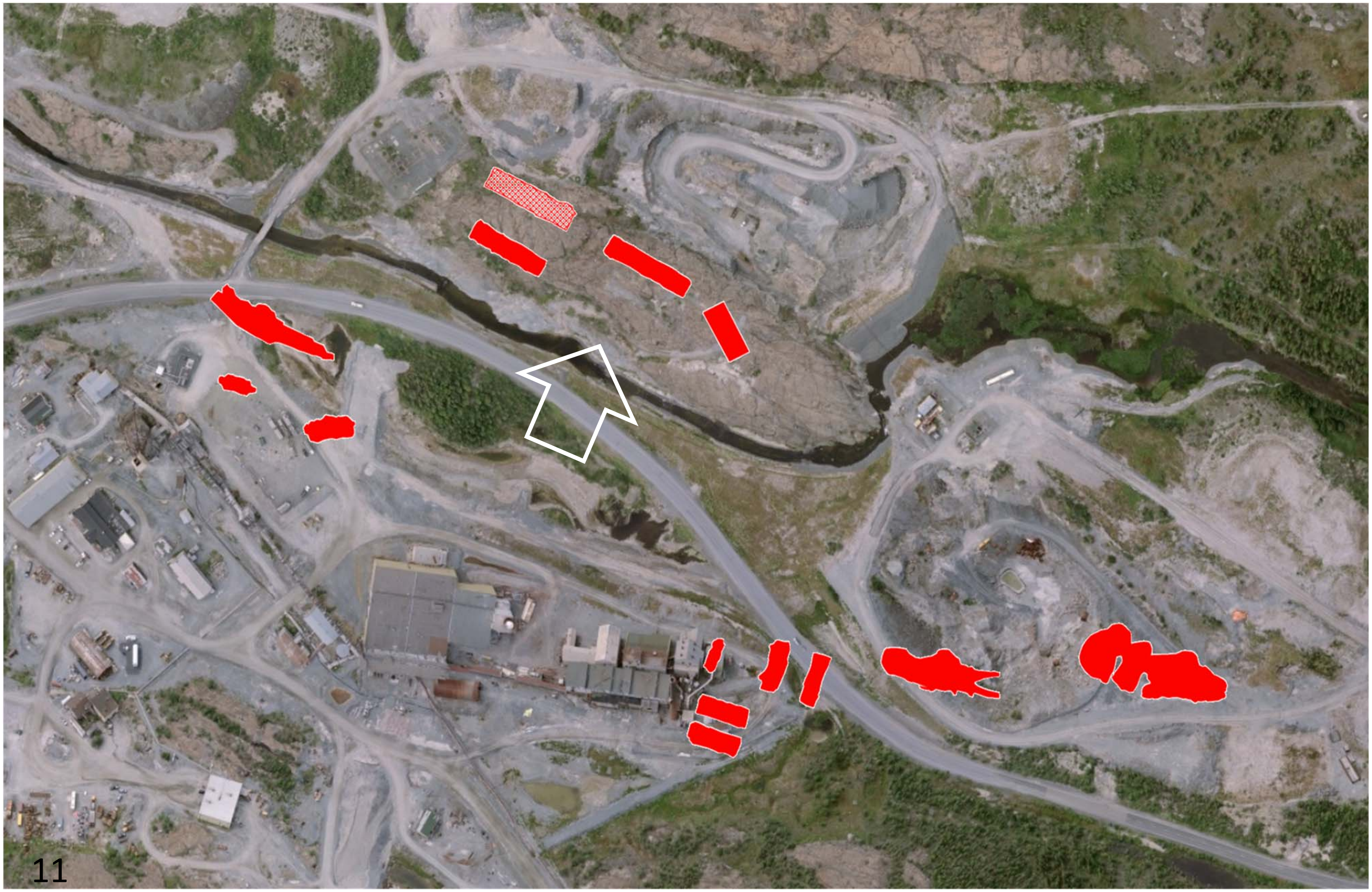
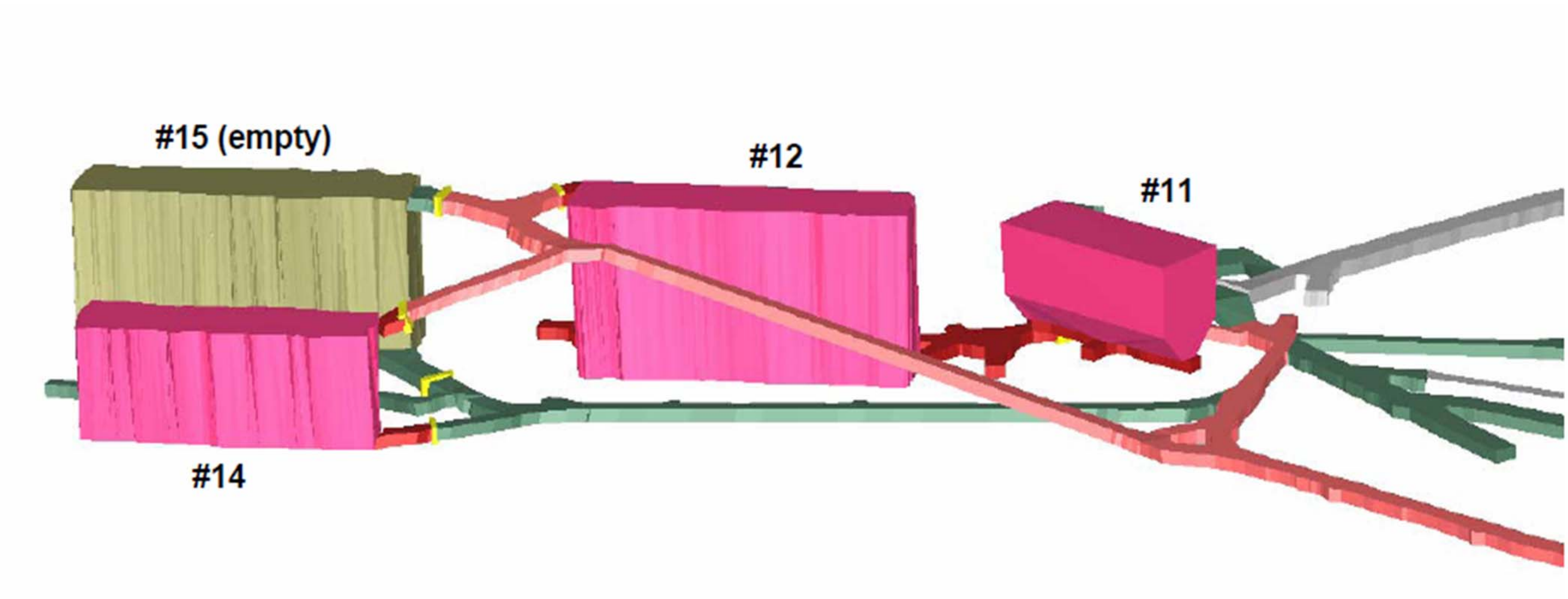
# Example Chambers

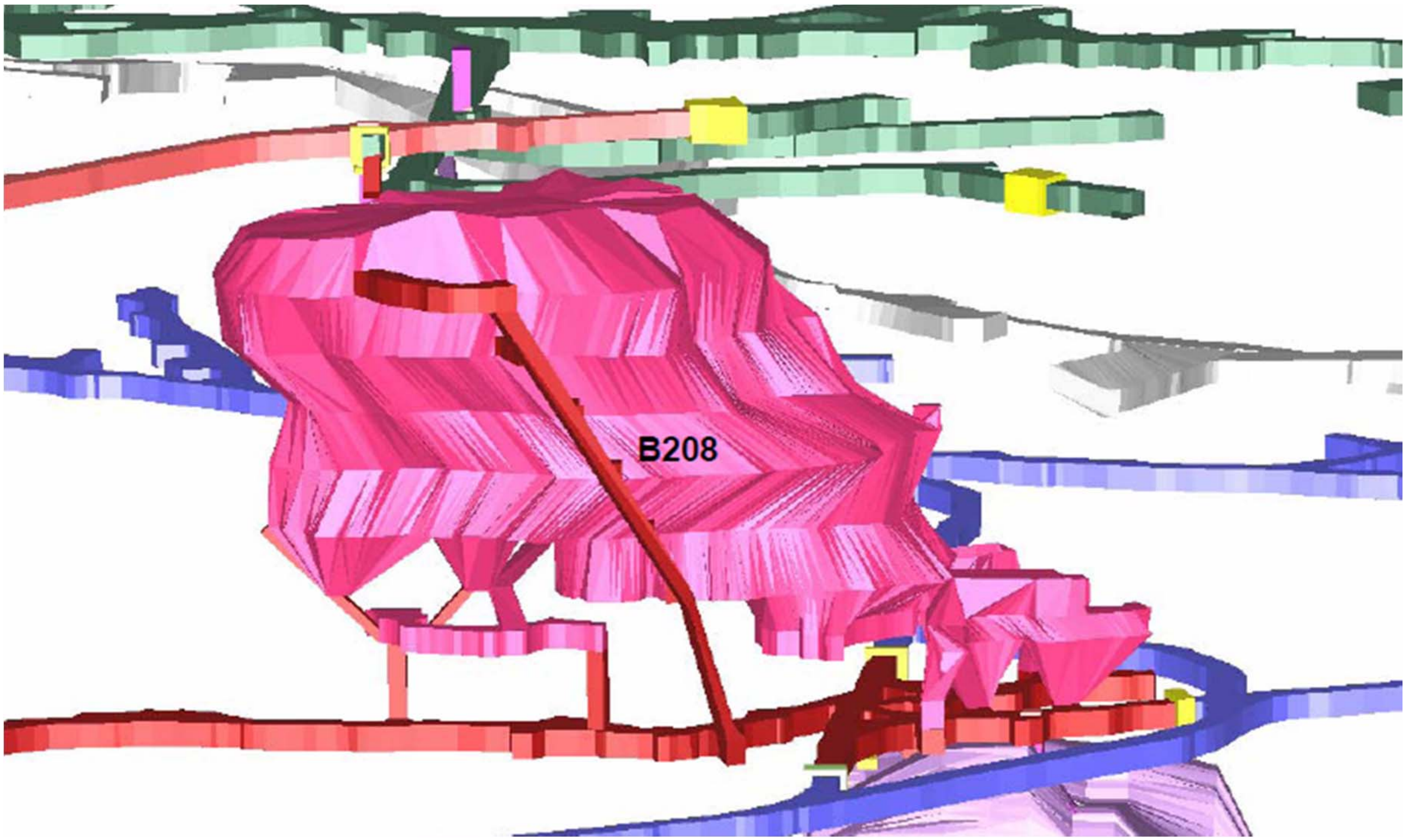


# Example Chambers



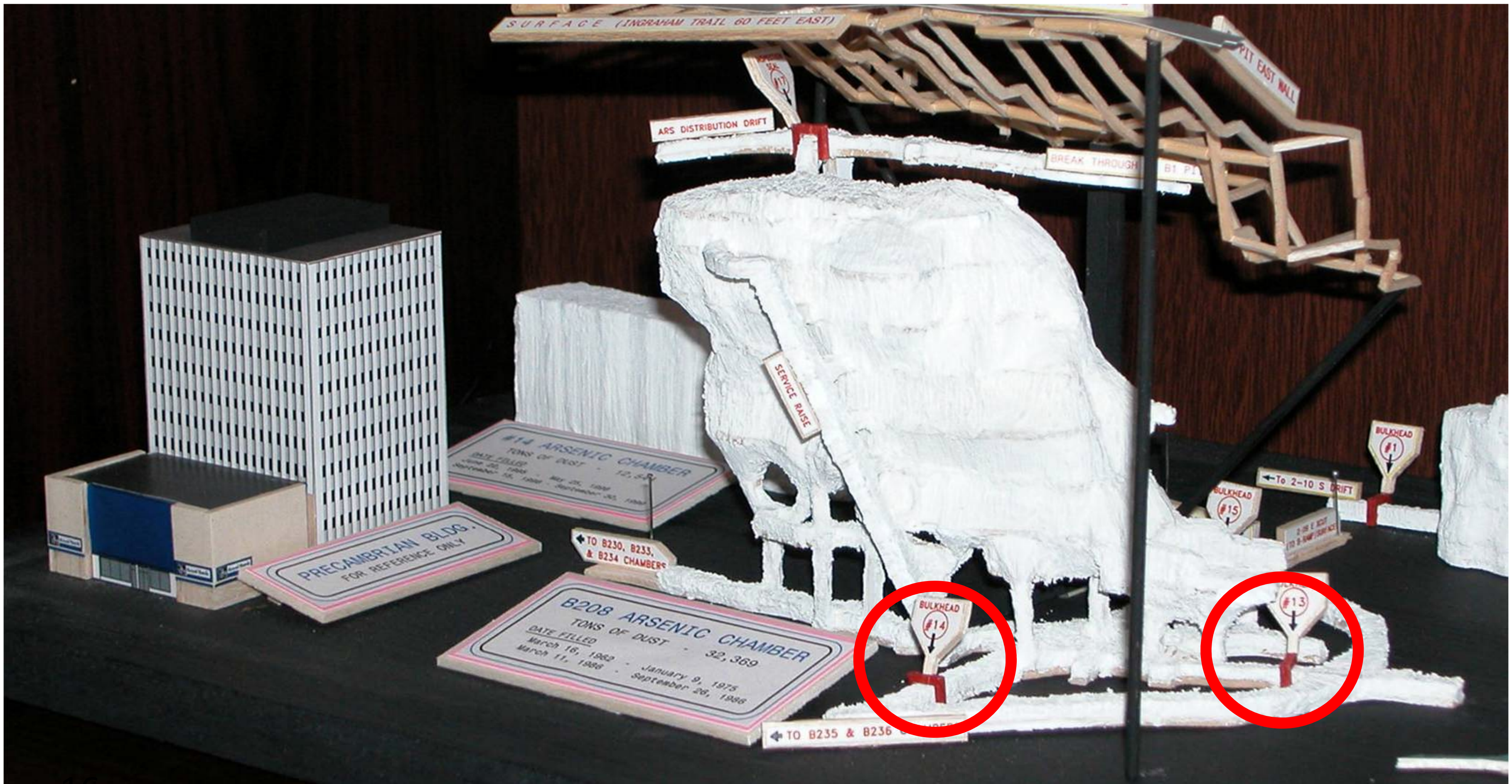
# Example Stope

# Example Stope



# Chamber and Stope Sizes

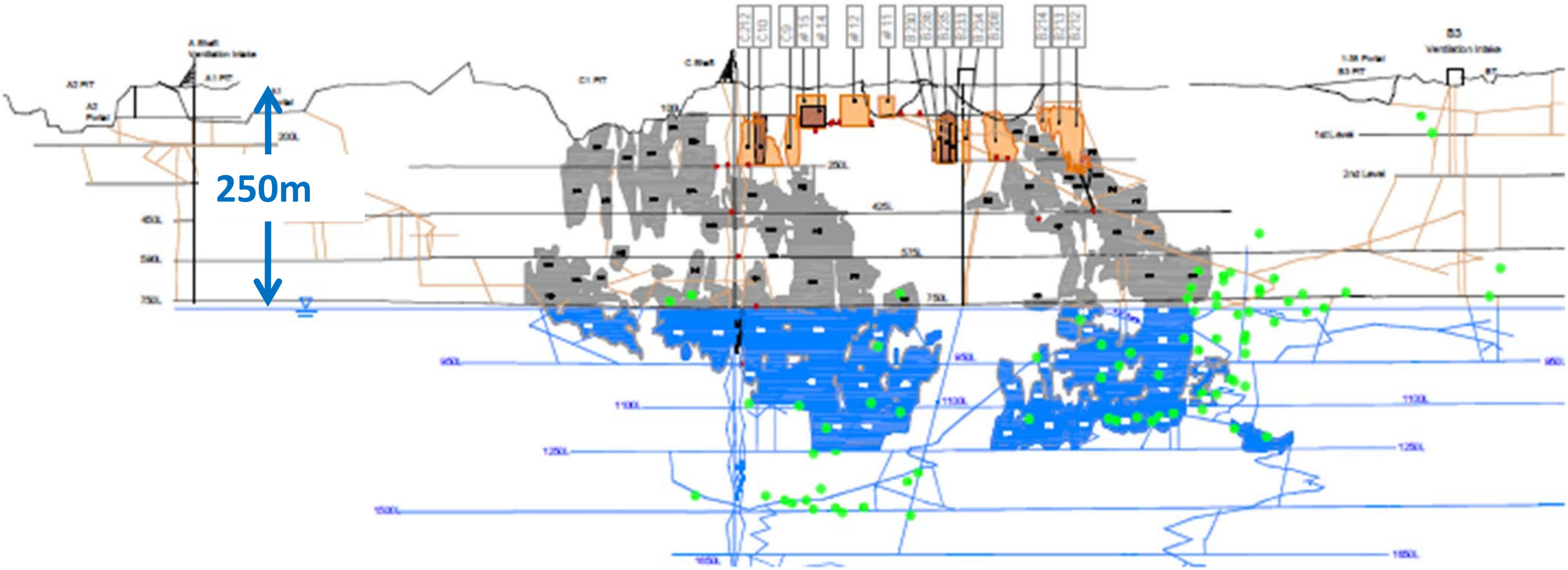
# Bulkheads



SURFACE (INGRAHAM TRAIL 60 FEET EAST)
ARS DISTRIBUTION DRIFT
PIT EAST WALL
BREAK THROUGH
SERVICE RAISE
#14 ARSENIC CHAMBER
TONS OF DUST
PRECAMBRIAN BLDG.
FOR REFERENCE ONLY
TO B230, B233, & B234 CHAMBERS
B208 ARSENIC CHAMBER
TONS OF DUST - 32,369
DATE FILLED
March 16, 1962 - January 9, 1975
March 11, 1986 - September 26, 1986
TO B235 & B236
BULKHEAD #14
#13
BULKHEAD #15
TO 2-10 S DRIFT
BULKHEAD #1

# Currently completely contained

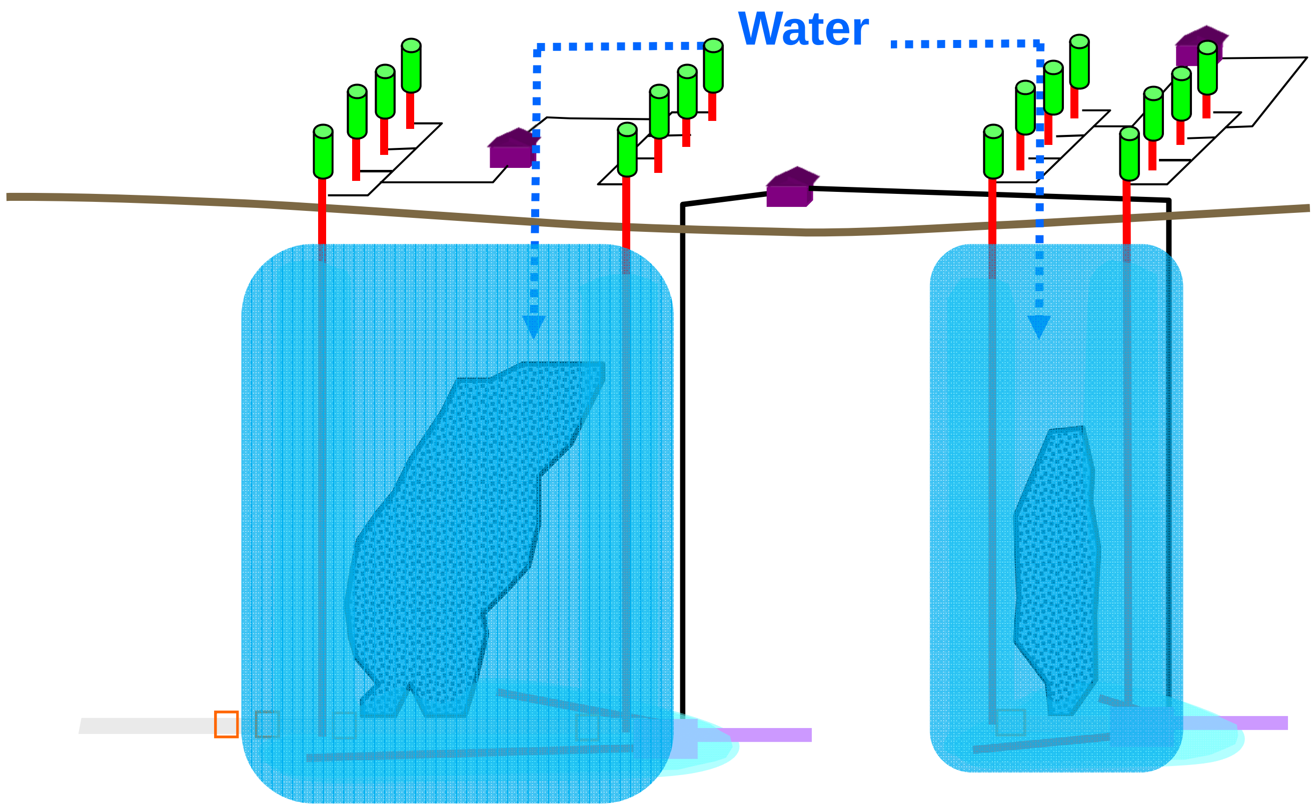
- Any water that leaves the mine is treated to remove arsenic



# Environmental Risks

- Long term
  - Without remediation, dust could release 12,000 kg of arsenic per year into groundwater
- Medium term
  - Collapse of underground bulkheads or crown pillars, or flooding of mine by Baker Creek, could lead to escape of arsenic

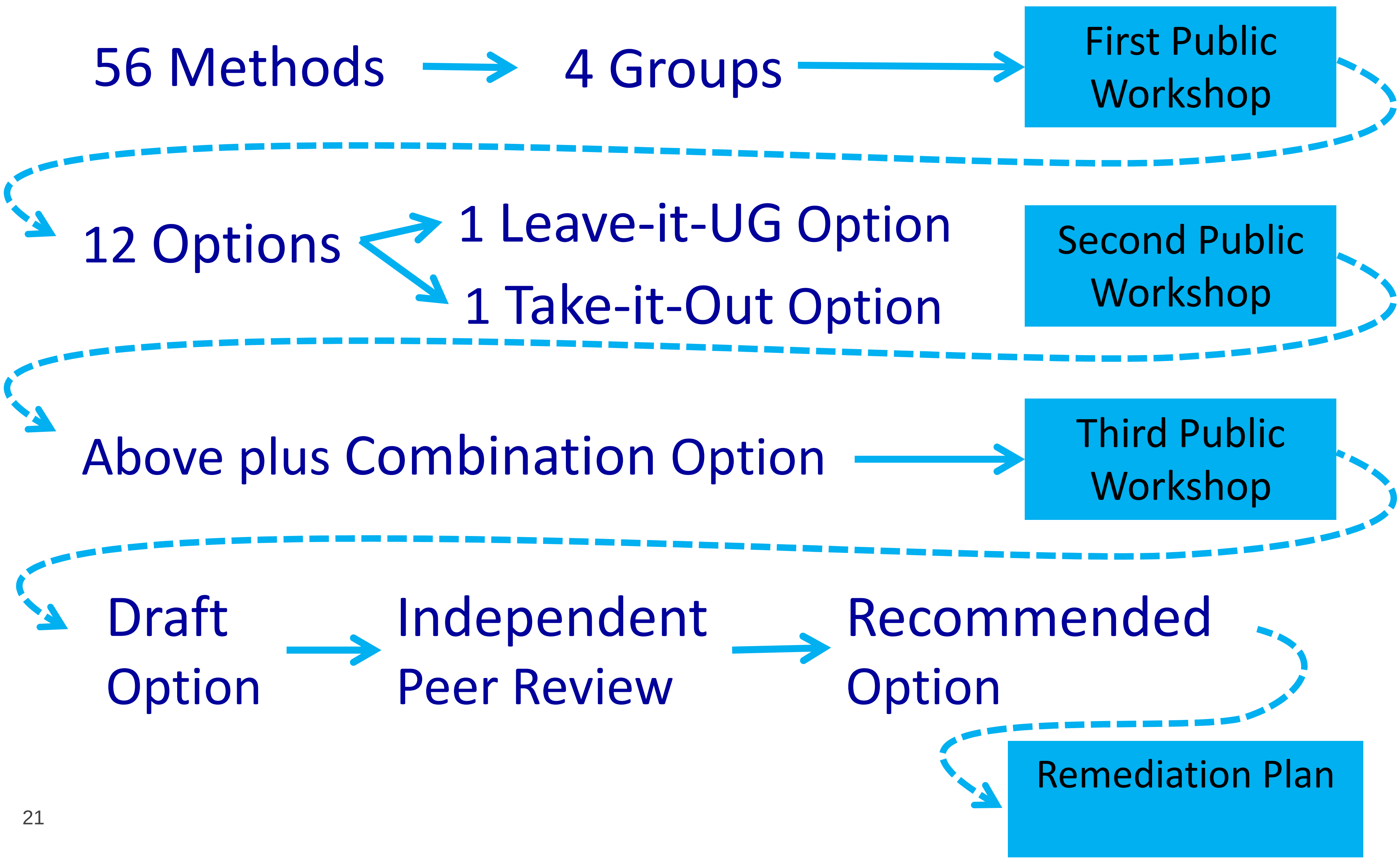
# Frozen Block Method



# Options Assessment Process

- 2001 – 2003
- Teams of engineers and Technical Advisor
- Over 40 public consultation sessions
- Three major public workshops
- Independent Peer Review Panel

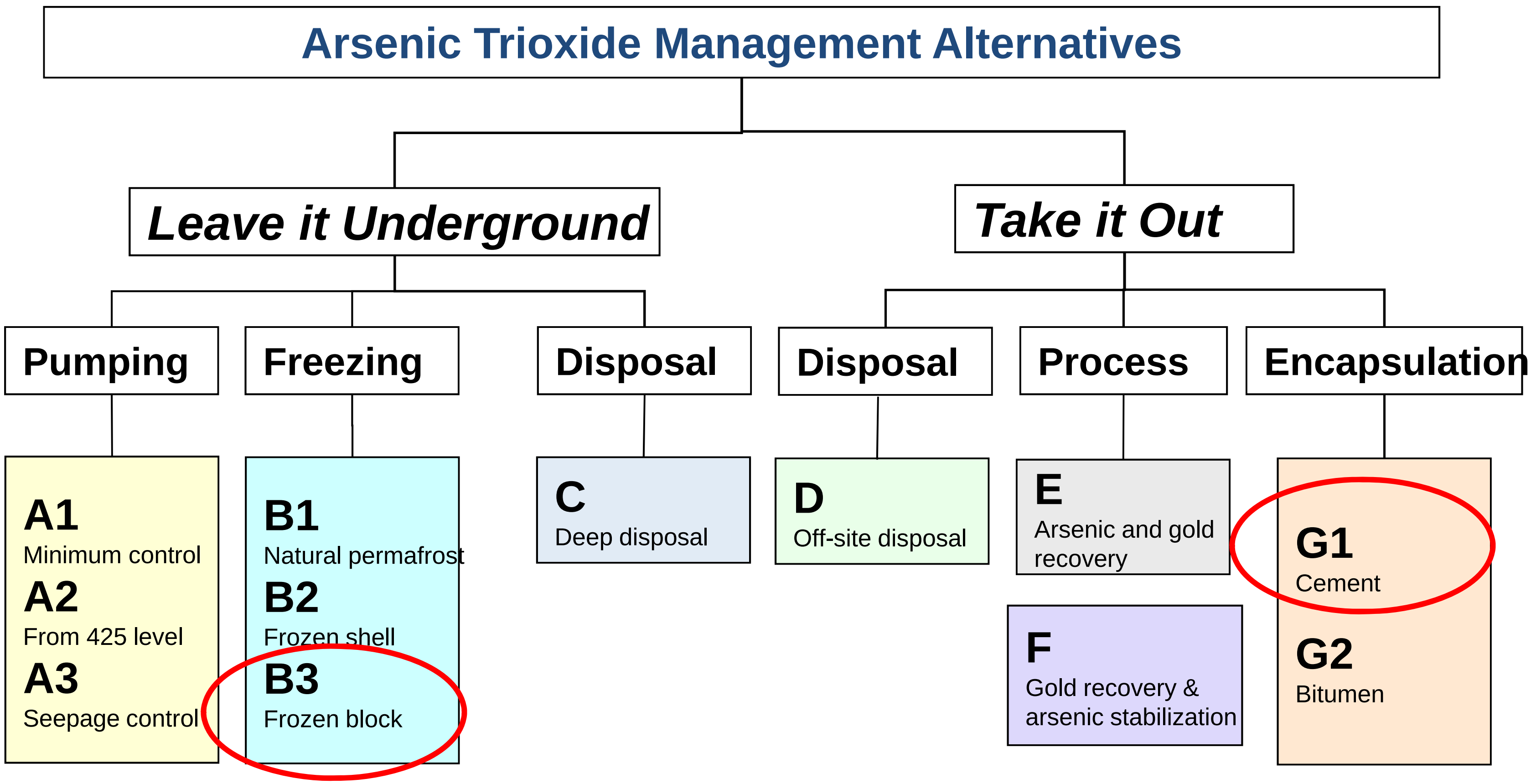
# Options Assessment Process



# Initial 56 Methods Considered for Management of Giant Mine Arsenic Trioxide Dust

| In Situ Management | Removal of Dust | Re-Processing to Recover Gold and/or Arsenic Value | Waste Stabilization and Disposal |
|---|---|---|---|
| • Pump and treat methods<br>- Status quo pump and treatment<br>- Flow segregation<br>- Partial flood<br>- Inflow reduction<br>Isolation methods<br>- Hydraulic cage<br>- Grout curtain<br>- Diversion of Baker Creek<br>- Surface cover<br>- Ground freezing<br>In situ modifications<br>- Engineered dilution<br>- Dust freezing<br>- Biological treatment<br>Relocation (and in situ management)<br>- Move deeper underground<br>- Move above water table<br>- New engineered/purpose built vaults<br>- Batch treatment/relocation | Bulk Mining Methods<br>- Open pit mining<br>- Re-stoping of dust<br>- Freezing and re-stoping of frozen dust<br>- Remote mechanical mining<br>- Clamshell excavation (from top of chamber)<br>Methods of Retrieving Dust in a Pipe<br>- Wet vacuum<br>- Dry vacuum<br>- Fluidization from base<br>- Flooding and pumps<br>- Wet reverse circulation<br>- Dry reverse circulation<br>- Jet Boring<br>- Dredging<br>In Situ Mining Methods<br>- Solution mining<br>- Volatilization | Direct shipment of crude dust<br>Production and shipment of refined dust<br>- Fuming (selective sublimation)<br>- Leaching & recrystallization (Hot water, caustic, etc.)<br>Arsenic metal production<br>Manufacture of added value products<br>- Copper Chromated Arsenate<br>- Lumber treated with CCA<br>Stabilization of $As_2O_3$ and preparation of refractory gold values for recovery<br>- Pressure oxidation<br>- Biological treatments<br>Cyanidation and gold recovery<br>Water treatment<br>- Water treatment for arsenic removal<br>- Cyanide destruction | Isolation and Containment<br>- Conventional landfill<br>- Lined basins<br>- Concrete/steel vaults (permanent)<br>- Concrete/steel structures or containers (temporary)<br>- Underground disposal<br>Physical stabilization<br>- Bitumen<br>- Cement<br>- Zeolite or Clay Additive<br>- Vitrification<br>- Vibrasonic<br>Chemical stabilization<br>- Precipitation With Iron<br>- Precipitation With Calcium<br>- Slag Disposal<br>- Polysilicates |

# Second Round – 12 Alternatives



# Risk Summary

| Alternative | Probability of Significant Arsenic Release | | Worker Health & Safety Risk |
|---|---|---|---|
| | Short Term | Long Term | |
| A1. Water Treatment with Minimum Control | Low | High | Low |
| A2. Water Treatment with Drawdown | Low | Moderate | Low |
| A3. Water Treatment with Seepage Control | Low | Moderate | Low |
| B2. Frozen Shell | Very Low | Low | Low |
| B3. Frozen Block | Very Low | Low | Low |
| C. Deep Disposal | Low | Very Low | Moderate |
| D. Removal & Surface Disposal | High | Very Low | Moderate |
| F. Removal, Gold Recovery and Arsenic Stabilization | Moderate | Very Low | Moderate |
| G1. Removal & Cement Encapsulation | Moderate | Low | Moderate |

# Option Assessment Conclusion

Concluded that keeping the dust in the ground and freezing it was the best option:

- Low risk to workers
  - no need to mine the dust
- Low risk of short-term arsenic release
  - No need to transport or re-process dust
- Low risk of long-term arsenic release
  - Easy to monitor and adapt if needed

# Freeze Optimization Study (FOS)

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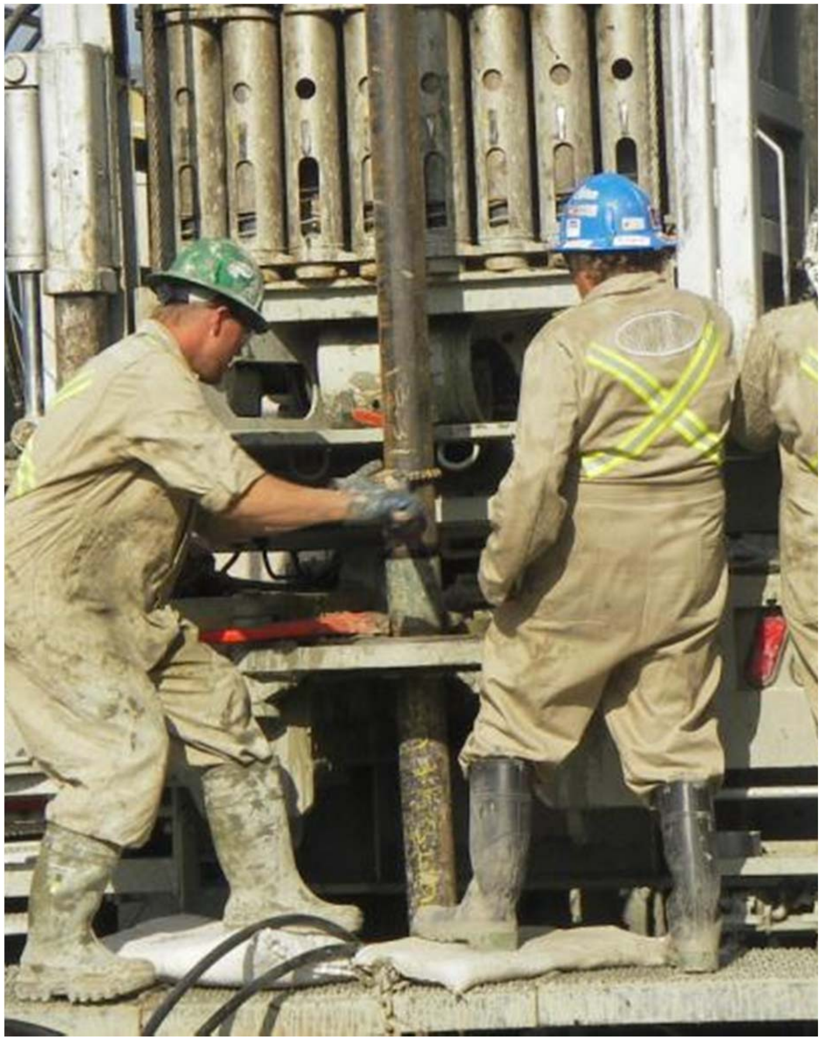
FOS Objectives

- Demonstrate to the public that ground freezing works
- Inform further engineering design
  - Model calibration – Material properties, heat removal rates, etc.
- Provide input to the environmental assessment and water licensing processes

# Site Preparation

# Drilling Freeze Holes



# Installing Freeze Pipes

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# Installing Thermosyphons

# Freeze Plant

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# Coolant Distribution Piping

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# Freeze Optimization Study – Results to Date

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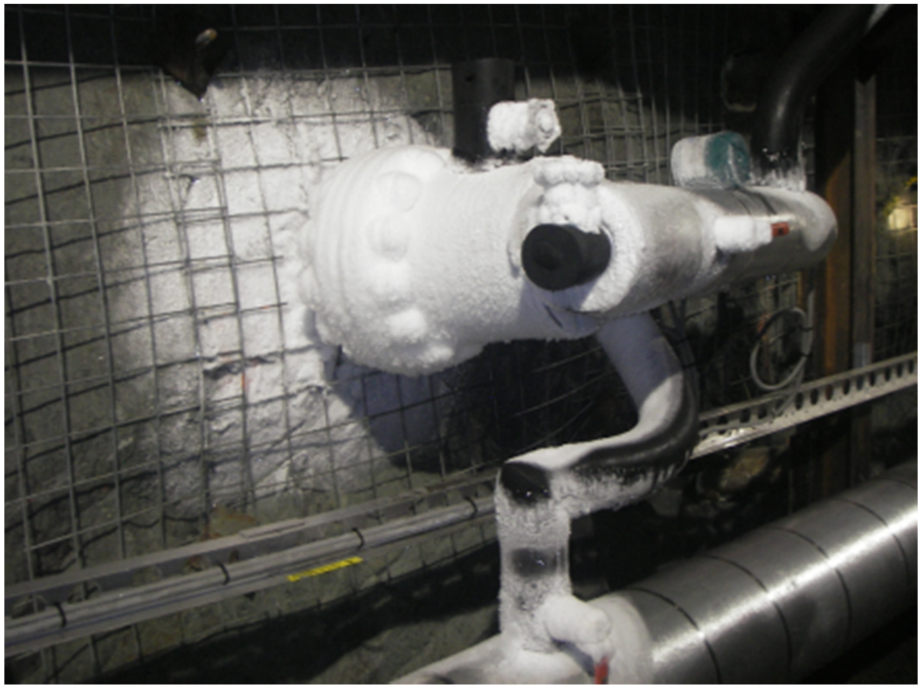
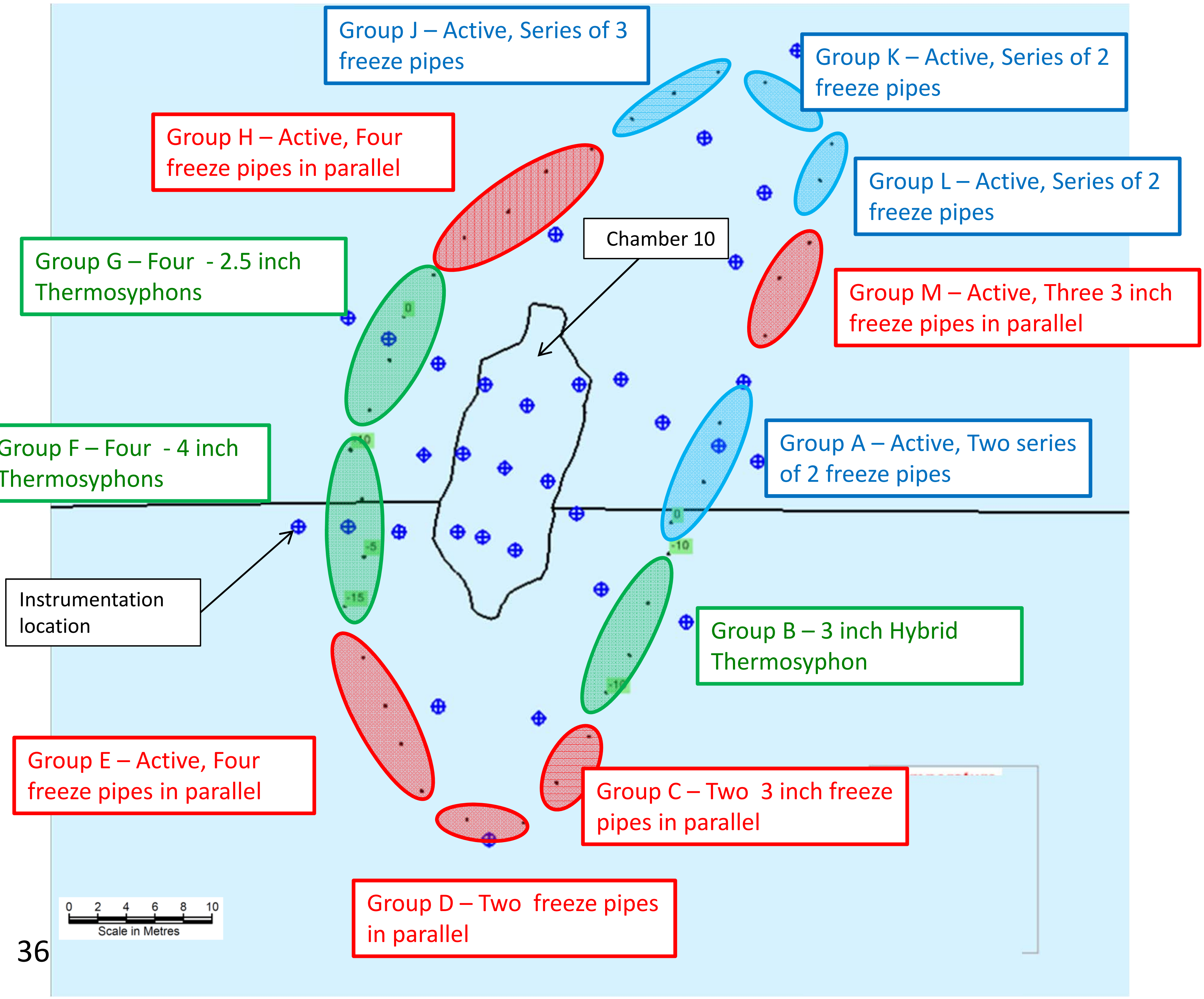
- Ground is freezing faster than expected
- Both active freezing and hybrid freezing systems are working well
- Good data set for further engineering analyses and design optimization

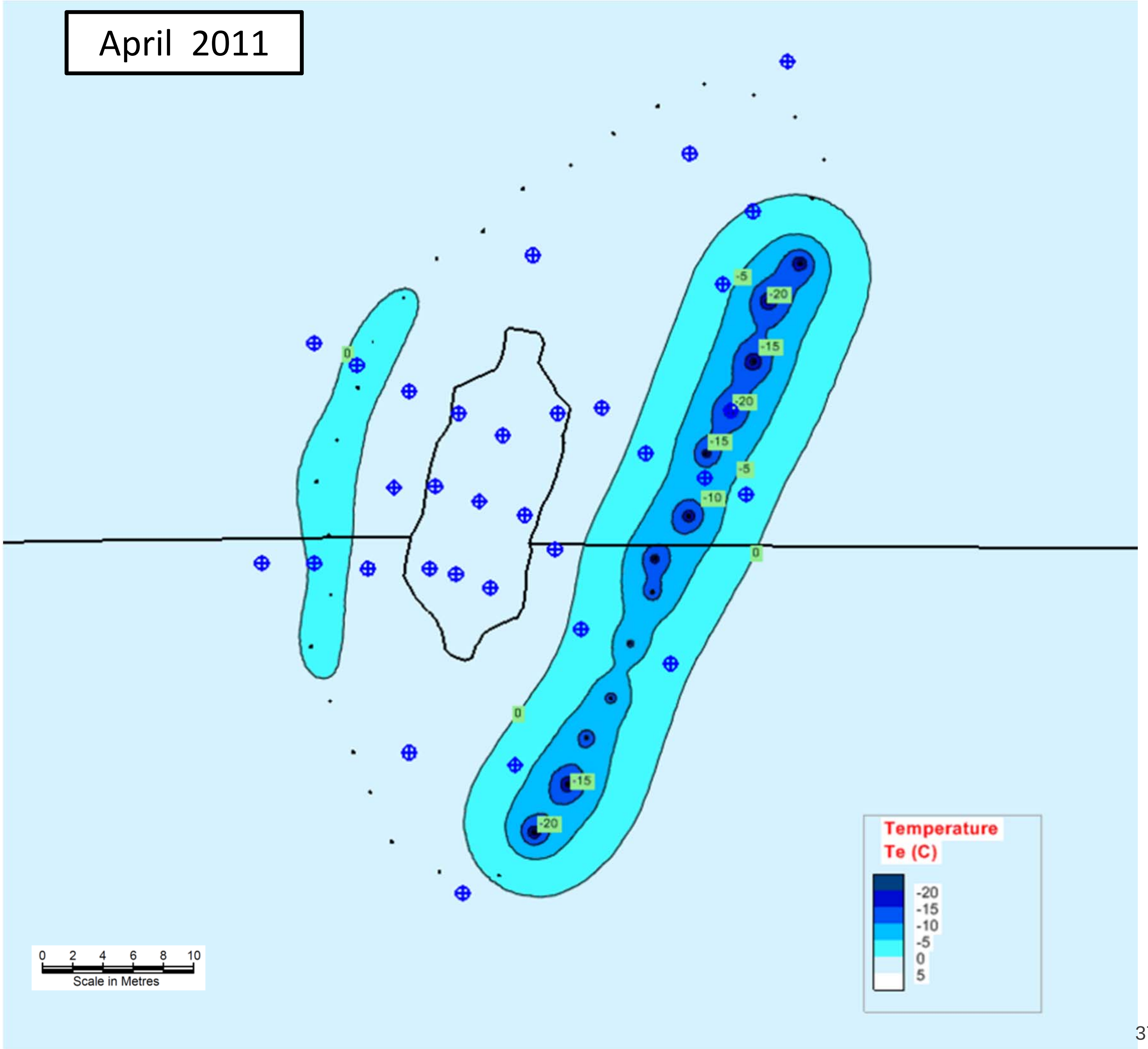
# Underground Freeze System



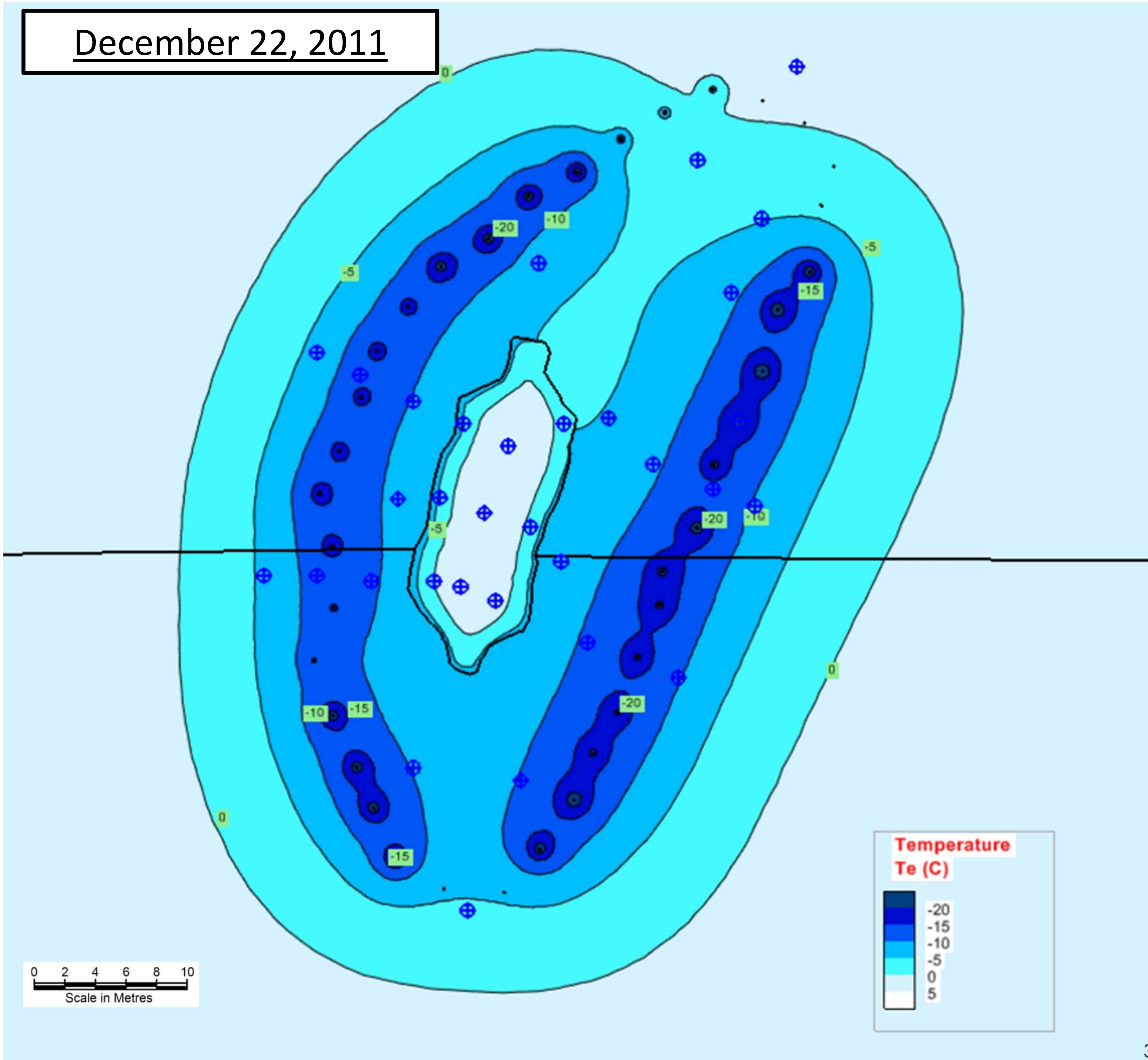
- Underground tunnel below Chamber 10 in  March 2011

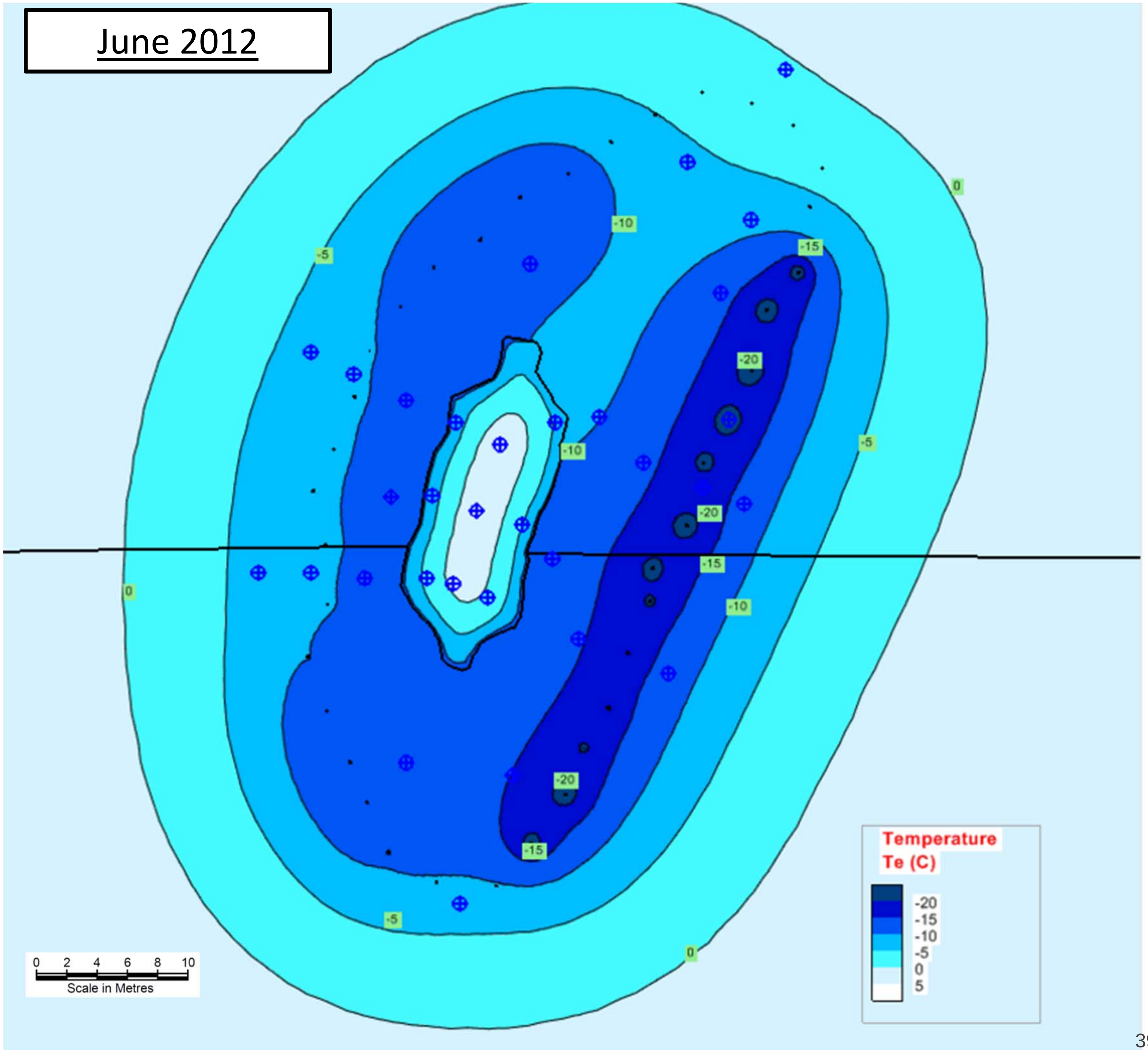
- Same tunnel in September 2011

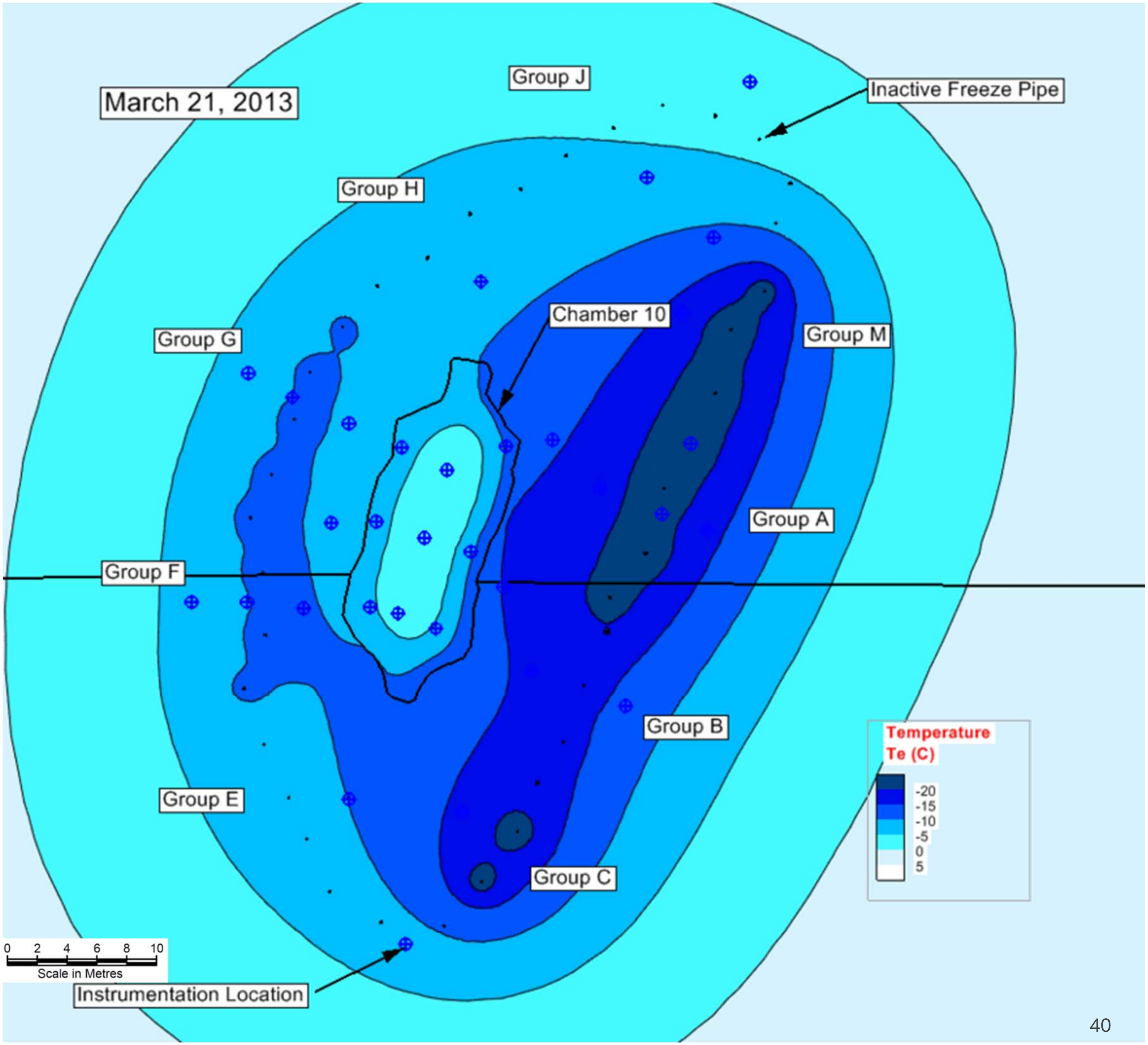

Group J – Active, Series of 3 freeze pipes
Group K – Active, Series of 2 freeze pipes
Group H – Active, Four freeze pipes in parallel
Group L – Active, Series of 2 freeze pipes
Chamber 10
Group G – Four - 2.5 inch Thermosyphons
Group M – Active, Three 3 inch freeze pipes in parallel
Group F – Four - 4 inch Thermosyphons
Group A – Active, Two series of 2 freeze pipes
Instrumentation location
Group B – 3 inch Hybrid Thermosyphon
Group E – Active, Four freeze pipes in parallel
Group C – Two 3 inch freeze pipes in parallel
Group D – Two freeze pipes in parallel
0 2 4 6 8 10
Scale in Metres



April 2011
-5
-20
-15
-20
-15
-5
-10
0
0
0
-15
-20
Temperature
Te (C)
-20
-15
-10
-5
0
5
0 2 4 6 8 10
Scale in Metres


December 22, 2011
0
-10
-20
-5
-5
-15
-5
-20
-10
0
-10
-15
-20
0
-15
Temperature
Te (C)
-20
-15
-10
-5
0
5
0
2
4
6
8
10
Scale in Metres


June 2012
0
-5
-10
-15
-20
-20
-15
-10
-5
-20
-15
-5
0
Temperature
Te (C)
-20
-15
-10
-5
0
5
0 2 4 6 8 10
Scale in Metres



March 21, 2013
Group J
Inactive Freeze Pipe
Group H
Chamber 10
Group G
Group M
Group A
Group F
Group B
Temperature
Te (C)
-20
-15
-10
-5
0
5
Group E
Group C
0 2 4 6 8 10
Scale in Metres
Instrumentation Location

# Data Analysis to Date

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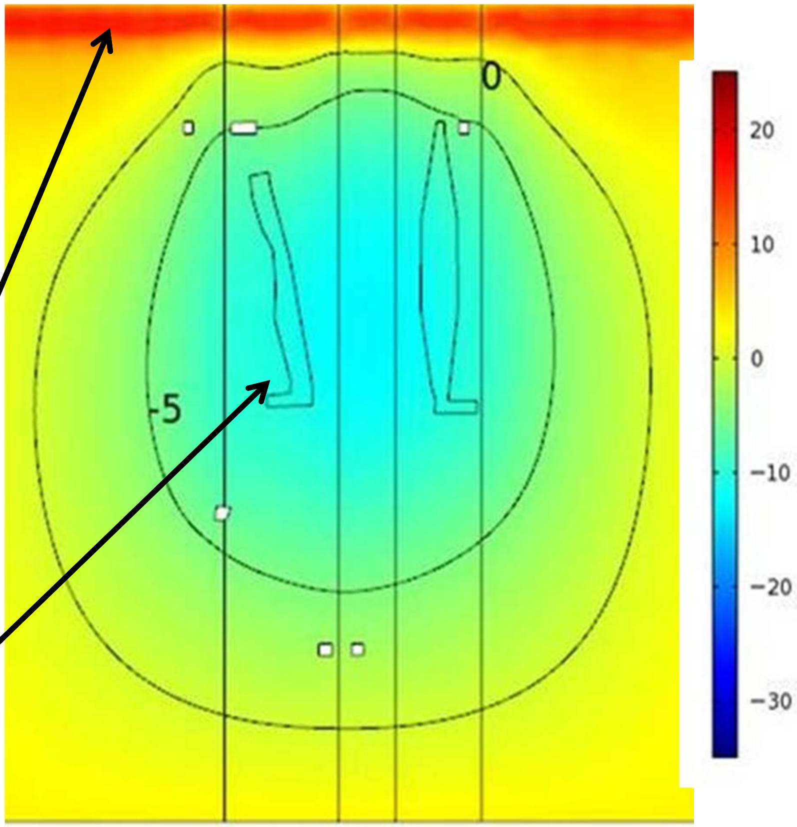
- Estimate material properties – calibrate thermal models
- Show influences on rate of initial freezing
- **Assess long-term performance** under worst case climate change
- **Assess possible design improvements**

# Assessing Long-term Performance

- Worst case climate warming (+6.1$^{o}$C increase to the MAAT)
- Passive freezing (thermosyphons) only
- Thermosyphons maintain the frozen block even under extreme climate warming
- Chambers C10 & C212
  - Ground surface gets quite warm in summer
  - Dust remains at -5C



# Design Improvements

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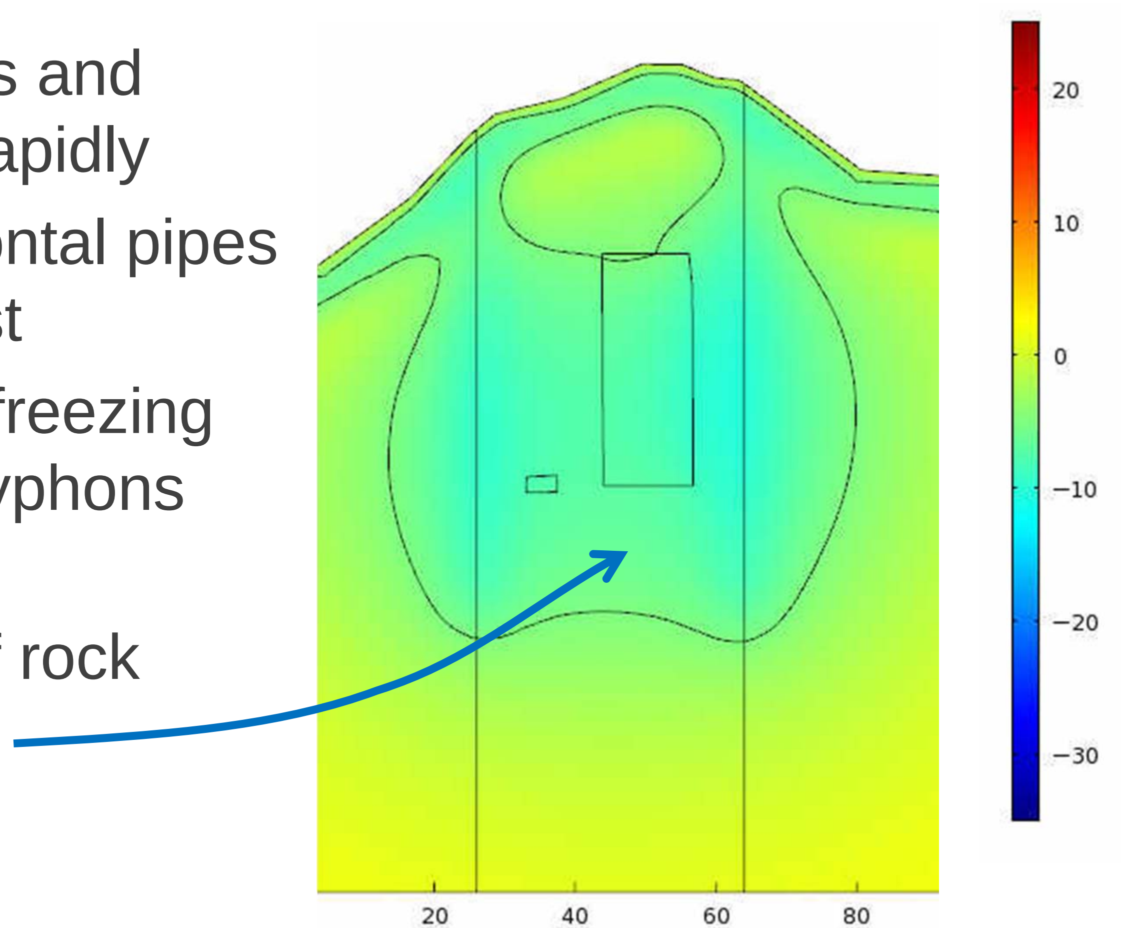
- Important part of the engineering process
- New information
  - Environmental assessment
  - Stakeholder input
  - Field tests and engineering studies
- Optimization at every step
  - "Is there a way to do this even better?"

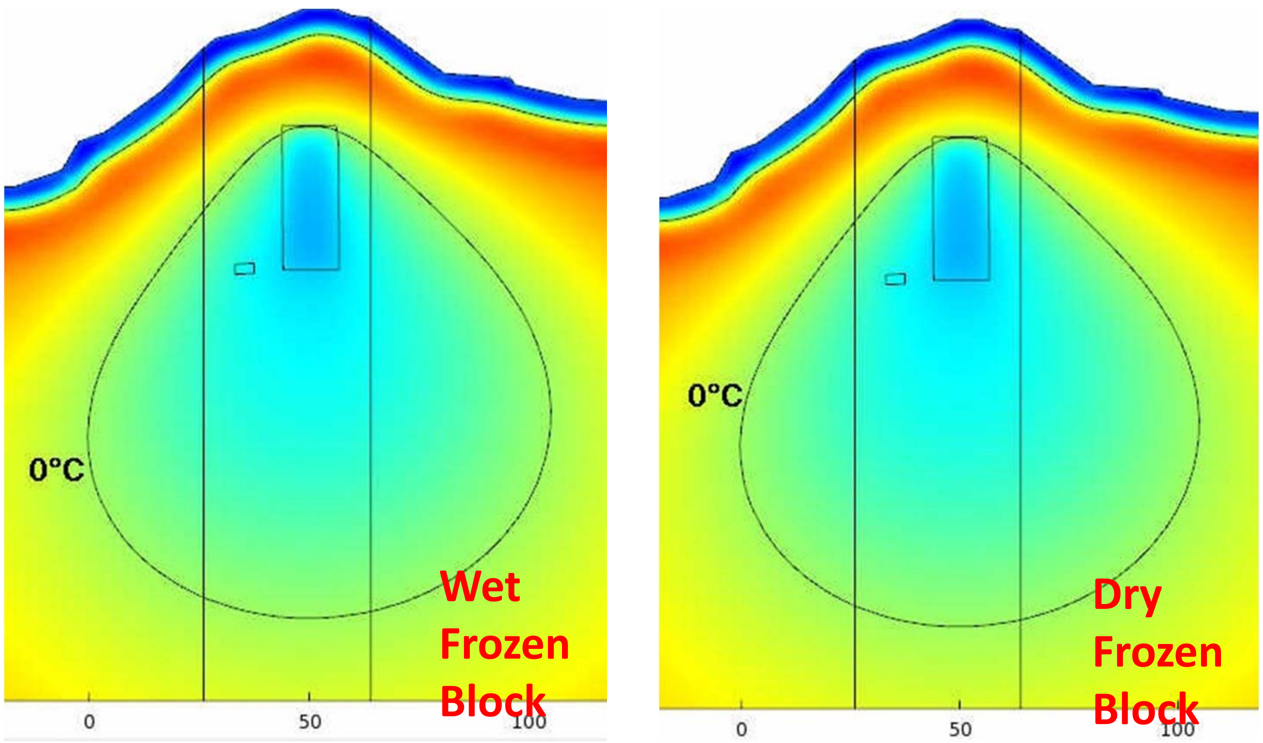
# Possible Design Improvements (Example 1)

- Rock below chambers and stopes freezes very rapidly
- Might not need horizontal pipes under the arsenic dust
- This example shows freezing with surface thermosyphons only
- Note good freezing of rock below chamber



# Possible Design Improvements (Example 2)

- Rock around a dry frozen block stays cold for as long as rock around a wet frozen block
- Might not need to add water




Both figures assume extreme climate warming & all thermosyphons inoperable for 20 years

# Possible Design Improvements (Many Other Examples):

Other detailed design elements currently under evaluation:

- More pipes, less pipes, deeper pipes?
- Active or hybrid, pipe diameter, pipe materials, freeze plant type and size, power supply, etc.
- Temperature monitoring by thermistors or thermocouples, how many, where located, etc.
- Data handling methods, error checking, report generation, remote access, stakeholder access, etc.

# Summary

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- The arsenic trioxide dust in its current state at the Giant Mine represents a real risk
- The frozen block method was selected through a long and careful process and is the best option available, it will mitigate the risk and be safe over the very long term.
- The freeze optimization study had been successful in demonstrating that method will work and useful for optimization of the full-scale freeze design.

# Thank-you for your attention