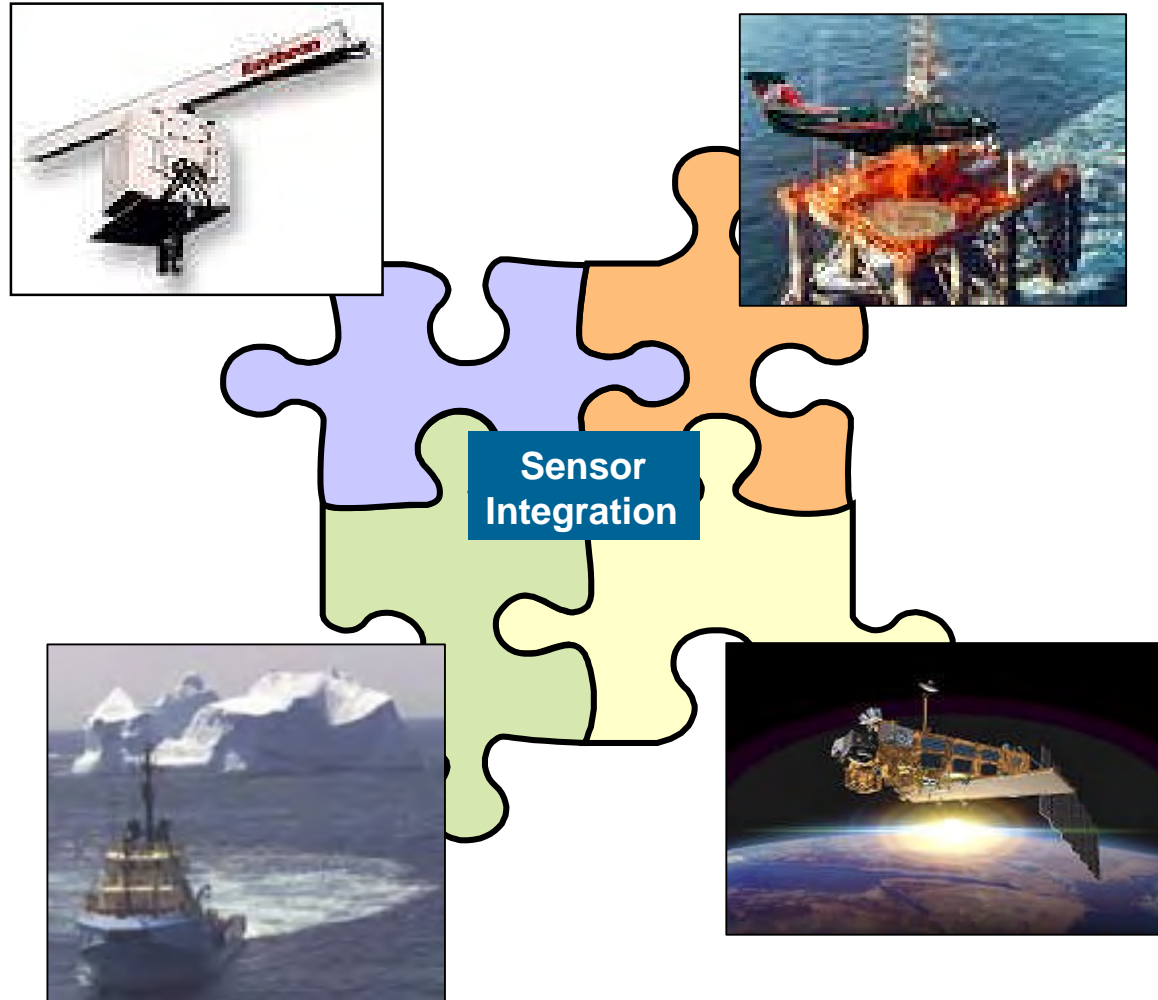


Ice Management



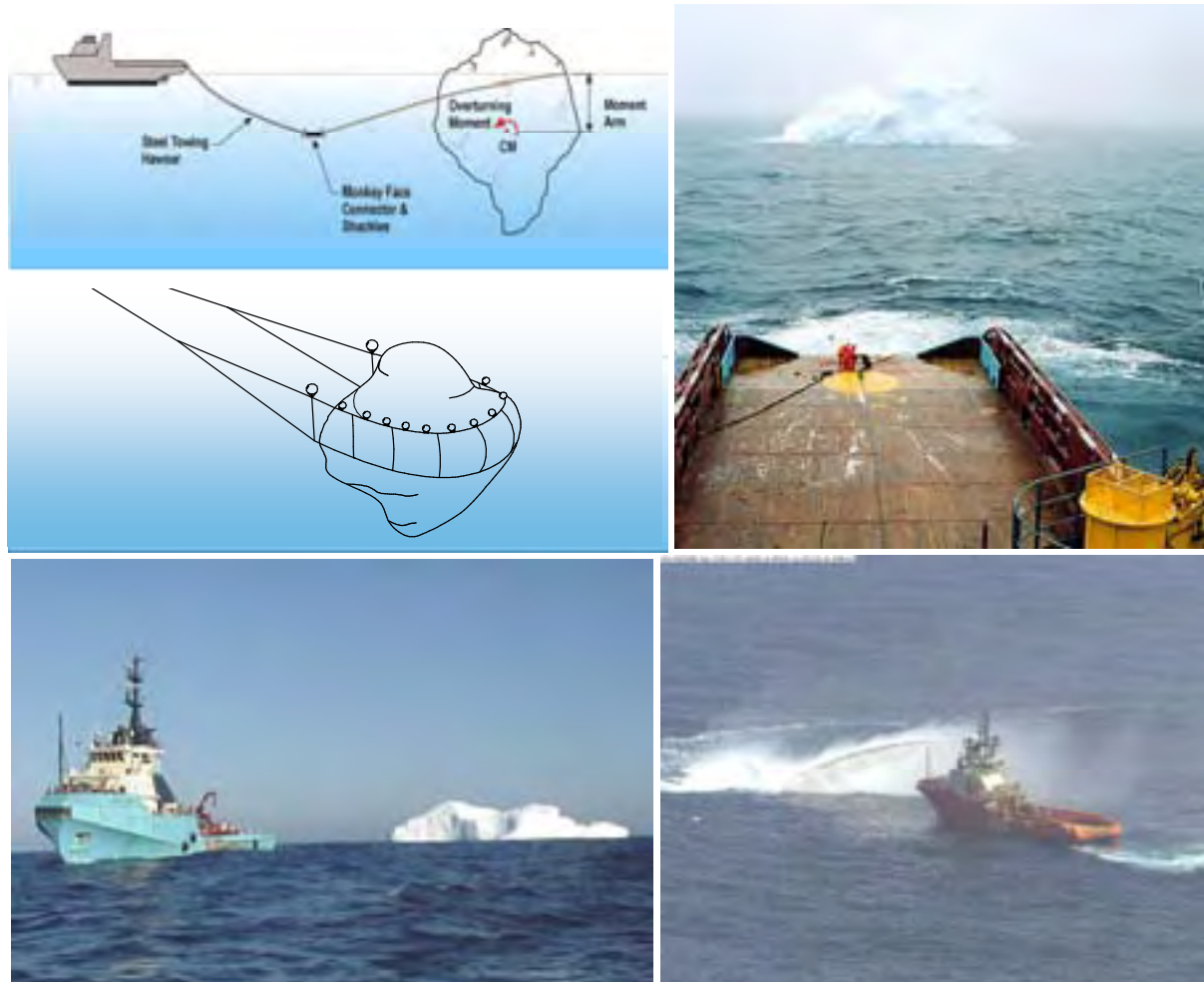
Ice Management



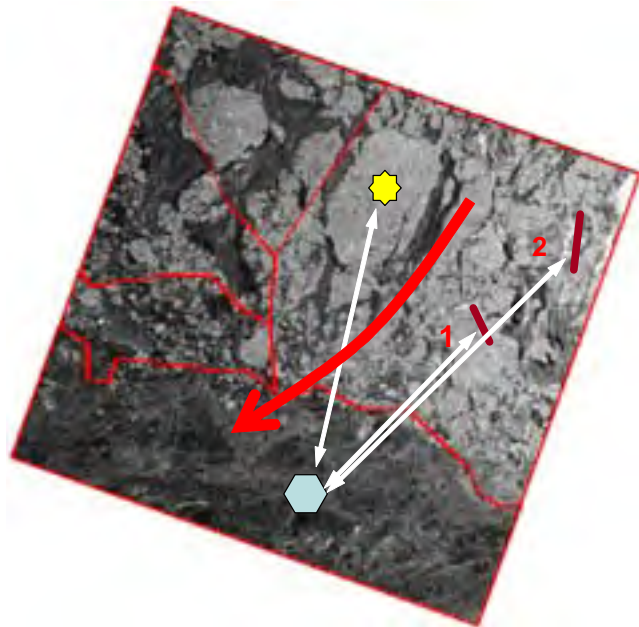
- Detection
 - Marine Radar
 - Satellite Radar
 - HF Radar
 - Aerial & Vessel Reconnaissance
 - Detections vary in space and time
 - DATA FUSION

Ice Management

- Physical Management
 - Towing, water cannon, towing catenary



Ice Management



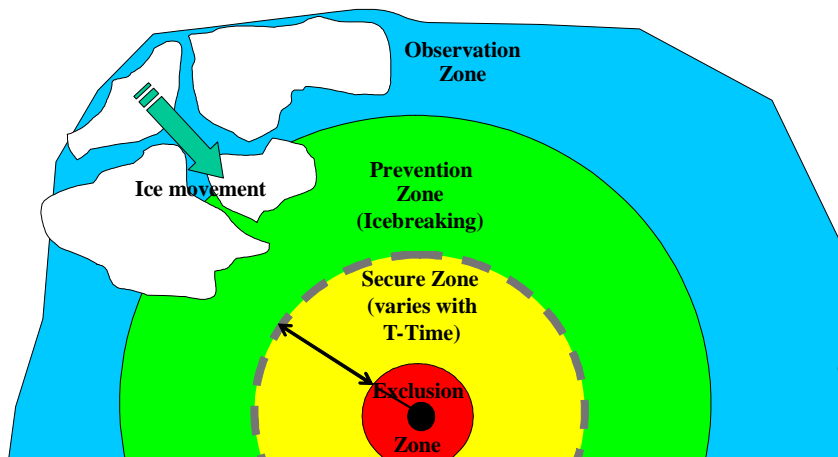
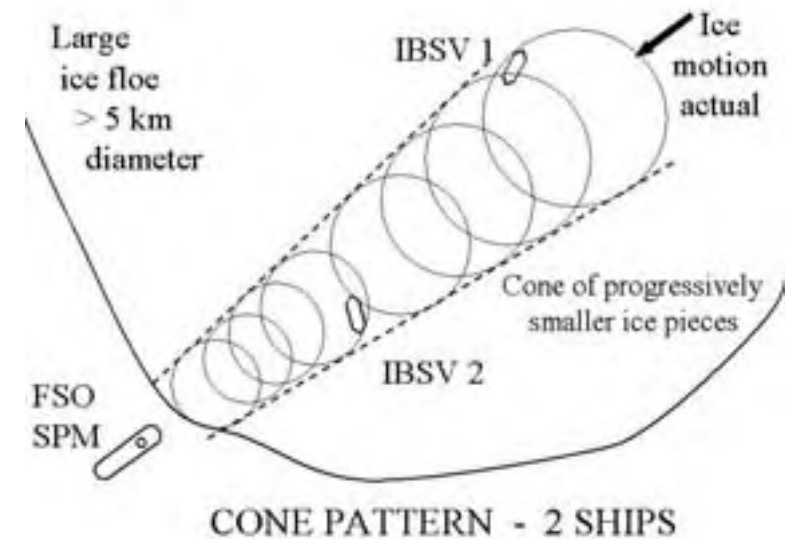
Ice Condition Analysis

☀ floe 5 km diameter
25 km distance

1 - ridge
1500m length
15 km range

2 - ridge
2000m length
30 km distance

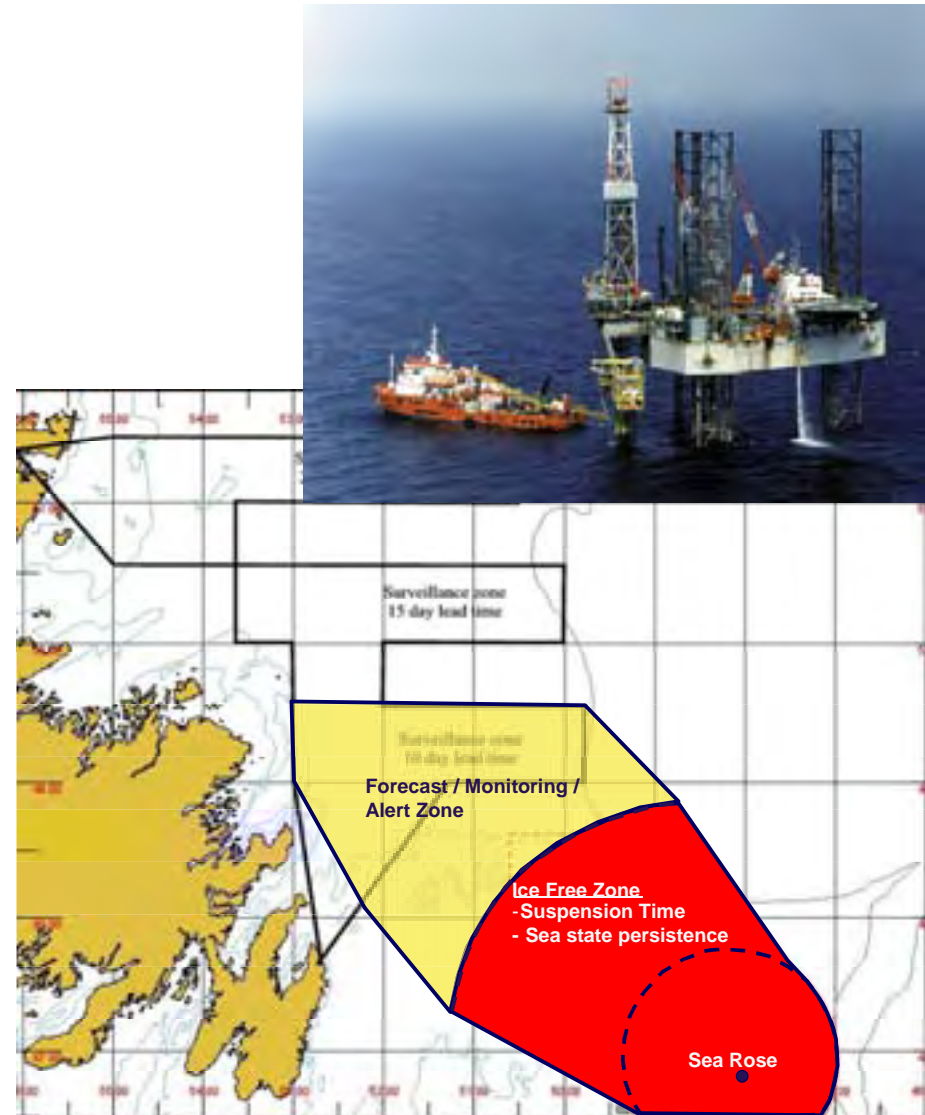
➡ - forecasted drift



Hazard Response Time (HRT)	> 24 hrs	24 to 12 hrs	12 to 6 hrs	6 – 1 hour	< 1 hour
Unmanageable Hazard	GREEN	YELLOW	ORANGE	RED	Brown
Hazard Manageable with 1 IBSVs	GREEN	GREEN	YELLOW	ORANGE	RED
Hazard Manageable with 2 IBSV	GREEN	GREEN	GREEN	YELLOW	ORANGE

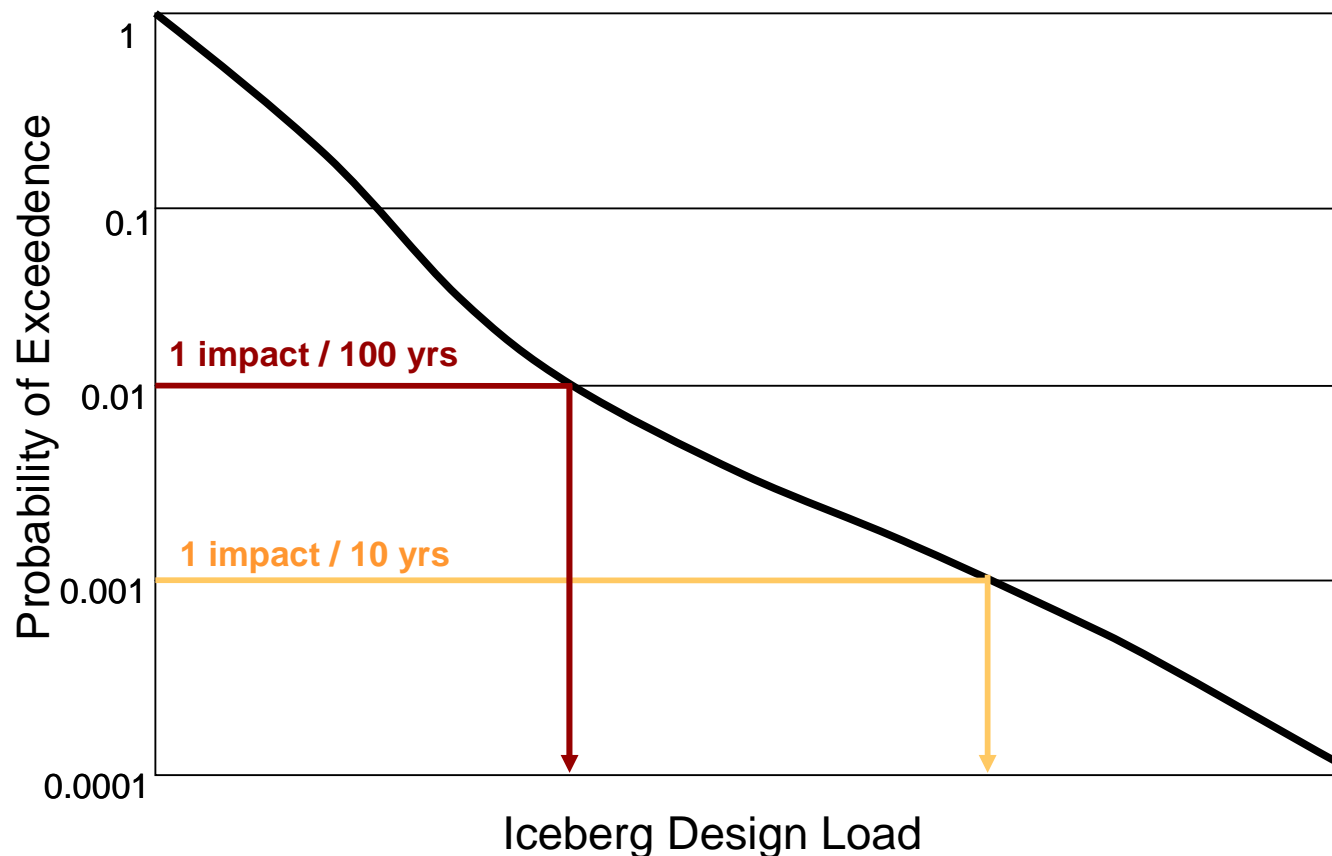
Jack-ups on Grand Banks

- Seasonal ice occurrence
- Analysis of risk
- T-Time
 - Suspend operations and move
- Zone size
 - Ice free
 - Evacuation
 - Sea state persistence
- Basis for safe operation



Risk Mitigation - Design Loads

- Global Loads (10^{-4} exceedence)
- Reduced risk ... reduced load
 - The longer you fish ... the bigger fish you will catch.



Facility Considerations

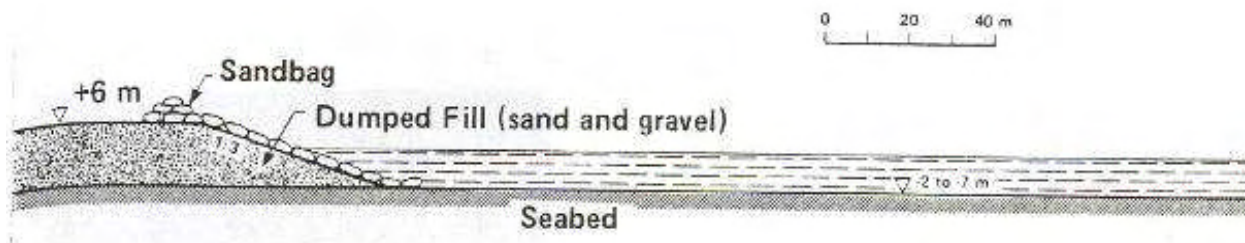
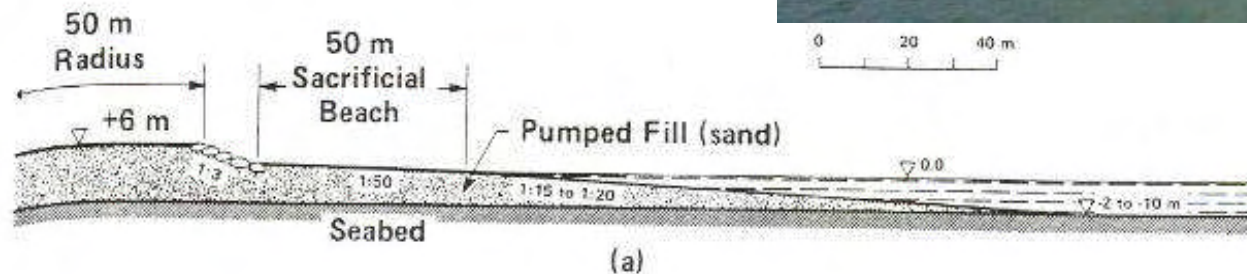
Influence of environment on
structure type

Drilling / Production Structural Considerations

- Ice movement
- Ice loads
 - Lateral sliding resistance ... but wider .. the higher the load
 - Overturning moment
 - Structural integrity
- Ice erosion
- Wave erosion
- Wave loads

Selection of Structure

- Conditions
 - Shallow Water 0-10m
 - Landfast Ice
- Structure
 - Gravel Island



Selection of Structure

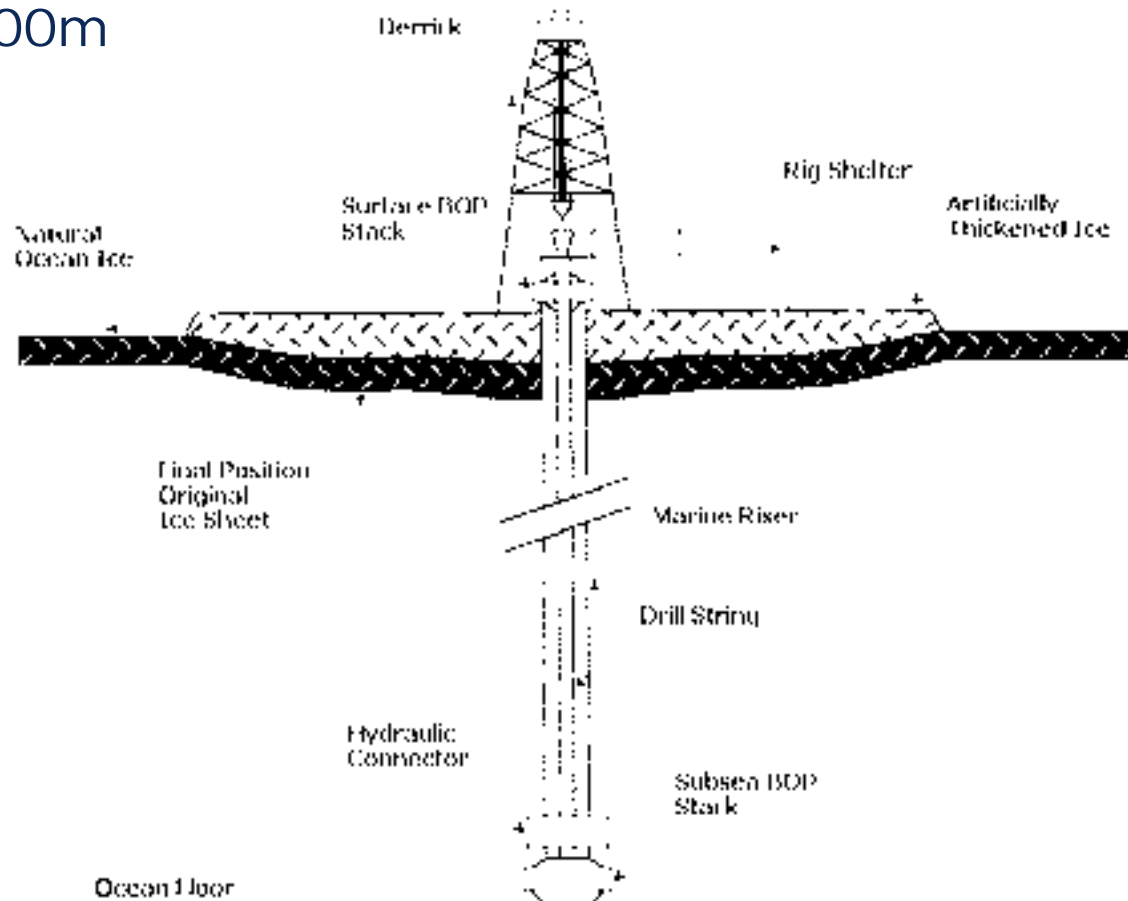
- Conditions
 - Shallow Water 0-10m
 - Light to mod ice conditions (1st year & multi-year floes and ridges)
 - Ice force <500MN
- Structure
 - Spray Ice Island



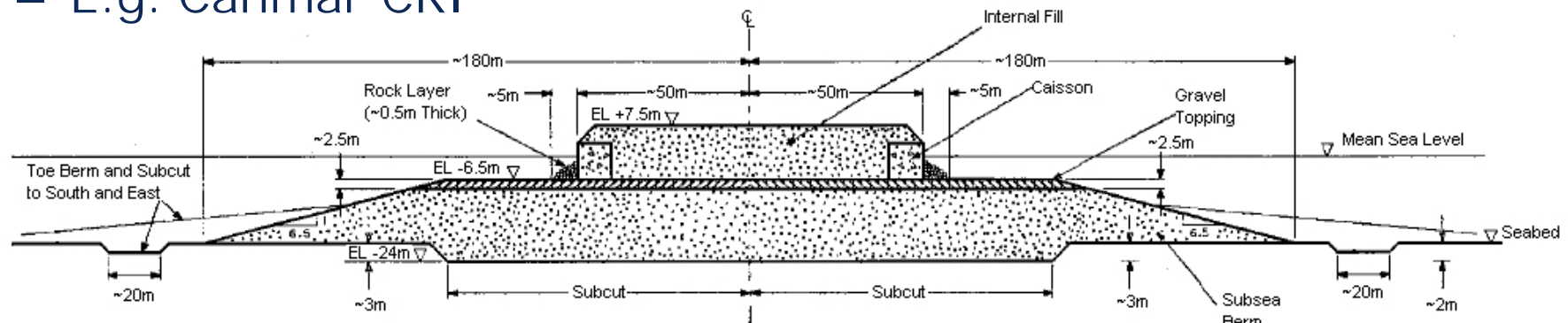
Selection of Structure

- Conditions
 - Water depth 10 - 100m
 - Stable landfast ice
 - Winter operations

- Structure
 - Floating ice island
 - Panarctic



-
- Diagram illustrating the cross-section of a breakwater structure, showing various components and dimensions:
- Ice Deflector:** The upper sloped structure.
 - Water Ballast:** The central rectangular core.
 - Longitudinal Bulkhead:** The internal vertical structure within the water ballast.
 - Ice Face:** The sloped structure on the right side of the water ballast.
 - Retained Fill:** The material on the left side of the structure.
 - Berm:** The base structure on the left.
 - Mean Water Level:** Indicated by a horizontal line at 0.0 m.
 - Erosion Protection:** The material on the right side of the structure.
- Dimensions and Elevation Markers:
- Radius $R = 45.5 \text{ m}$
 - Horizontal distance from core to ice face: 7.5 m
 - Core height: 12.2 m
 - Core width: 13.1 m
 - Ice face angle: 60°
 - Vertical distance from base to ice face: 2.4 m
 - Elevation markers: $+7.6 \text{ m}$, $+3.0 \text{ m}$, 0.0 m , -9.2 m
 - Sea bottom varies from -10 m to -20 m

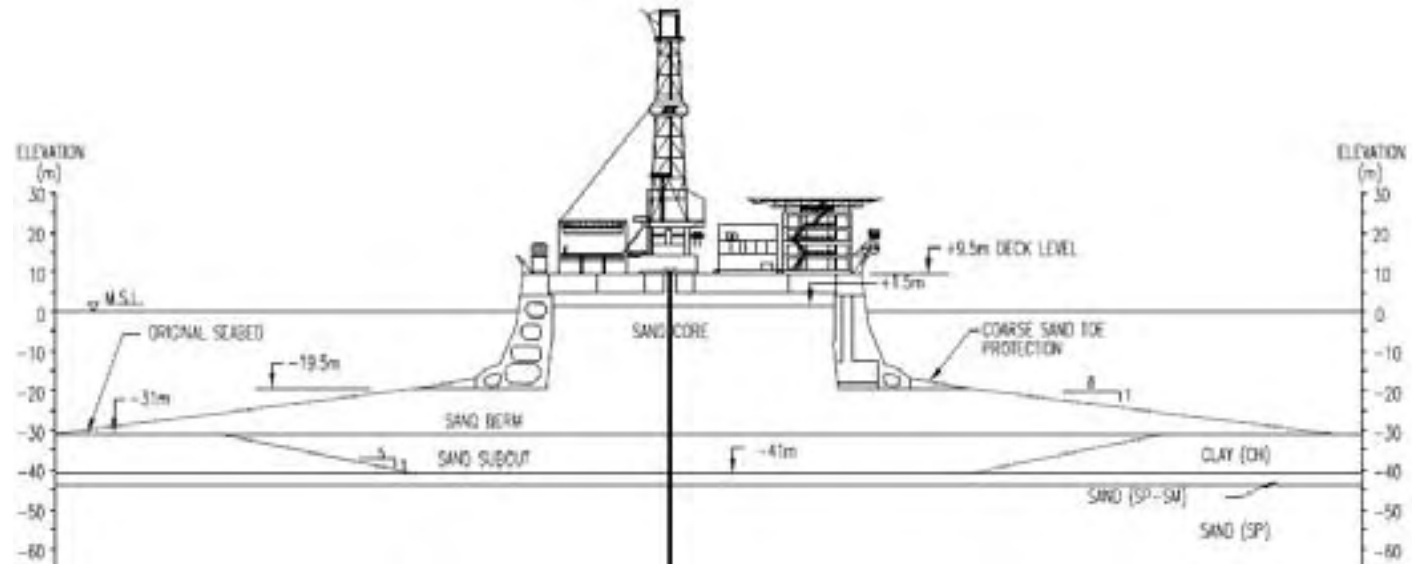


Selection of Structure

- Conditions
 - Moderate to Deep Water 15-50m
 - Heavy ice conditions (1st year multi-year level ice and ridges)
 - Ice force ~ 750MN



- Structure
 - GBS
 - Gulf Molikpaq
 - mobile



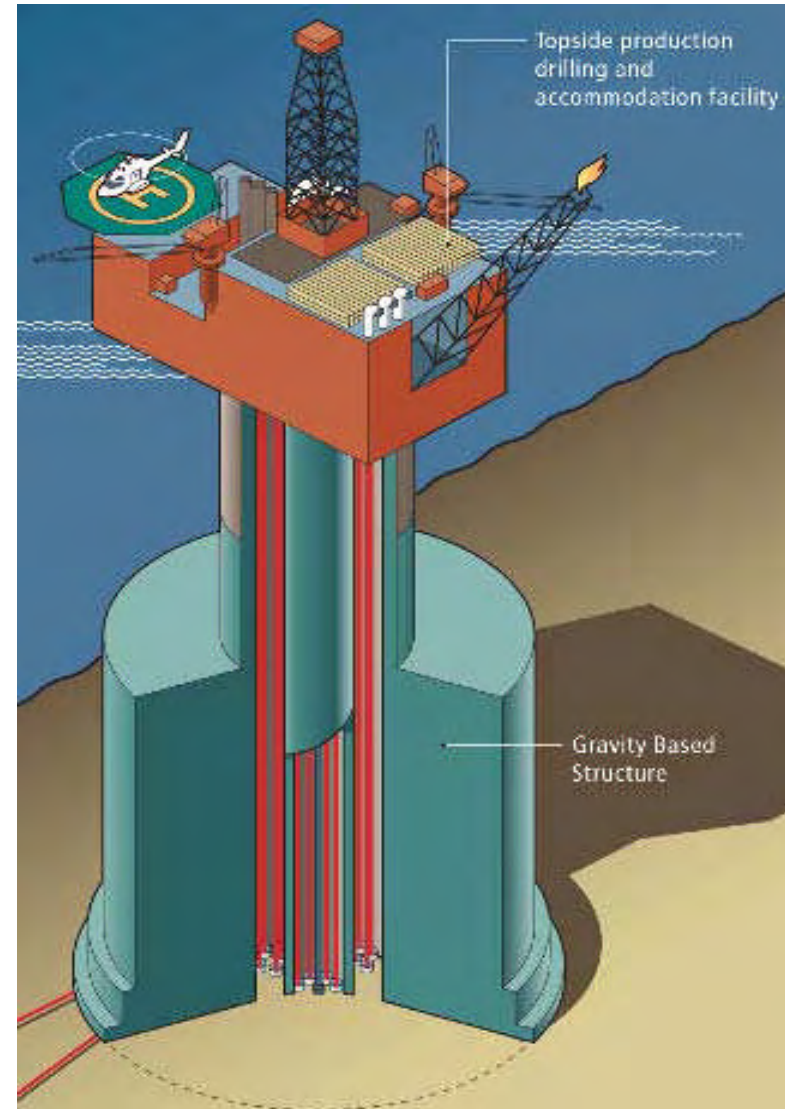
Selection of Structure

- Conditions
 - Mod to deep Water
15-50m
 - Deeper water with berm
 - Light to mod ice
(1st year level and
ridged ice)
 - Year round operations
- Structure
 - GBS
 - Lunskeye (Lun-A)
platform



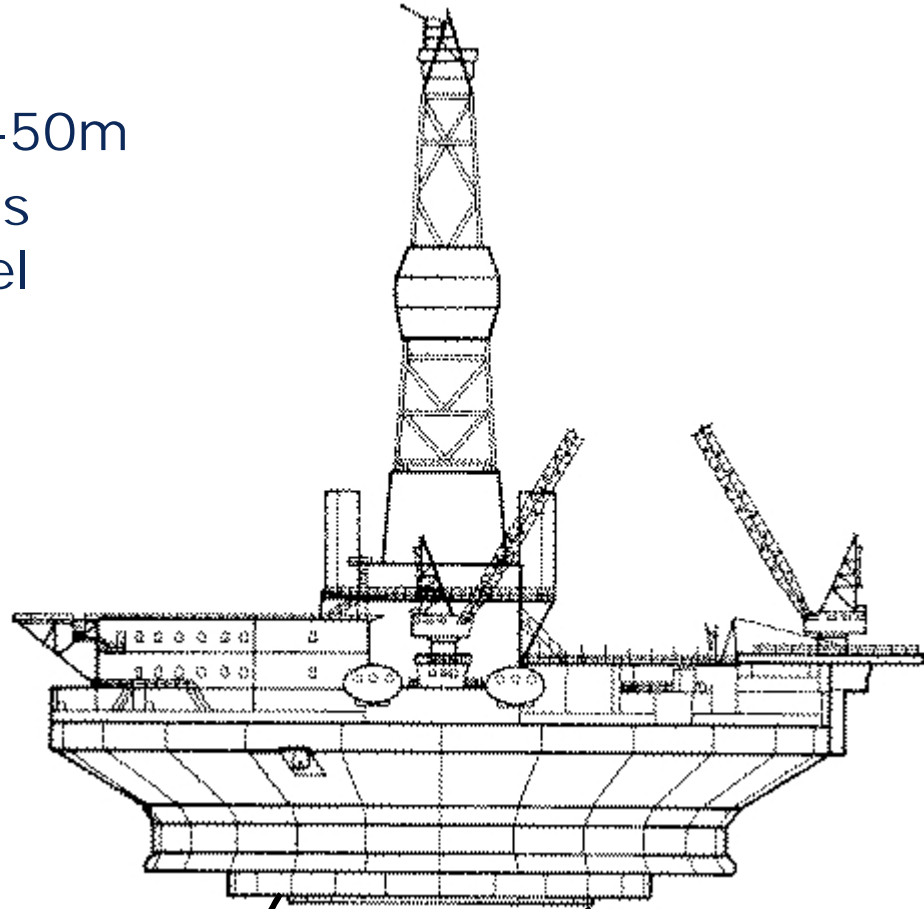
Selection of Structure

- Conditions
 - Water Depth 50 -100m
 - Moderate ice conditions
 - Load <1000MN
 - Rare iceberg loads
 - If open water, wave loads may dominate
- Structure
 - Conventional GBS



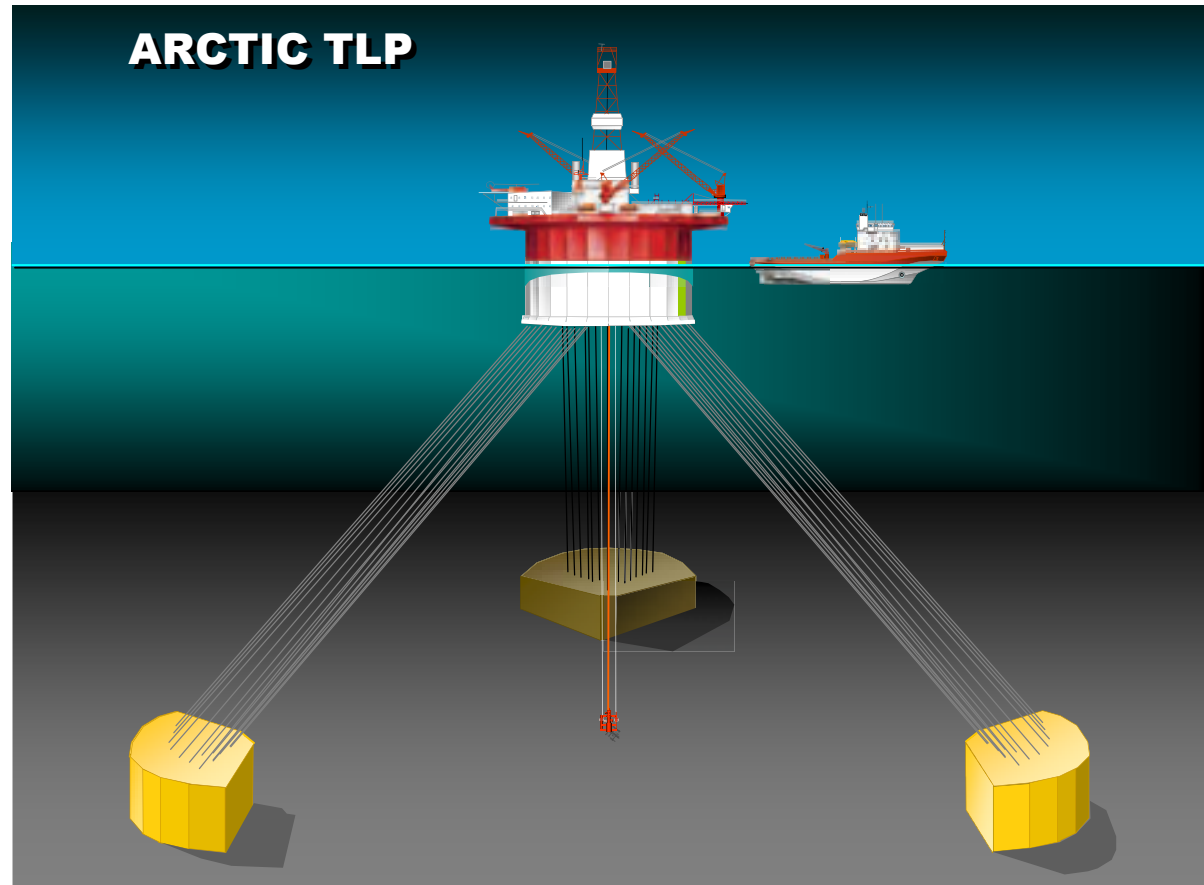
Selection of Structure

- Conditions
 - Moderate water depth 22-50m
 - Light to mod ice conditions (1st year & multi-year level ice and ridges)
 - Low waves
 - Seasonal operations
- Structure
 - Mobile
 - Moored floating structure
 - Extended season with management
 - E.g. Kulluk



Selection of Structure

- Conditions
 - Deepwater
 - Heavy ice
 - Year round operations
- Structure
 - mobile
 - Moored floater



Selection of Structure

- Conditions
 - Mobile unit
 - Deepwater 100 - 250m
 - Light ice conditions
 - Seasonal Operation
- Structure
 - Moored floating structure
 - Ice classed vessel
 - Extended season with management
 - E.g. Canmar Explorer III



Grand Banks Developments



Hibernia GBS



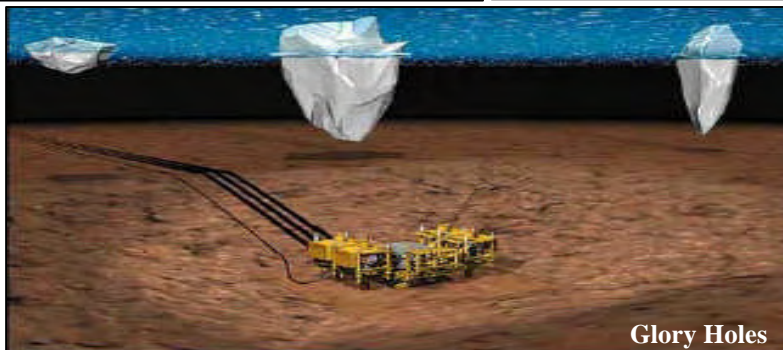
White Rose FPSO



Terra Nova Development



Terra Nova FPSO



Glory Holes

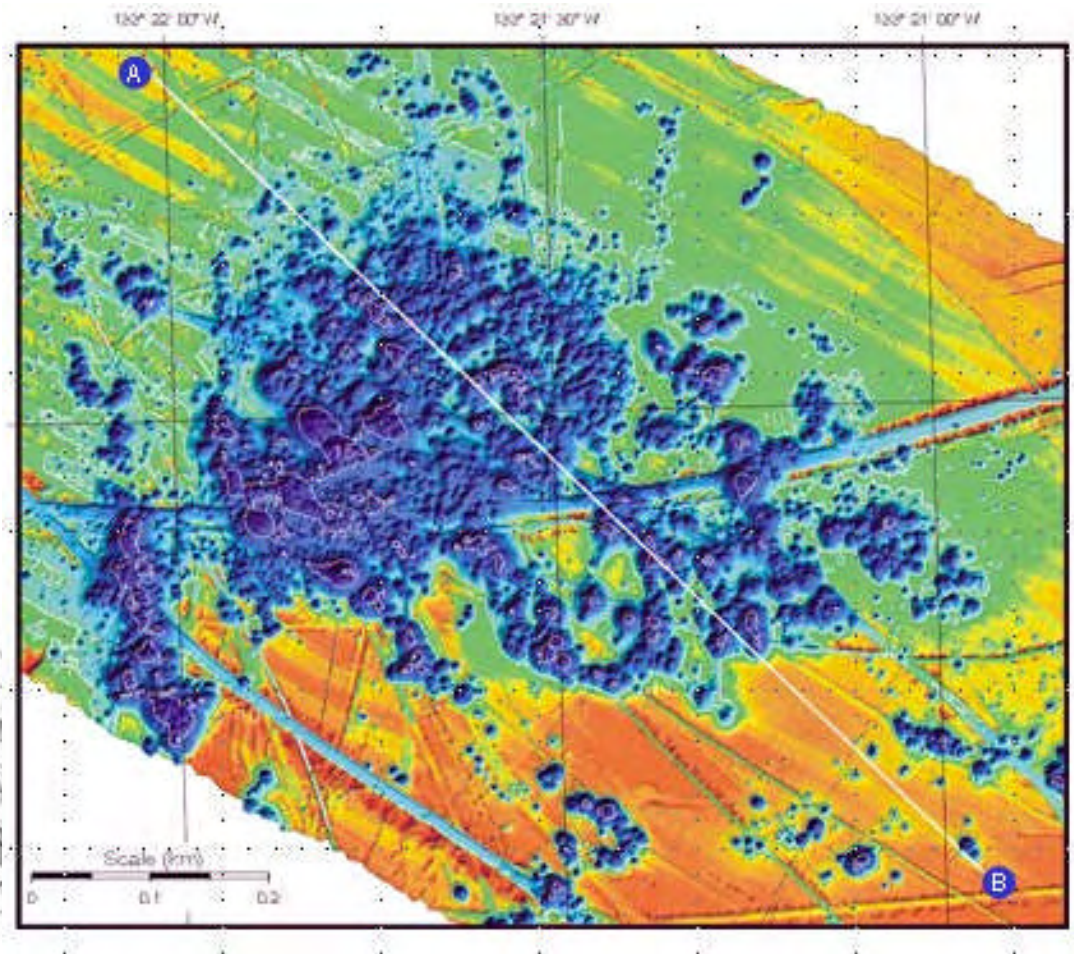
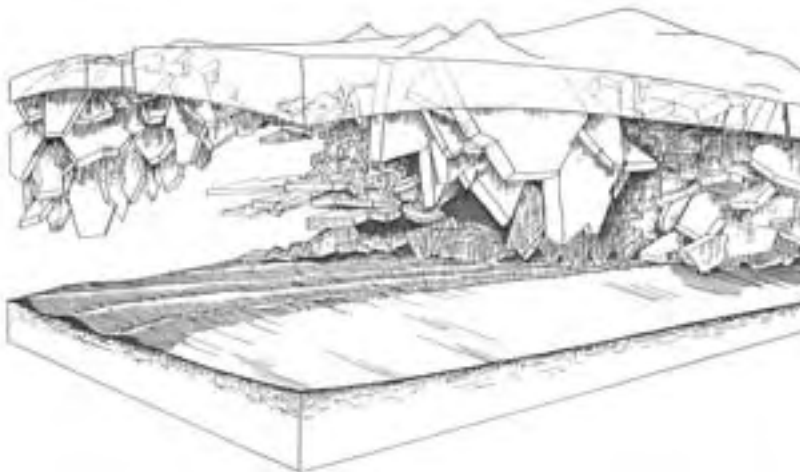
- Challenges
 - Sea ice and iceberg risk
 - Geotechnical properties
- Facility Types
 - GBS, FPSO, Subsea
- Special Design Features
 - Structural Reinforced
 - Disconnection
 - Gloryhole
- Risk Mitigation
 - Iceberg detection and towing
 - Alert zones
 - Glory Holes
 - Pipeline trenching

Ice Gouging

Subsea pipeline protection

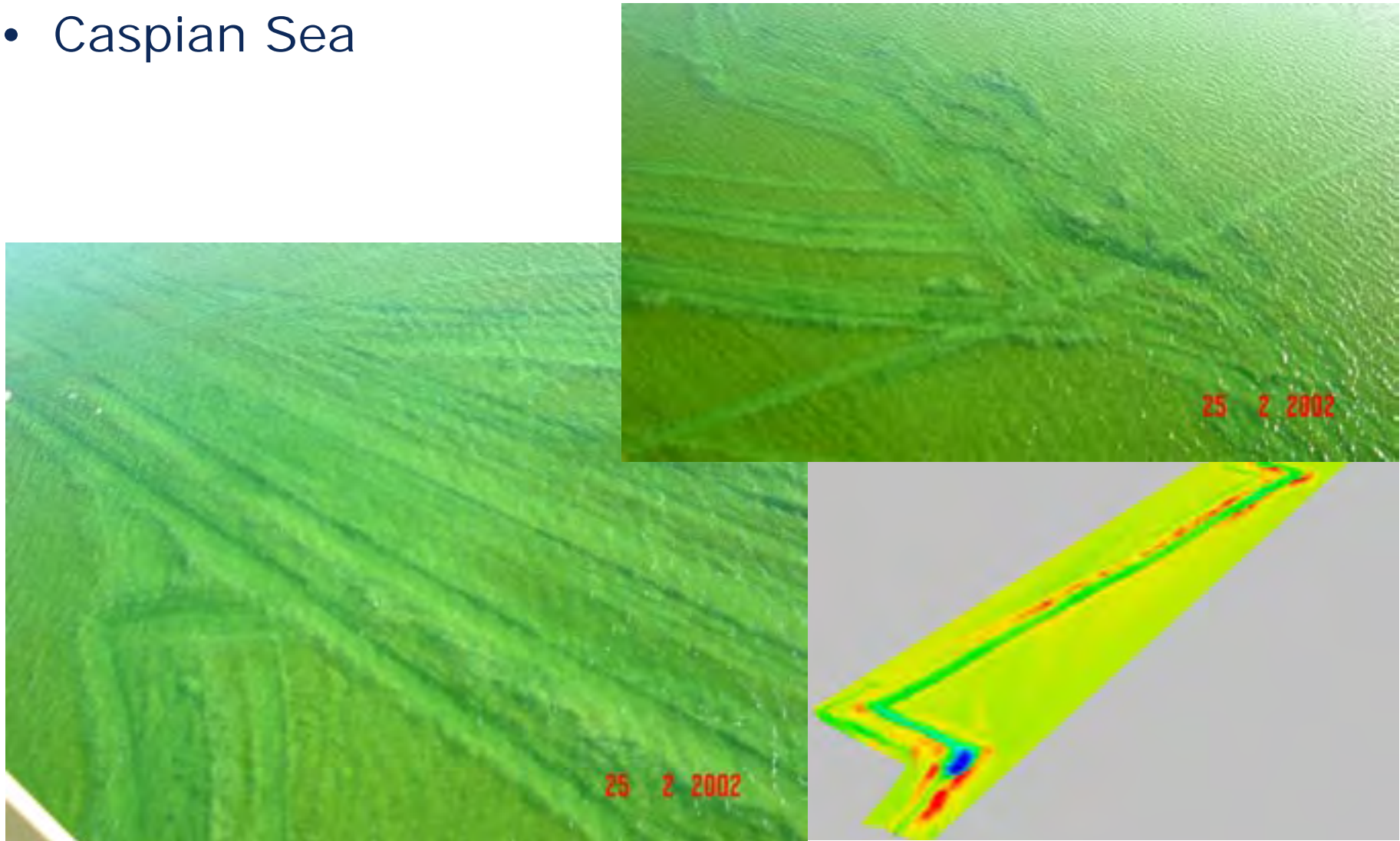
Ice Gouge

- Protection
 - Pipeline burial depth
 - Gloryhole for subsea equip
- Ice gouge parameters
 - Gouge dimensions
 - Recurrence rate
 - Gouge infill
- Route selection
 - Hazard maps

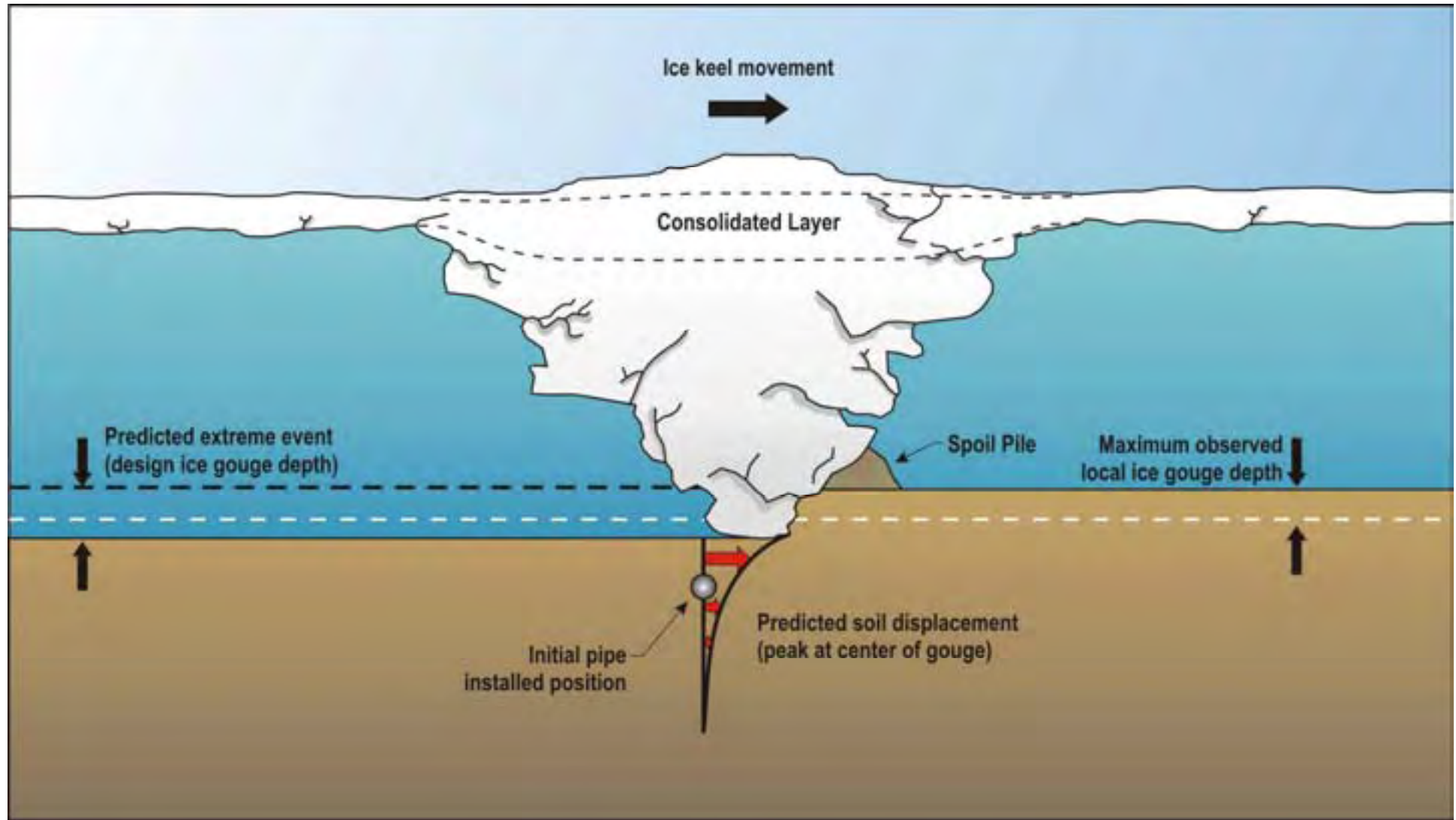


Ice Gouge

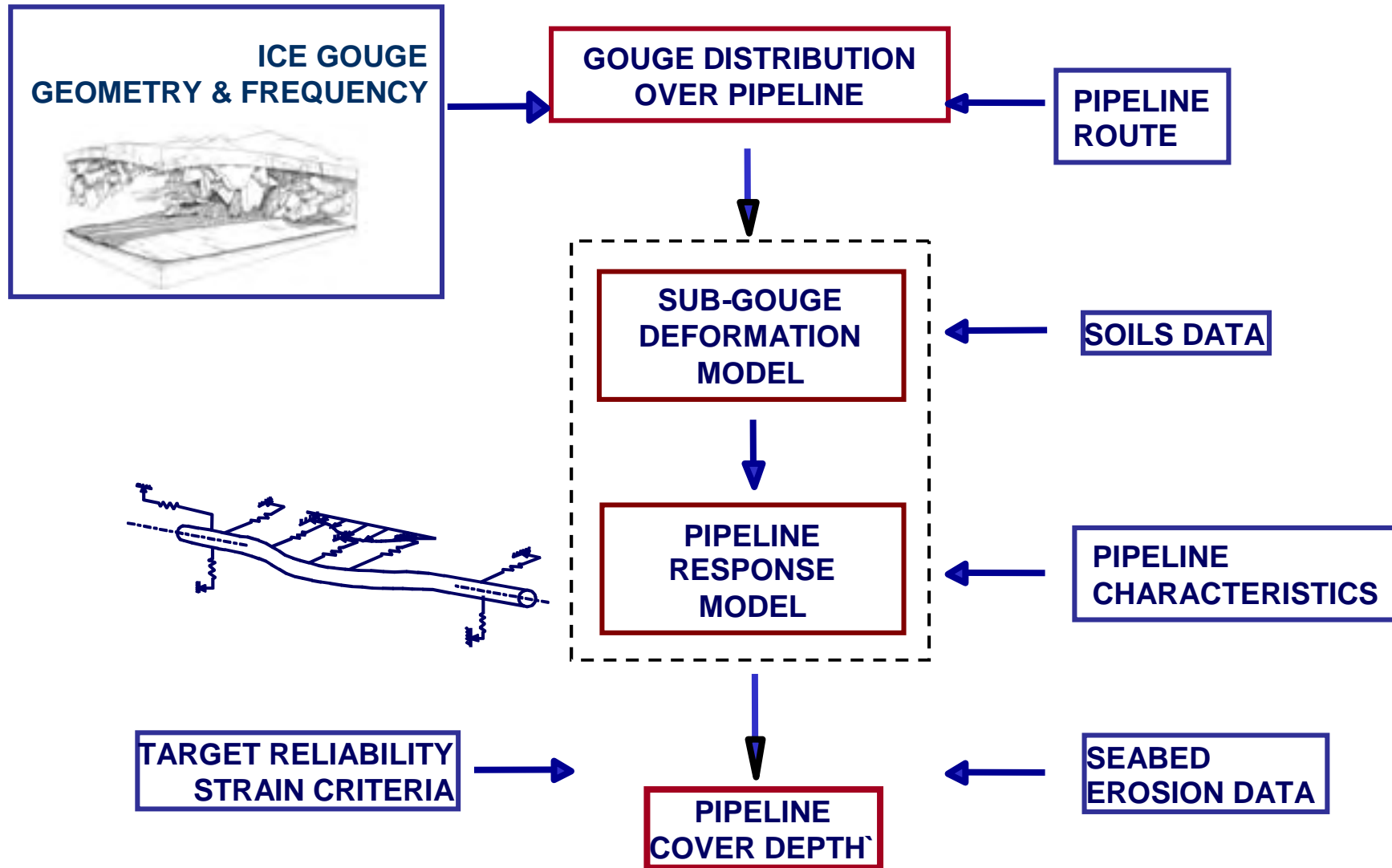
- Caspian Sea



Ice Gouge

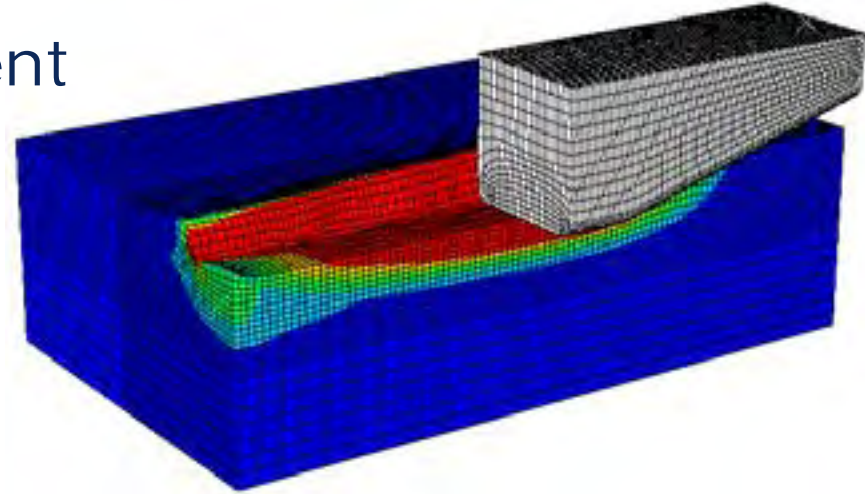


Design Methodology

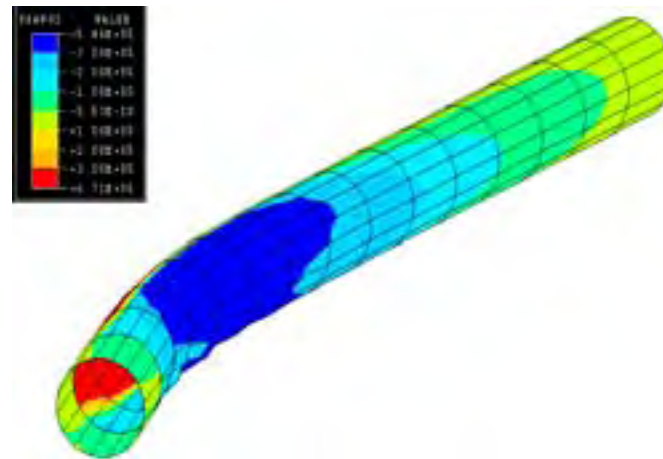


Ice Keel/Soil/Pipe Response Model

- Subgouge soil displacement
 - Keel geometry
 - Keel strength
 - Soil strength



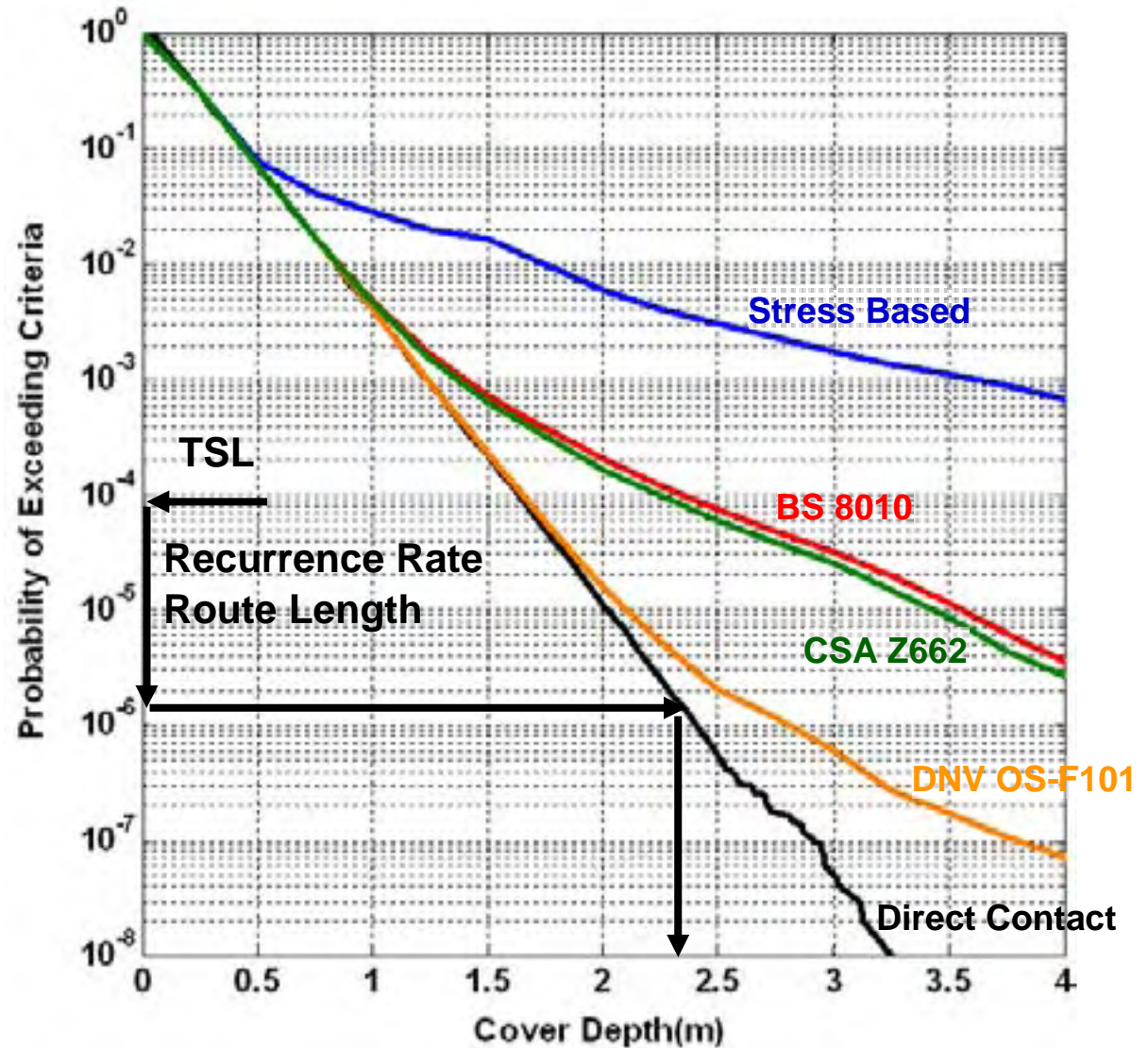
- Pipeline response
 - Large deformation
 - Strain



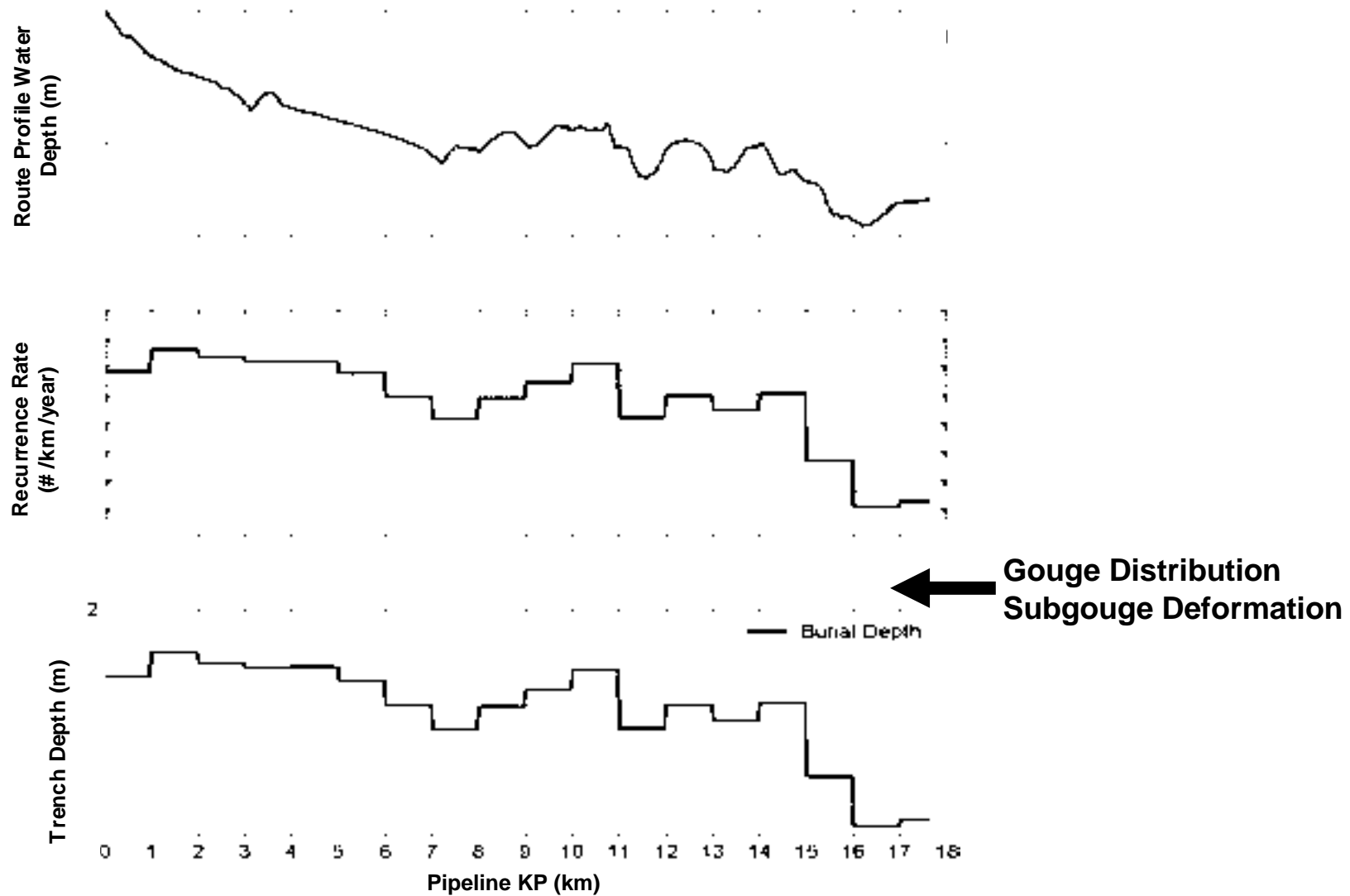
Probabilistic Design

Burial Depth

- Design Approach
- Pipeline specification
 - D/t
 - Internal press
 - Straining hardening
 - Pipe grade
 - Weld parameter
- Strain limits



Typical Analysis Result



The End

