Arctic Well Construction

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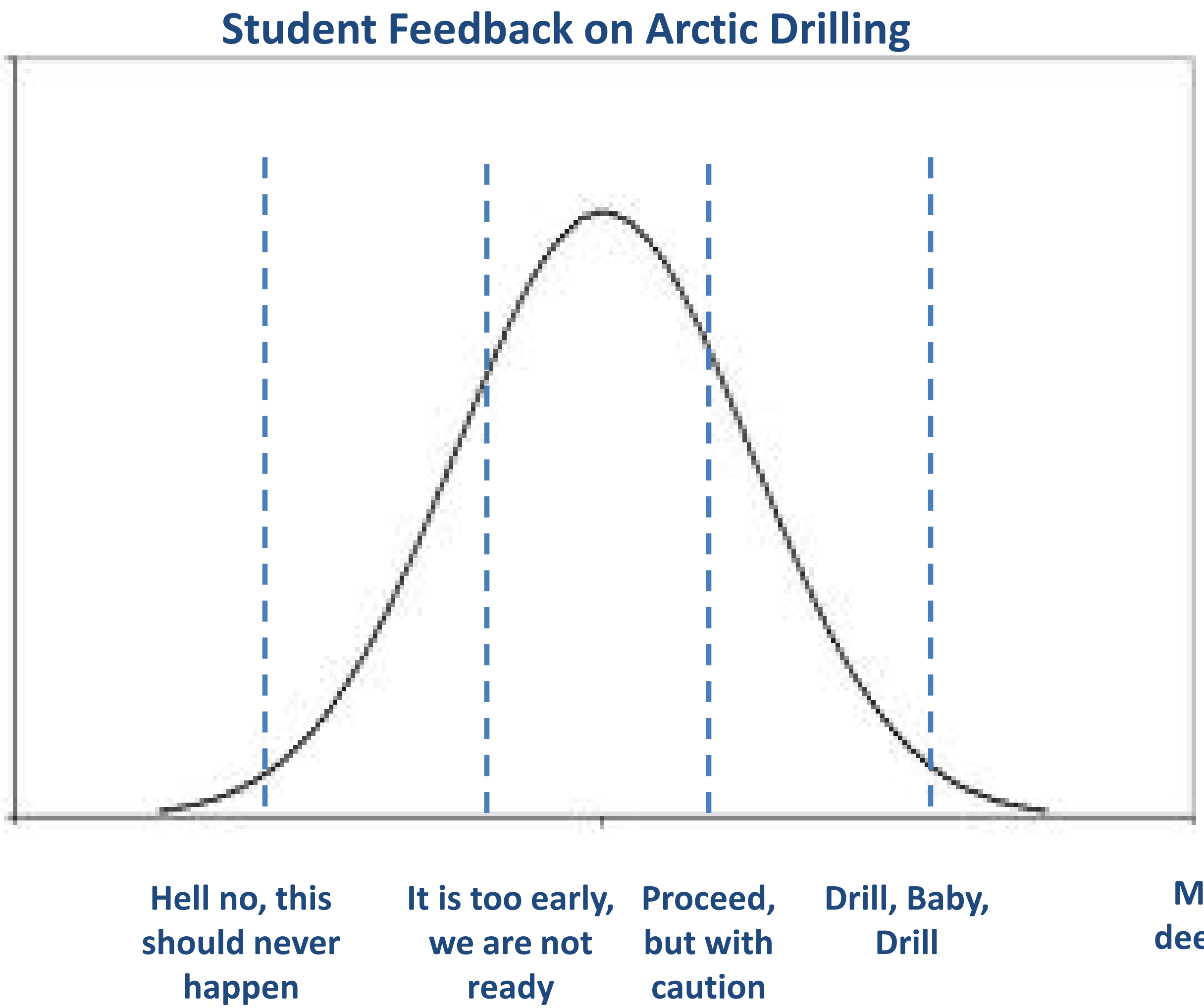
Arctic Drilling: Economic Opportunity or Environmental Disaster?



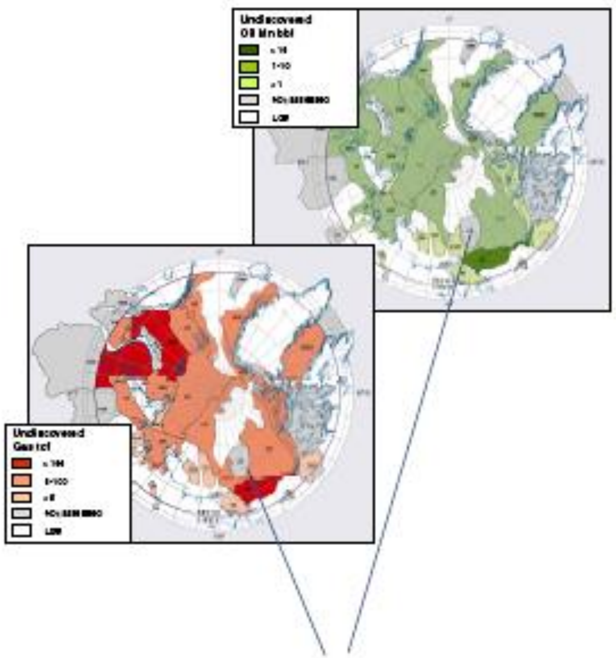
Most students believe deepwater development in the Arctic was premature

Kulluk Towing Problems

Shell's Artic Presence / Ambitions

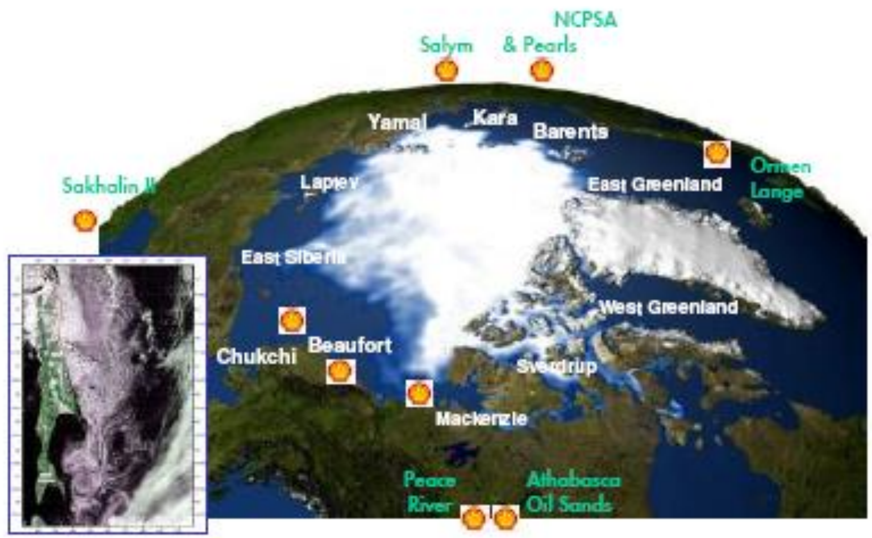
SHELL IN THE ARCTIC

USGS-ARCTIC RESOURCE APPRAISAL 2008

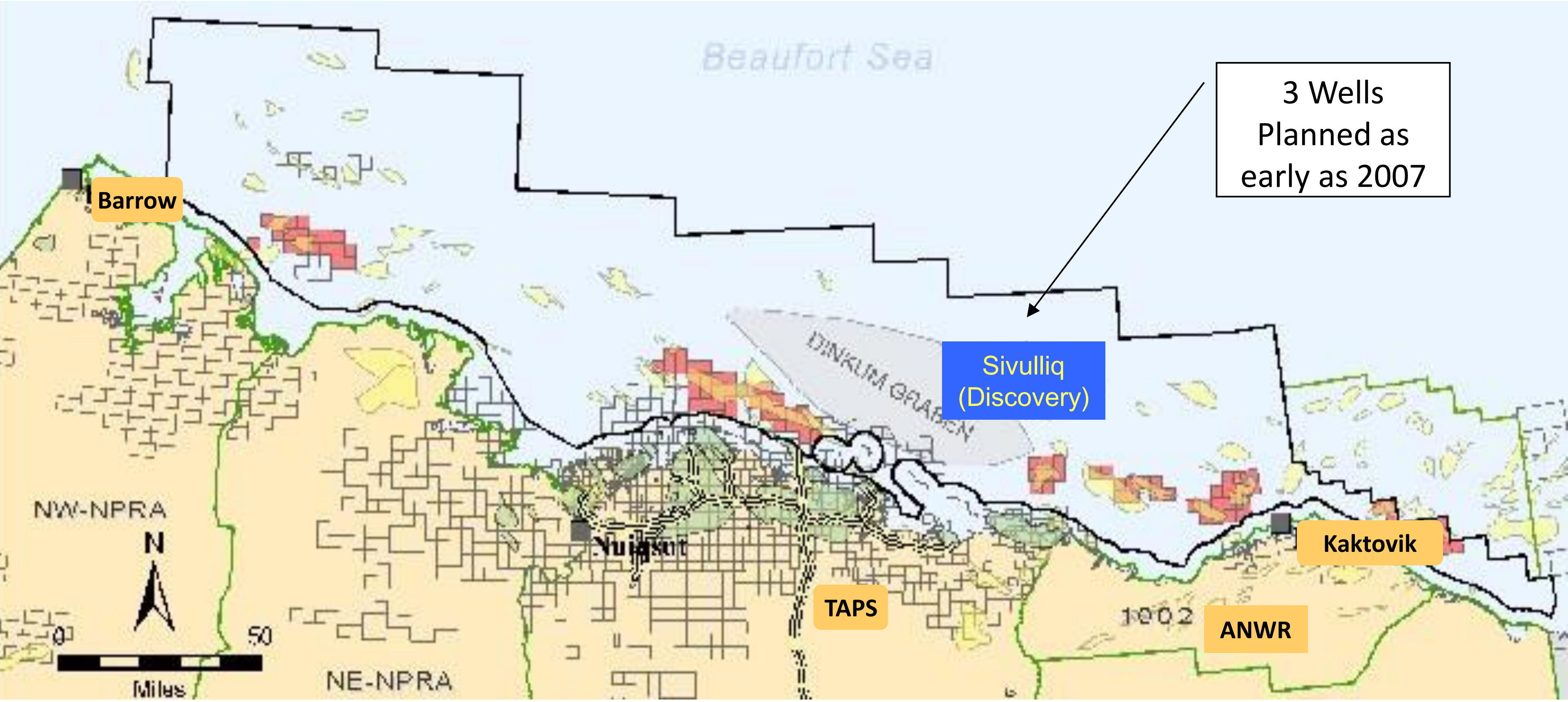


Alaska province alone contains ~30 billion boe + 221 Tcf gas

SHELL POSITIONS



Shell Beaufort Exploration



Sivulliq Opportunity:

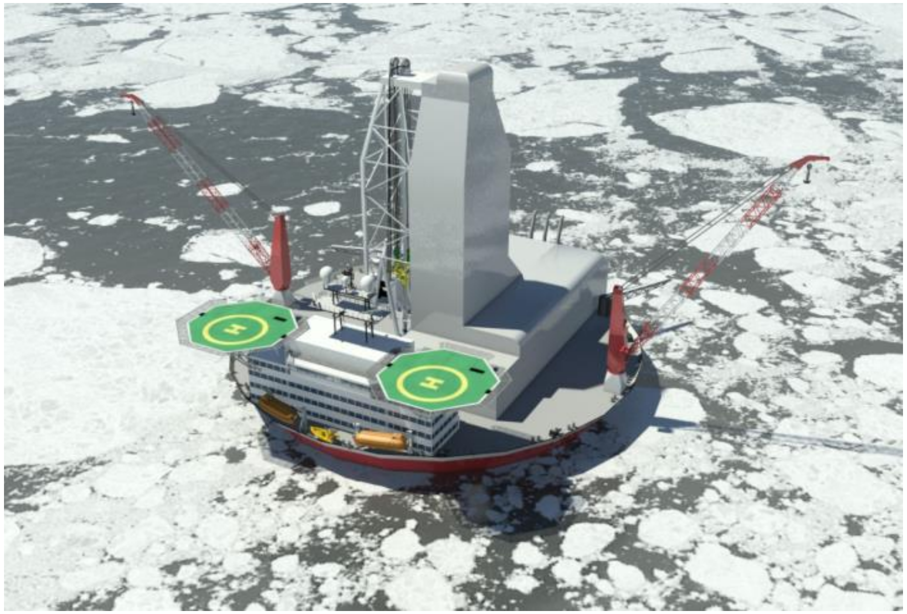
- Leverages Hammerhead discovery (1986).
- Potentially one of the first truly offshore developments in the Arctic OCS.
- Concerns over sensitive environmental area and impacts on subsistence lifestyle.
- Technical challenges (harsh weather, ice, cold climate, remote logistics, etc.).

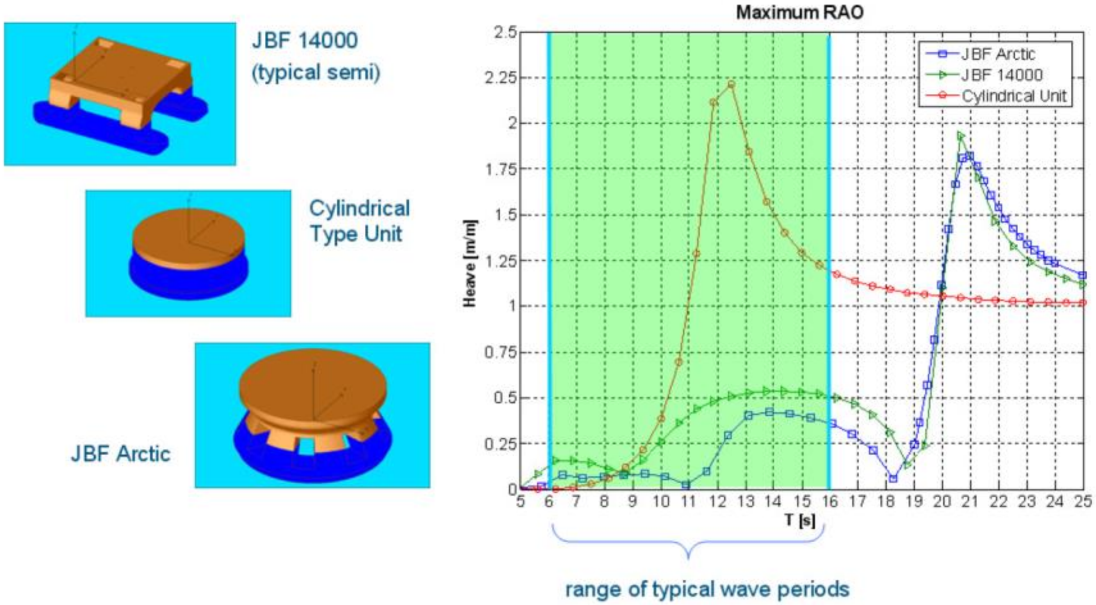
Shell’s Artic Drilling “Fleet”

Kulluk – Shell Owned

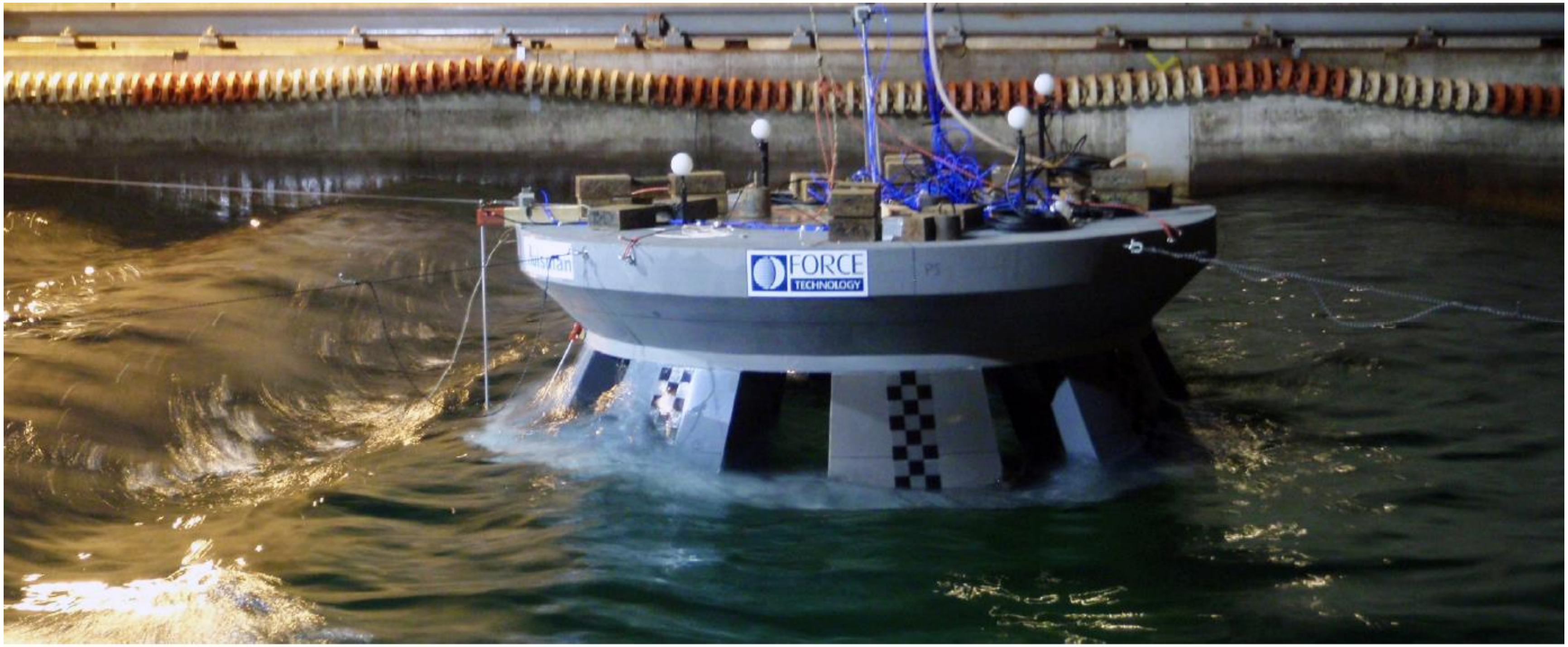
Frontier Discoverer – Leased from Noble Drilling

Huisman's New JBF Arctic Rig

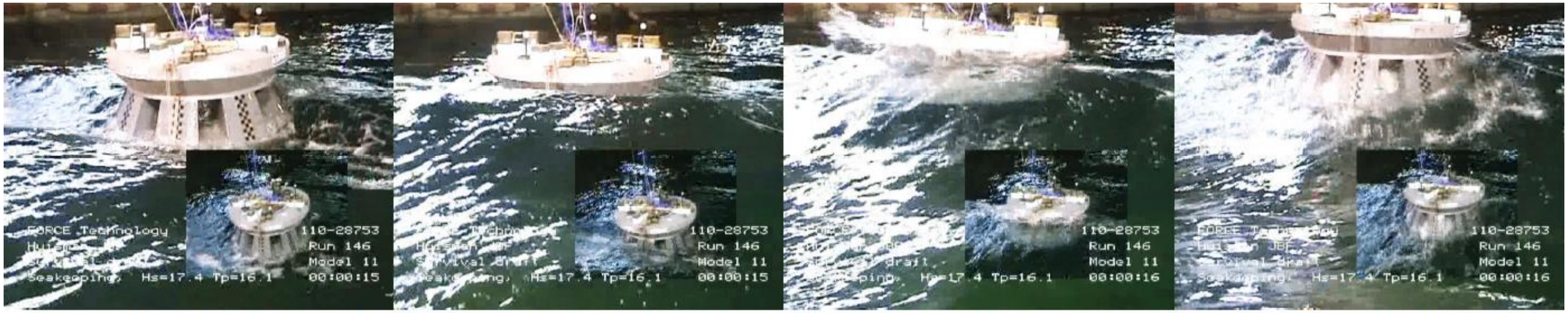




JBF Arctic Model Testing – 1. Wave Loads



Model tests of JBF Arctic in irregular waves at open water operating draft



Model tests of JBF Arctic in irregular waves in survival condition meeting the wave H_{sig}=17.4m

JBF Arctic Model Testing – 2. Ice Draft Loads

Model tests of JBF Arctic in ice (ice draft and transit draft)

Key Support Vessels

3-D Seismic – Gilavar (& support)

Oil Spill Contingency – OSRV, Endeavor, Arctic Tanker

Ice Class-Drill Ships – Kulluk & Frontier Discoverer

Site Surveys – Henry C.

Geotech Boring – vessel TBD

Strudel scour – Annika Marie

Note: Excludes on-ice seismic pilot (Mar) and additional support vessels for crew change, etc.

Drilling Support Vessels

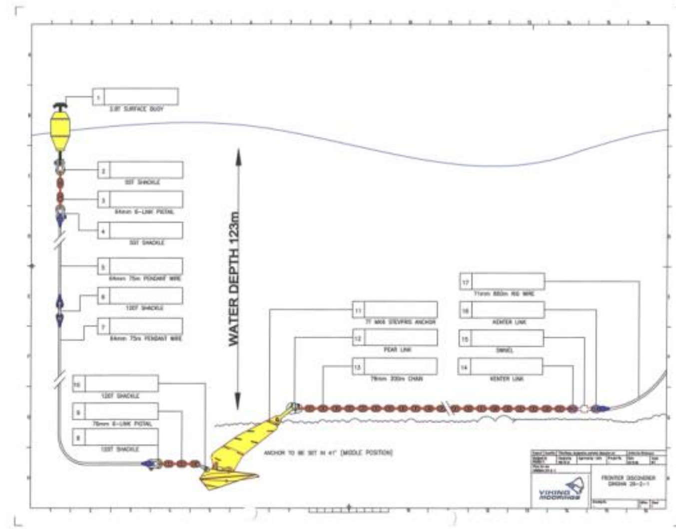
Ice Management –
Kapitan Dranitsyn
Vladimir Ignatjuk (formerly *Kalvik*)

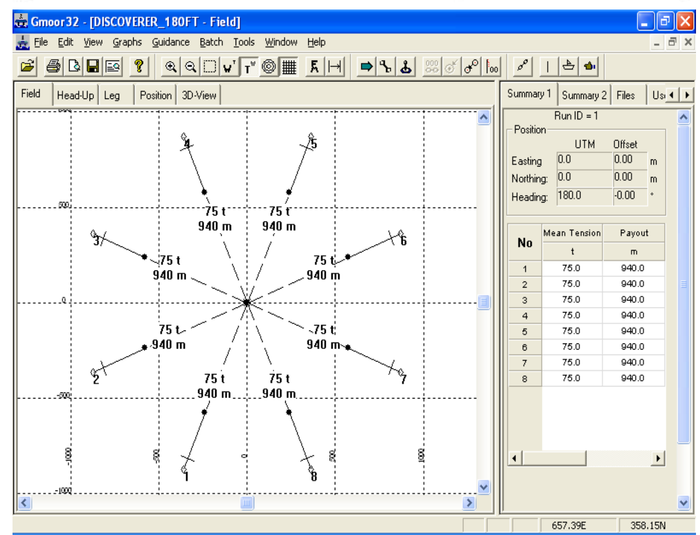
Anchor Handling & Ice Management –
Tor Viking
Fennica

Support –
Jim Kilabuk

Mooring

- Hold Position
  - 1-2’ Watch Circle in 100’ Water
  - API Design Criteria (Line Loss)
- Assembly
  - Line (2-3/4” Wire Rope)
  - RAR (Rig Anchor Release)
  - Chain (3-1/8” Chain)
  - Shackles
  - Anchor (7 Ton Anchors – 14,000 lbs)
  - Buoy





Marine Mammal Monitoring & Mitigation Plan

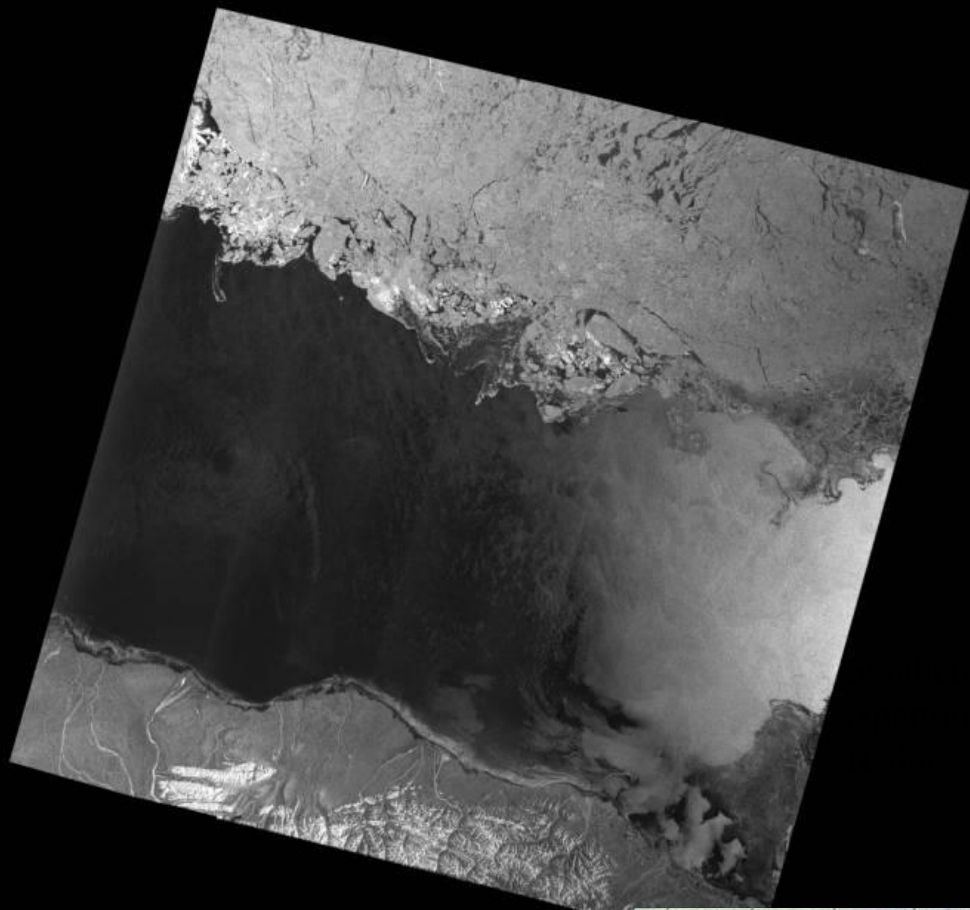
- Focus is protection of the animals.
- Collection of distribution data, patterns, and evaluation of potential deflection
- MMO's on-board most vessels
- Incorporation of local expertise
- Aerial surveys & pilot program for unmanned drone
- Acoustic recorder arrays

Herbert Tagarook, MMO from Wainwright

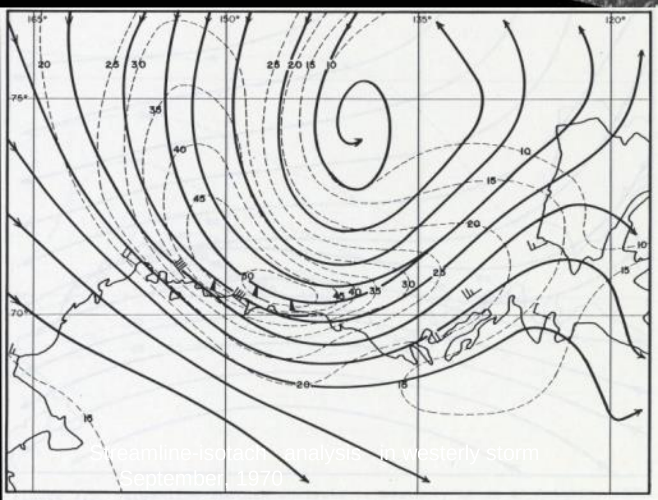
Billy Gordon, MMO from Kaktovik

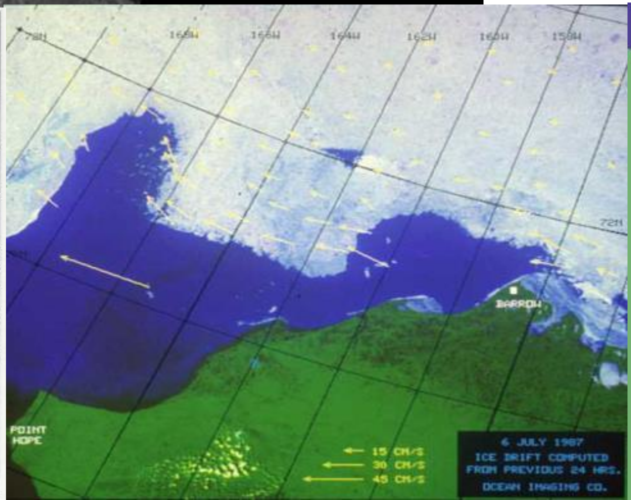
Jesstin Patterson, MMO from Barrow

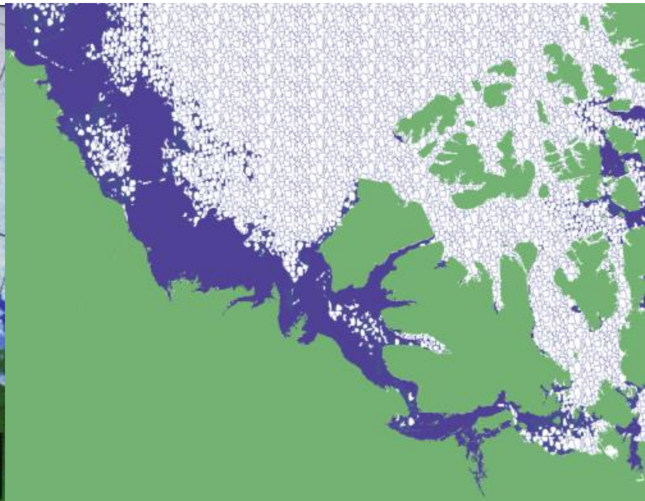
Ice Forecasting



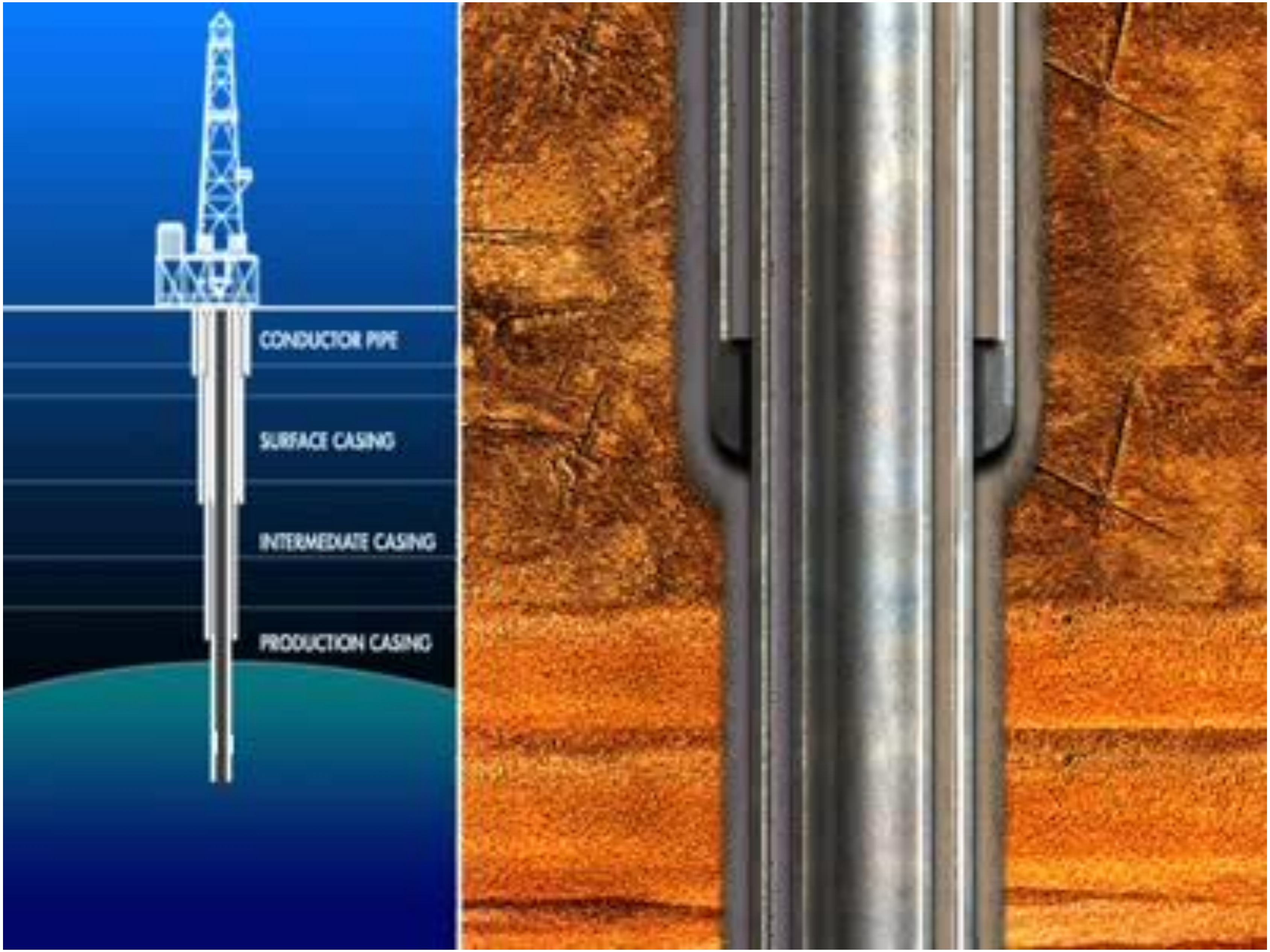
- Long Range (4-6 Months) Breakup Prediction
- Short Range Weather Forecasting
- Ice Motion Tracking with GIS software
- Real-Time Ice Positioning
- Short Range Ice Edge Predictions





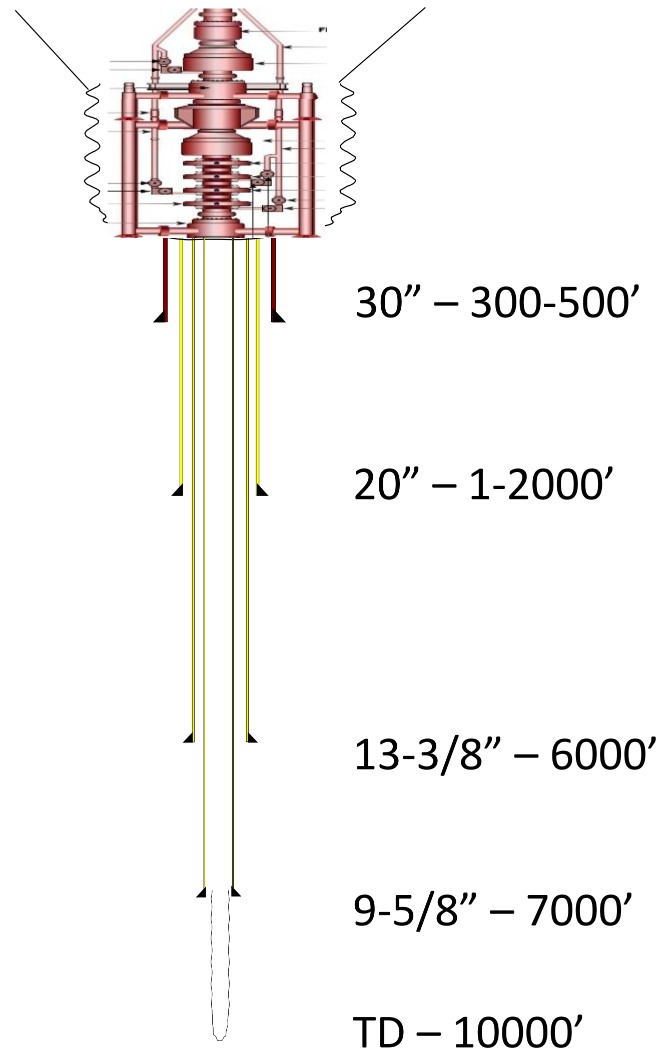


Drilling 101 – The Drilling of a Simple Arctic Well

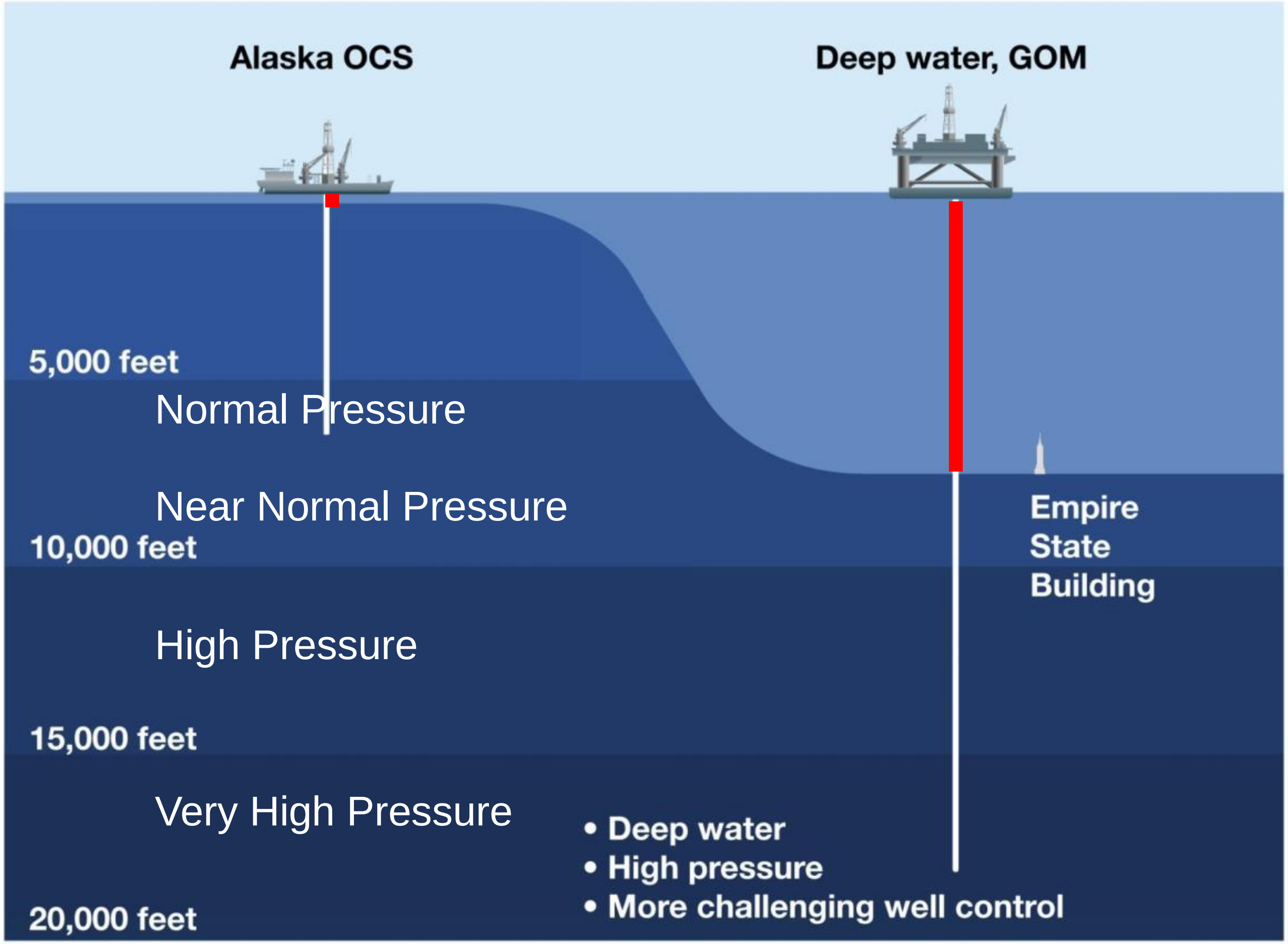


Arctic Well Sketch

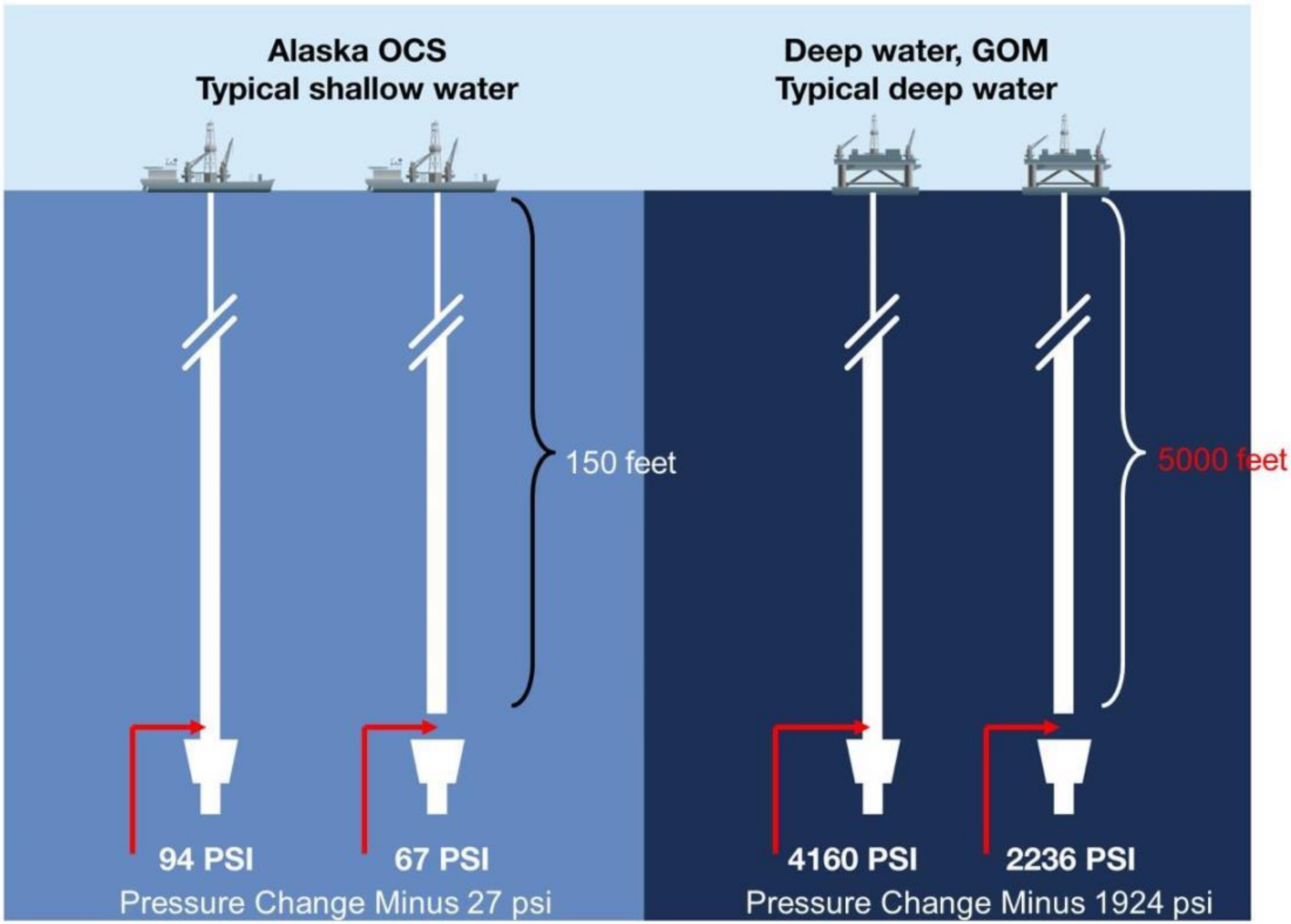
- BOP Disconnect Below Ice Scour
- 30" Is the Foundation Pipe:
  - Carries the weight of subsequent casing strings
- Surface & intermediate string casing points chosen on:
  - Pore-Pressure
  - Fracture Gradient / Rock Strength
  - Kick Tolerance



Comparison of Arctic & GOM Deepwater Pore Pressure Environment

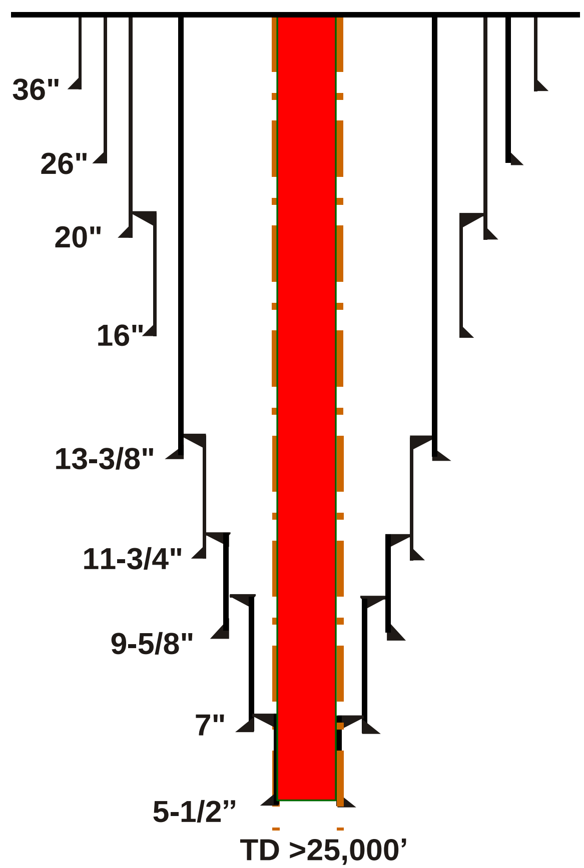


Arctic & GOM Deepwater Emergency Riser Disconnect – Effect of Riser Margin

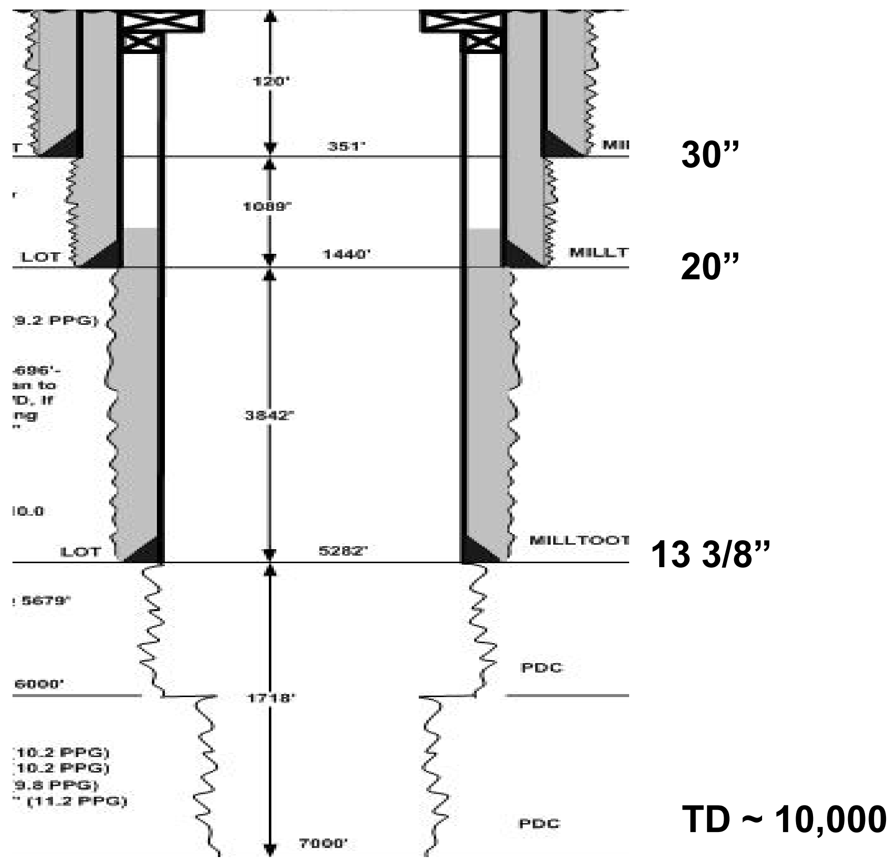


Arctic & GOM Well Designs

Conventional DW Well Plan

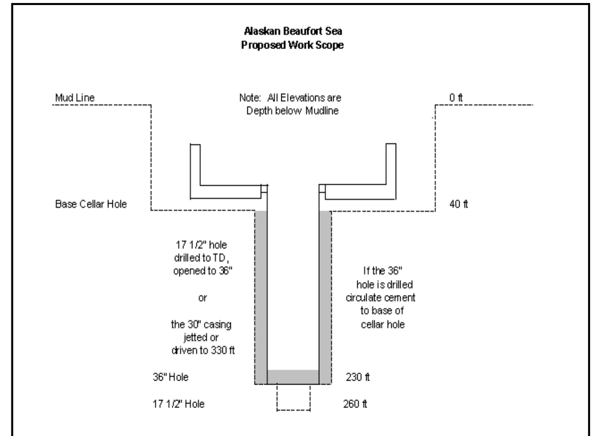


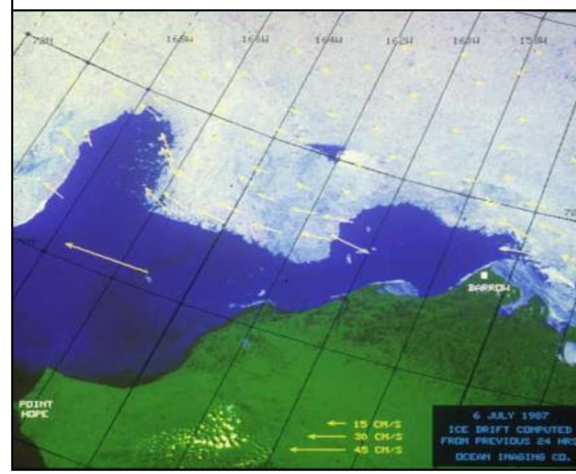
Typical Alaska Well Plan

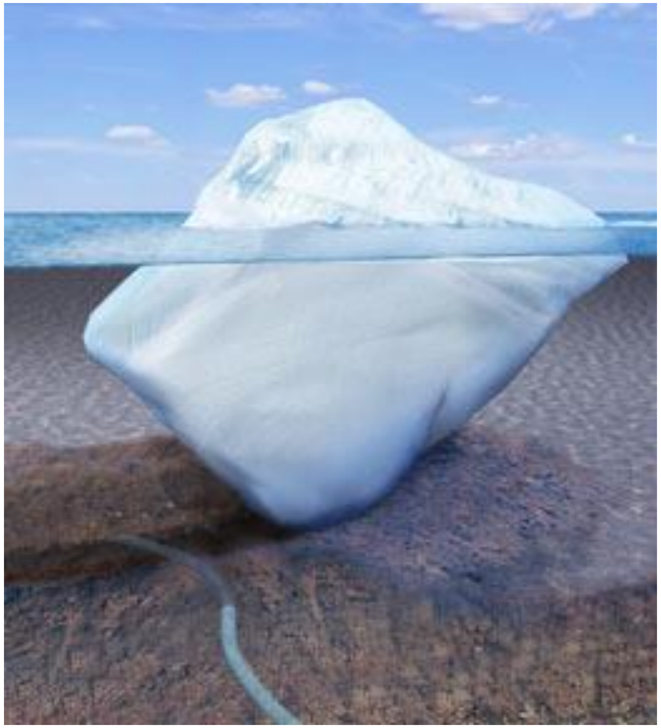


Special Arctic Prevention Measures

- Critical Operations Curtailment Plan
- Mud Line Cellars – protect BOP
- Ice Monitoring & Management
  - Satellite imagery
  - Shipboard marine radar
- Weather Monitoring & Forecast

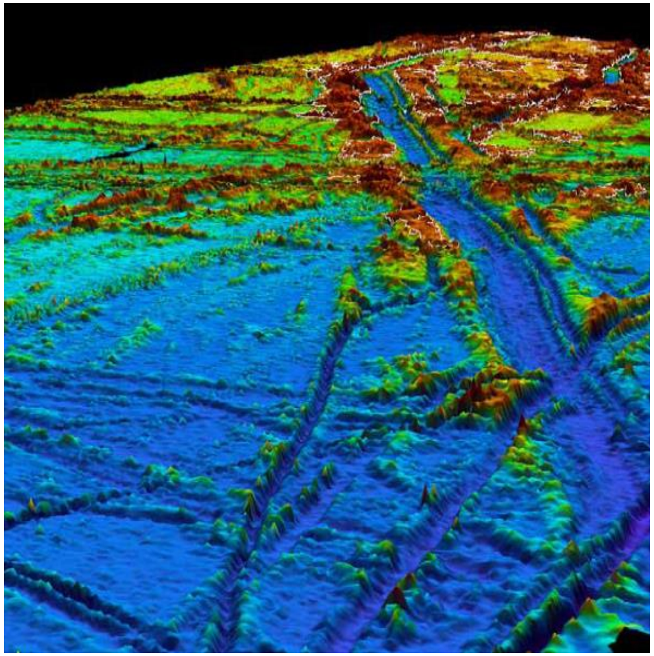


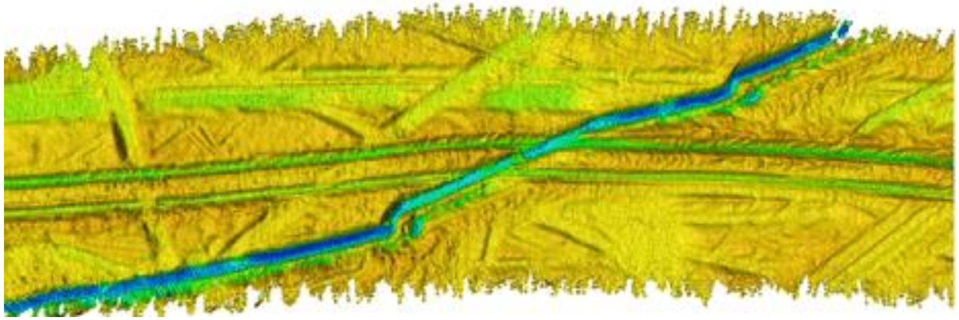




Ice Scour

Canadian Beaufort – multi-beam sonar images





Strudel Scour

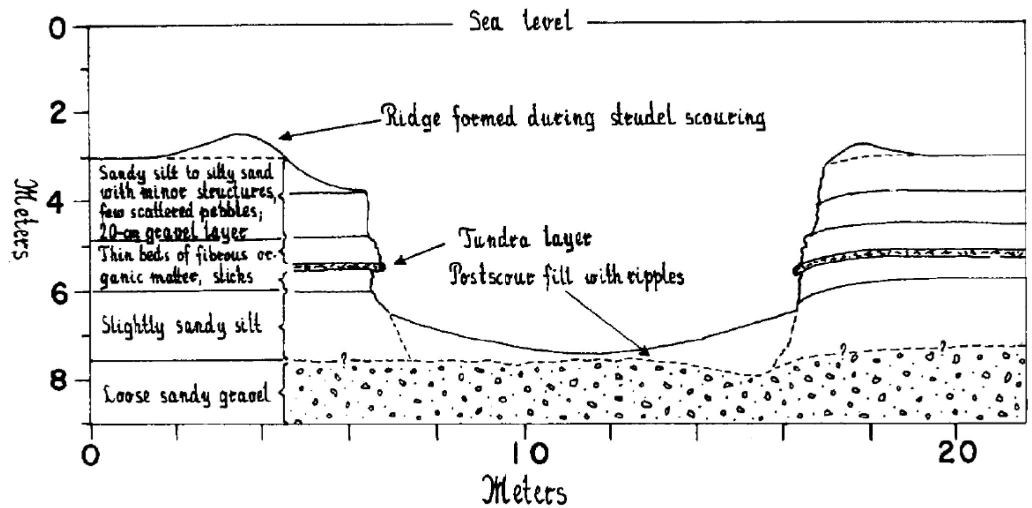


FIG. 10.—Strudel scour investigated by direct diving observations, showing generalized stratigraphy of the sediments exposed in steep walls.

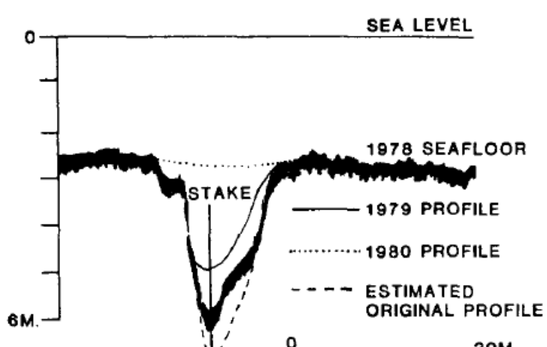
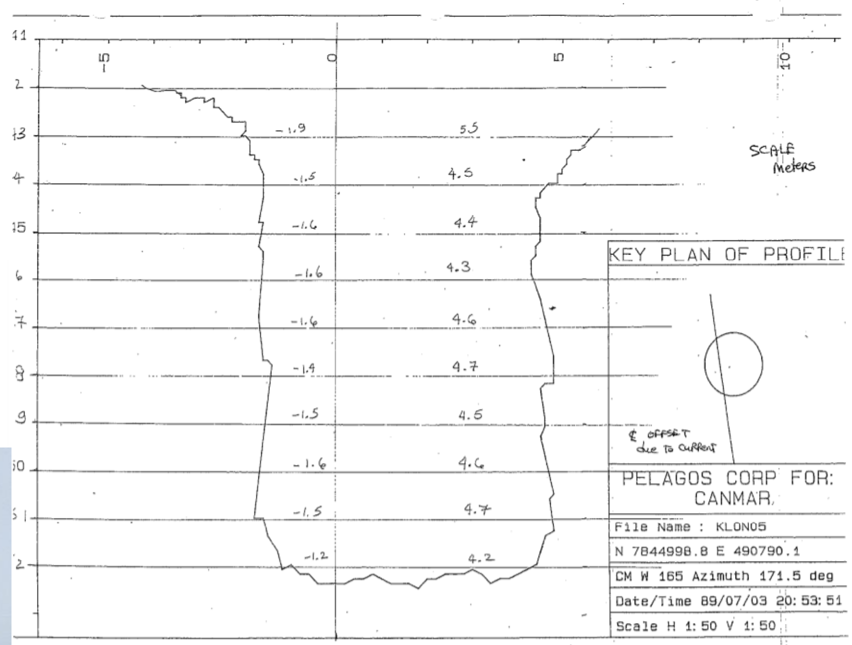


Fig. 4. Fathogram of deepest profile of strudel scour B in 1978, and two successive years. Divers found vertical walls on upper 1 m of left (west) side and estimated original scour depth by driving the stake shown.

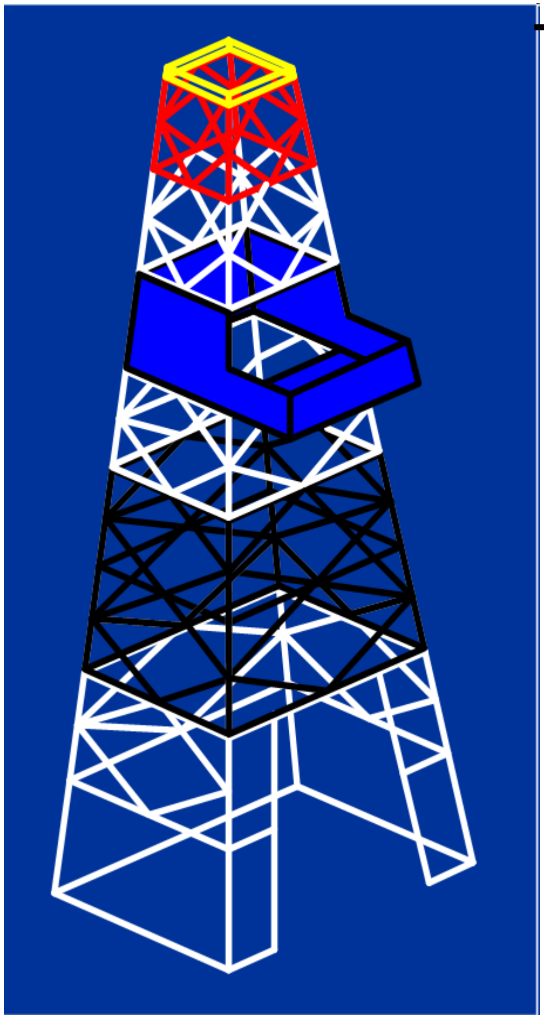
Mud Line Cellar

Top Holes—MLC

- Regulatory requirement
- 40 ft deep x 20 ft diameter
- 20 ft diameter plow bit



Blowout Prevention: Layers of Prevention



Layer IV– Relief Well Operations

Contingency plans in place

Layer III – Mechanical Barriers

Including special arctic barriers

Layer II – Early Detection and Response

Continuous Monitoring, RTOC

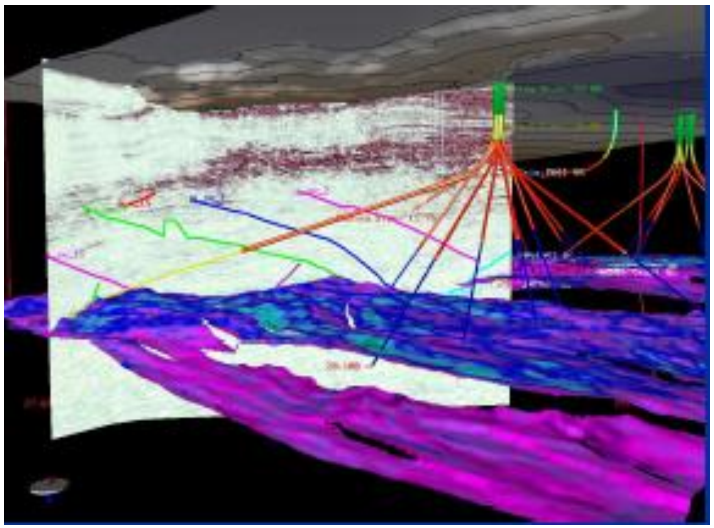
Layer I – Planning, Training, and Preparation

To build a strong foundation

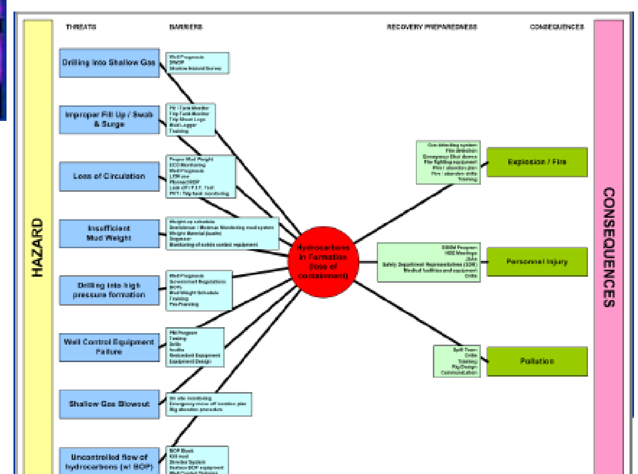
No single point failure leads to the worst case blowout scenario

Prevention Layer I -Planning, Training & Preparation

Drill the Well on Paper (DWOP)

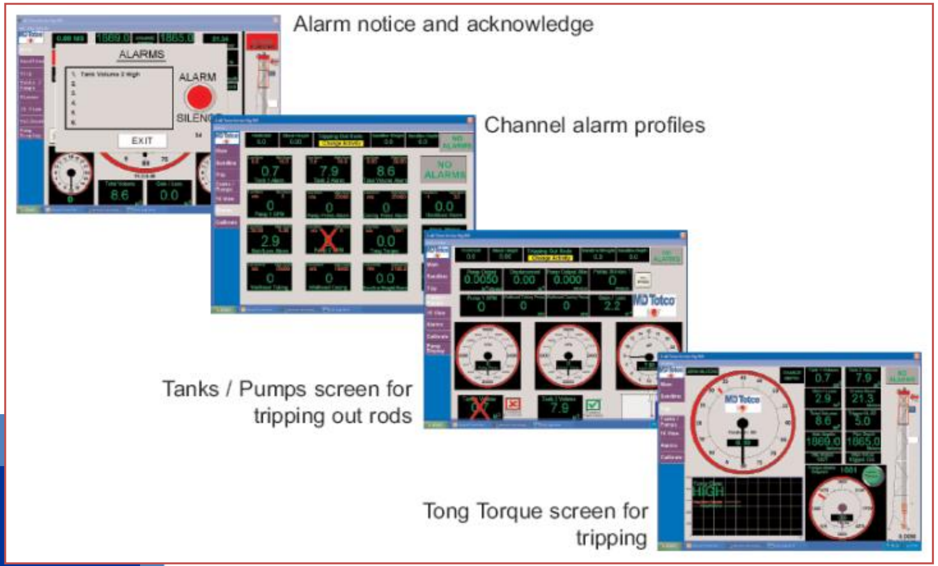


Visualization Center



Risk Identification & Mitigation

Prevention Layer II- Early Detection & Response



Prevention Layer III – Redundant Barriers to Maintain Well Control

Fluid Barriers

- Drilling Mud
- Completion Fluid

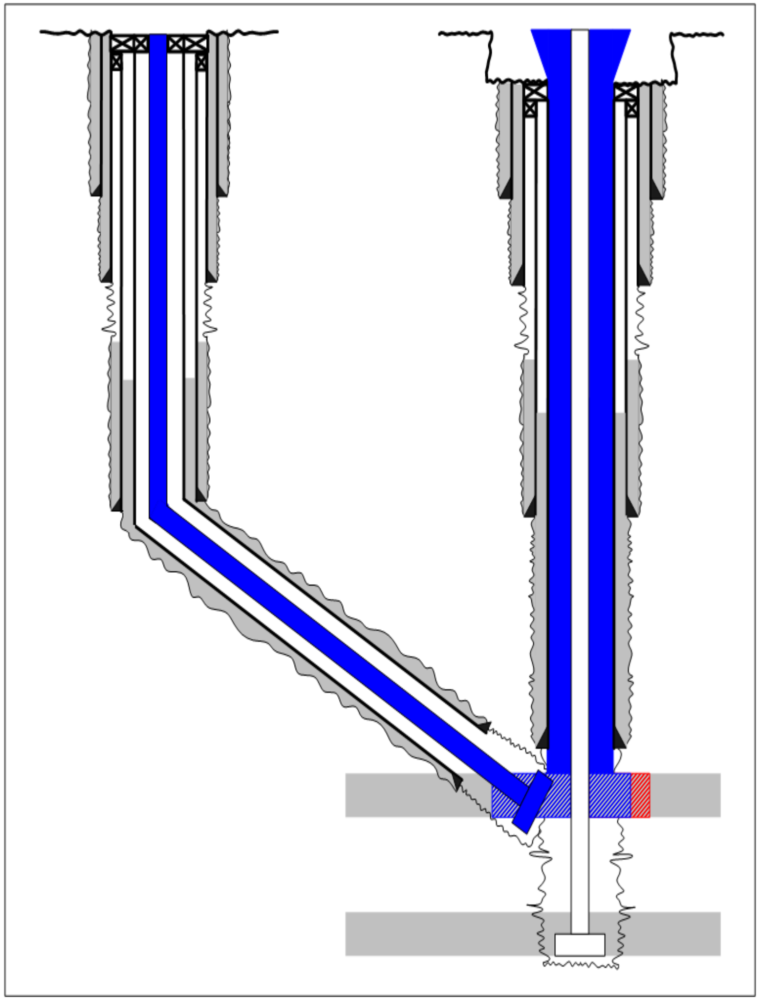
Mechanical Barriers

- Blowout Preventers
- Cemented Casing
- Mechanical Isolation Plugs (SSSV)
- Storm/Ice Isolation Packers

Layer IV - Contingency Plans for Relief Well

Regardless of the low probability, contingency plans are put in place for a relief well:

- Drilling rig availability guaranteed (Discoverer & Kulluk)
- Well design in place
- Wellhead, casing, fluid, & other equipment in place

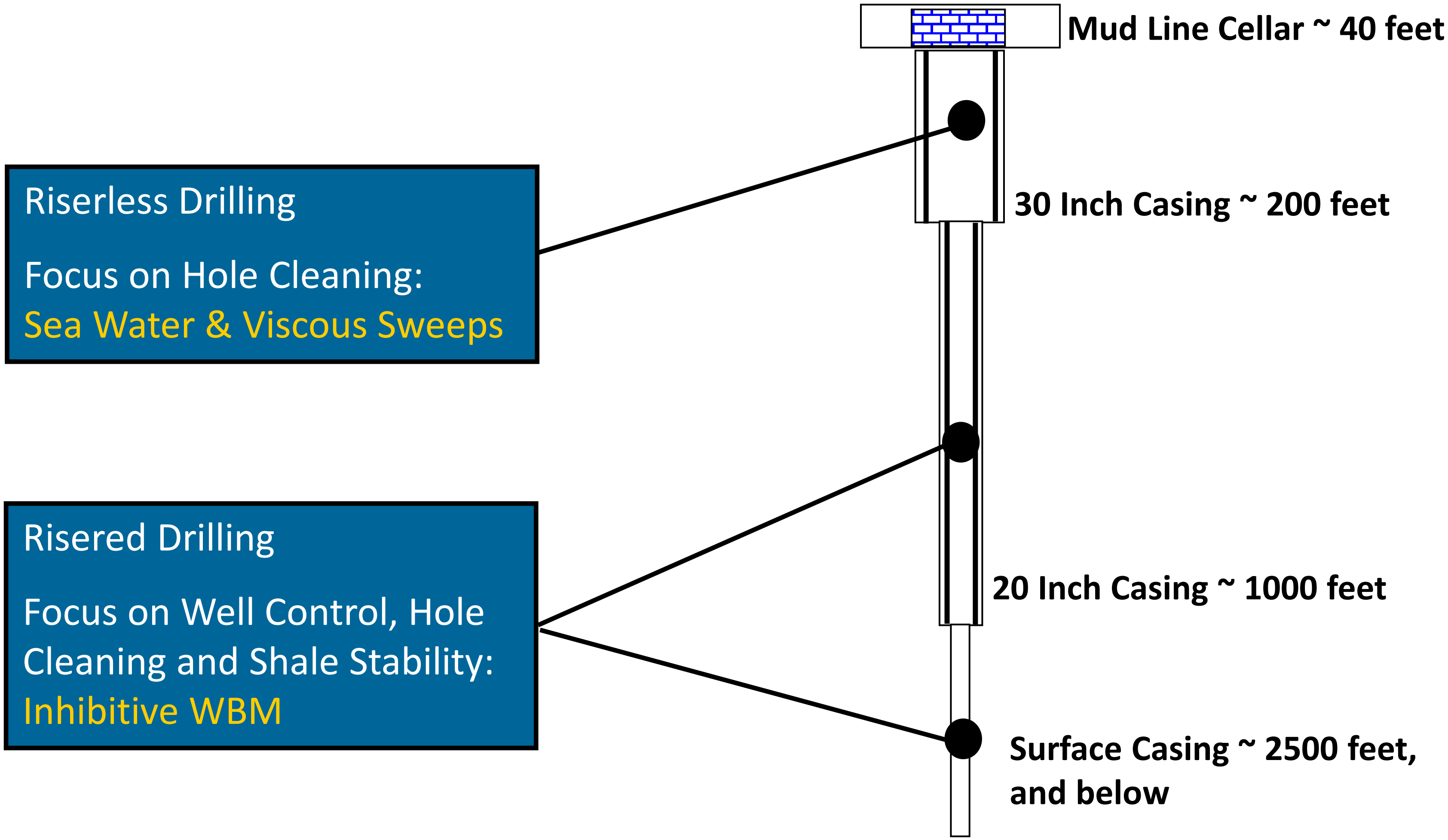


Waste/Pollution & Eskimo Subsistence Hunting Lifestyle

Waste Streams – What are they?

- Drilling Mud
  - Mud
  - Additives
  - Cuttings
- Deck Drainage (precipitation run-off)
- Sanitary and Domestic Waste
  - Grey and Black Water
  - Food
  - Paper
  - Glass
  - Cans
- Air Emissions

Drilling Fluid Program



“Muddied Waters” Quote

“Over the years individual drilling companies, and their expert drillers have devised proprietary and secret formulations to deal with specific types of drilling job. These mud “recipes” are based on long experience, arcane knowledge and special skills. One of the problems in studying the effects of drilling waste discharges is that the drilling fluids are made from a range of 1,000 ingredients – many of them known, confusingly, by different trade-names, generic descriptions, chemical formulae, and regional or industry slang words”

J. Wills, *Muddied Waters*, May 2000, p.11

Acceptability of WBM additives

- All proposed WBM additives are acceptable to EPA Regions 10 (Alaska) and 9 (California = strictest offshore environmental guidelines in USA); they are routinely used and discharged in EPA GoM Regions 4 and 6
- All additives are either on the Norwegian PLONOR (= “Pose Limited Or NO Risk to the environment”) list or are deemed acceptable for discharge by SFT (= Norwegian Pollution Control Authority);
- NPDES compliance is enforced through frequent environmental testing (see previous slide)

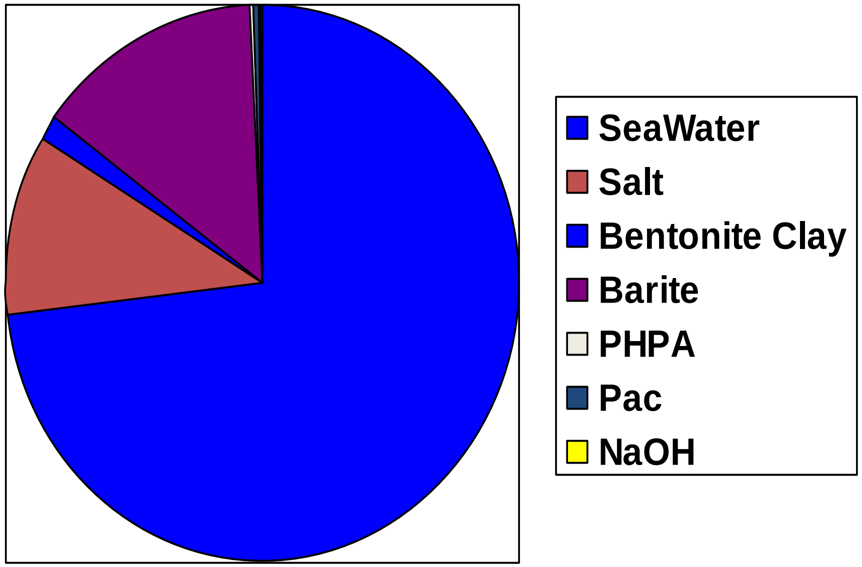
SW/Gel Sweeps Composition

Additive	**Function**	**Also Found in:**
Seawater	Base Fluid	Naturally Occurring
Xanthan Gum (poly-saccharide biopolymer)	Primary viscosifier	Gravy, Soups, Milk Shakes
Bentonite Clay	Secondary viscosifier & fluid loss control agent	Make-up, shampoos, facial creams and lipstick
NaOH (caustic), $NaHCO_3$ (sodium bi-carbonate, Citric Acid	pH control agents	pH regulation in food preparation

WBM Composition

Additive	**Function**	**Also Found in:**
Seawater	Base Fluid	Naturally Occurring
NaCl (sodium chloride)	Clay inhibition & density control	Naturally Occurring, Table Salt
Xanthan Gum (poly-saccharide biopolymer)	Primary viscosifier	Gravy, Soups, Milk Shakes
CMC / PAC (carboxy-methylated cellulose, poly-anionic cellulose)	Fluid loss control agent	Soups, Sauces, Ice Cream, Donuts
PHPA (partially hydrolyzed poly-acrylamide)	Clay inhibition	Water treatment
Barite (barium sulphate)	Weighting agent	Naturally occurring mineral, Barium meal for X-ray imaging
NaOH (caustic), $NaHCO_3$ (sodium bi-carbonate, Citric Acid	pH control agents	pH regulation in food preparation
Na_2CO_3 (sodium carbonate, soda ash)	Hardness control	Food additive (E500), anti-caking agent, sherbets, noodles
Bentonite Clay	Secondary viscosifier & fluid loss control agent	Make-up, shampoos, facial creams and lipstick

Composition of Drilling Fluids



Additive	Percentages
Seawater	73 %
Barite (barium sulphate)	14 %
NaCl / KCl (salt)	10.5 %
Bentonite Clay	1.5 %
Xanthan Gum, PAC, PHPA, NaOH, etc.	Less than 1%

Shell will discharge less than 1% of the mud and cuttings volume allowed under our NPDES permit (EPA allows 18,000 bbls/day, Shell plans 100 bbls/day).

Barite Origin: Low Cd & Hg Content

Barite source: Greystone Mine near Battle Mountain in Nevada

WBM Environmental Testing

Discharge	**Parameter**	**Effluent Limitation**	**Measurement Frequency**
Water-Based Drilling Fluid (WBM) and Cuttings	SPP Toxicity	96hr LC50>30,000 ppm	Monthly
	Drilling Fluid	No visible sheen	Daily
	Formation Oil	No discharge	Daily
	Diesel Oil	No discharge	Daily
	Hg in Barite	< 1mg/kg	Prior to drilling
	Cd in Barite	< 3 mg/kg	Prior to drilling
	Total Aqueous HC	-- (mg/l)	Once per well
	Total Aromatic HC	-- (mg/l)	Once per well
	Total Volume	500, 750 or 1000 bbl/hr depending on water-depth (>5-20m, >20-40m, >40m)	

Table shows effluent limitations and monitoring requirements for water-based drilling fluids and drilling cuttings as per NPDES permit AKG 280000

Environmental Benefit Analysis: When Environmentalism Stops Making Sense

Environmental Concern

Why not just haul the drill cuttings to shore and go zero discharge with skip & ship operations?

Zero Discharge Facts

- Zero discharge will lead to greater environmental impacts due to the absence of discharge sites in Alaska for skip & ship operations
- Increase marine traffic on coastal waterways and through subsistence hunting areas
- Increase air pollution
- Increase solid waste generation and management
- Increase energy consumption (for boats, cranes, trucks and earth-moving equipment at waste disposal sites)
- Increase consumptive water use
- Increased crew HSE exposure
- Gulf of Mexico – discharge to water in flourishing marine environment

Questions?

Presentation Overview

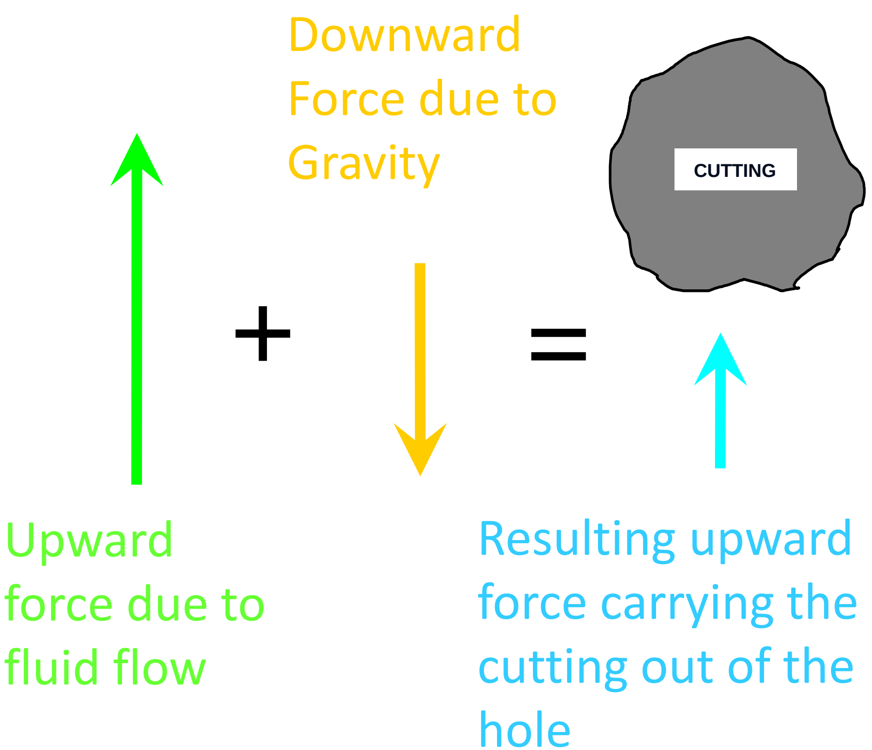
- General Fluids Introduction / Video
- Fluid Functions (emphasis on Alaska operations)
- Water-Based Mud Formulation & Drilling Fluid Components
- Environmental Compatibility
- Best Management Practices
- Comparison with Global Exploration Activities
- Discharge vs. Zero Discharge: Non-Water Quality Impacts
- Discussion

Drilling Fluid Functions

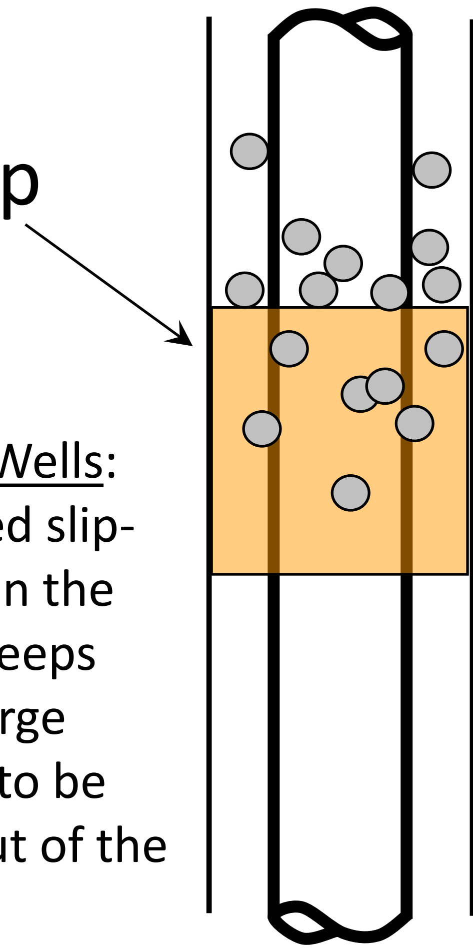
- Provide primary well control through hydrostatic pressure generated by fluid column
- Chemically and physically stabilize drill cuttings and uncased sections of the borehole
- Carry cuttings from beneath the bit and up the annulus, permitting their separation on surface
- Cool and clean the bit & BHA
- Reduce friction between the drillstring or casing and the sides of the hole
- Provide fluid loss control
- Enable downhole MWD/LWD communication through mud-pulsing technology
- Assist in the collection and interpretation of information available from drill cuttings, cores and electrical logs

Drilling Challenges: Hole Cleaning

- Hole cleaning in large diameter hole revolves around over-coming slip velocity of cuttings
- High-viscosity (Hi-Vis) sweeps are necessary to clean larger cuttings out of the hole



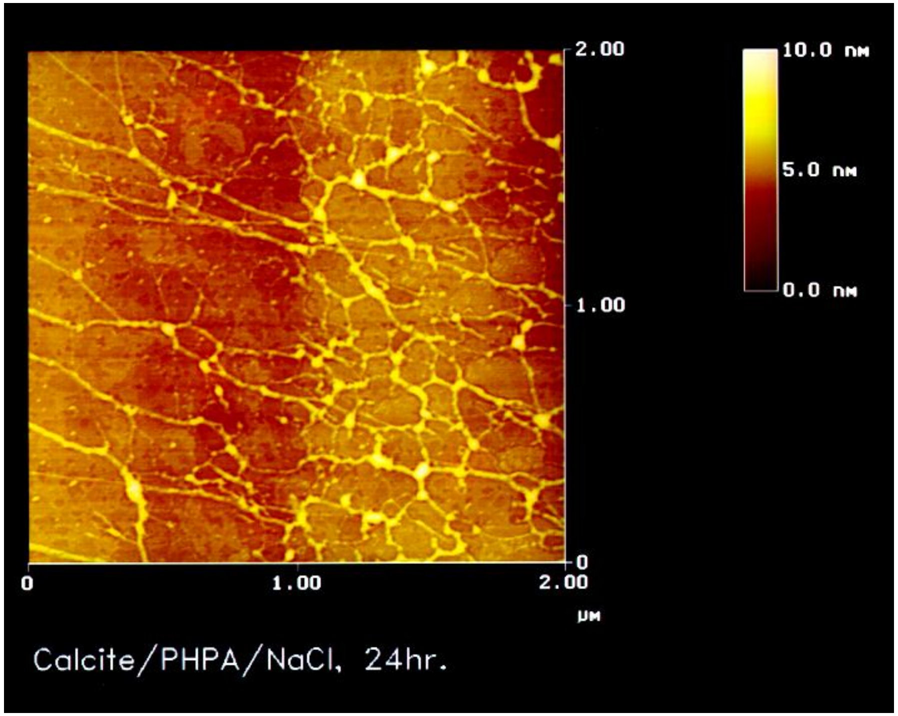
Hi-vis sweep



<u>Vertical Wells</u>: decreased slip-velocity in the hi-vis sweeps allows large cuttings to be swept out of the hole

Drilling Challenges: Shales

- Inhibition is required for control of more reactive clays (smectites / illites)
- Sivulliq shales are not highly reactive (low smectite)



PHPA adhering to reactive clay surface

Adverse mud-shale reaction: bit-balling

Fluid Selection Criteria

- Prior use in Alaska offshore environment
  - (i.e. proven track record, both technically & environmentally)
- Well-known, proven technology – no experimental system or additives
  - 40 year offshore history with salt/polymer muds (e.g. "Shell polymer mud")
- Simple system, built from minimum amount of essential additives
  - Sivulliq technical drilling challenges are straightforward
- System that meets NPDES discharge requirements of Region 10 (Alaska), Region 9 (California), Regions 6 & 4 (GoM)
- System that meets European OSPAR requirements, and more strict Norwegian SFT requirements (see later slides)

Arctic Comparison: Norway

- Discharge of WBM and associated cuttings is allowed throughout Norwegian offshore environment, provided mud additives meet appropriate requirements (i.e. PLONOR, green/yellow listed, etc.).
- Exception is current exploration in the Lofoten/Barents Sea area:
  - WBM discharge during riserless drilling is allowed (WBM = kill/pad mud made up primarily out of seawater, bentonite for viscosity and barite for density).
  - Once the riser is on the well, no discharge is allowed and all cuttings are either shipped to shore or slurrified and injected downhole.
  - Norwegian operators (e.g. Statoil) have agreed to this arrangement in order to expedite entry into the the Lofoten/Barents Sea area; however, they are currently considering to challenge this inconsistency in discharge policy

Arctic Comparison: Sakhalin

- Exploration wells not drilled by Shell
- Other Sakhalin operators are drilling riserless (i.e. mud & cuttings discharged to seafloor) up to setting of 18-5/8“ surface casing, using skip and shipping thereafter; Shell would probably adopt this pollicy also in case a floater is used
- Shell Plan: with Jack-Up, rig up after hammering conductor to take all returns to the surface, and skip & ship the entire well contents.
- Key difference with Alaska exploration: availability of injection well on Molikpaq platform and a landfill site to dispose of the cuttings
- Note: availability of CRI and landfill site has encouraged the use of OBM, a frequent consequence of having to adopt zero discharge

Non-Water Quality Impacts

- Examples of non-water quality environmental impacts as a result of boats, cranes, trucks and earth-moving equipment to facilitate zero discharge:
  - Cuttings and associated mud generated during drilling: typically 100-200 bbl/hr; typical 160-180 ft supply boat can store 12-18 cuttings boxes (25 bbl each) and 2500 bbl drilling fluids; 2-3 additional supply boats per day would be necessary to offload and transport cuttings under zero discharge conditions
  - 0.25 – 0.50 tons of increased air emissions (CO_2, NO_x, SO_2, CO, Total Hydrocarbons and Total Suspended Particulates) for every 1000 bbl of cuttings and associated mud volume transported
  - 120 - 200 gallons of fuel burned for every 1000 bbl of cuttings and associated mud volume handled and transported

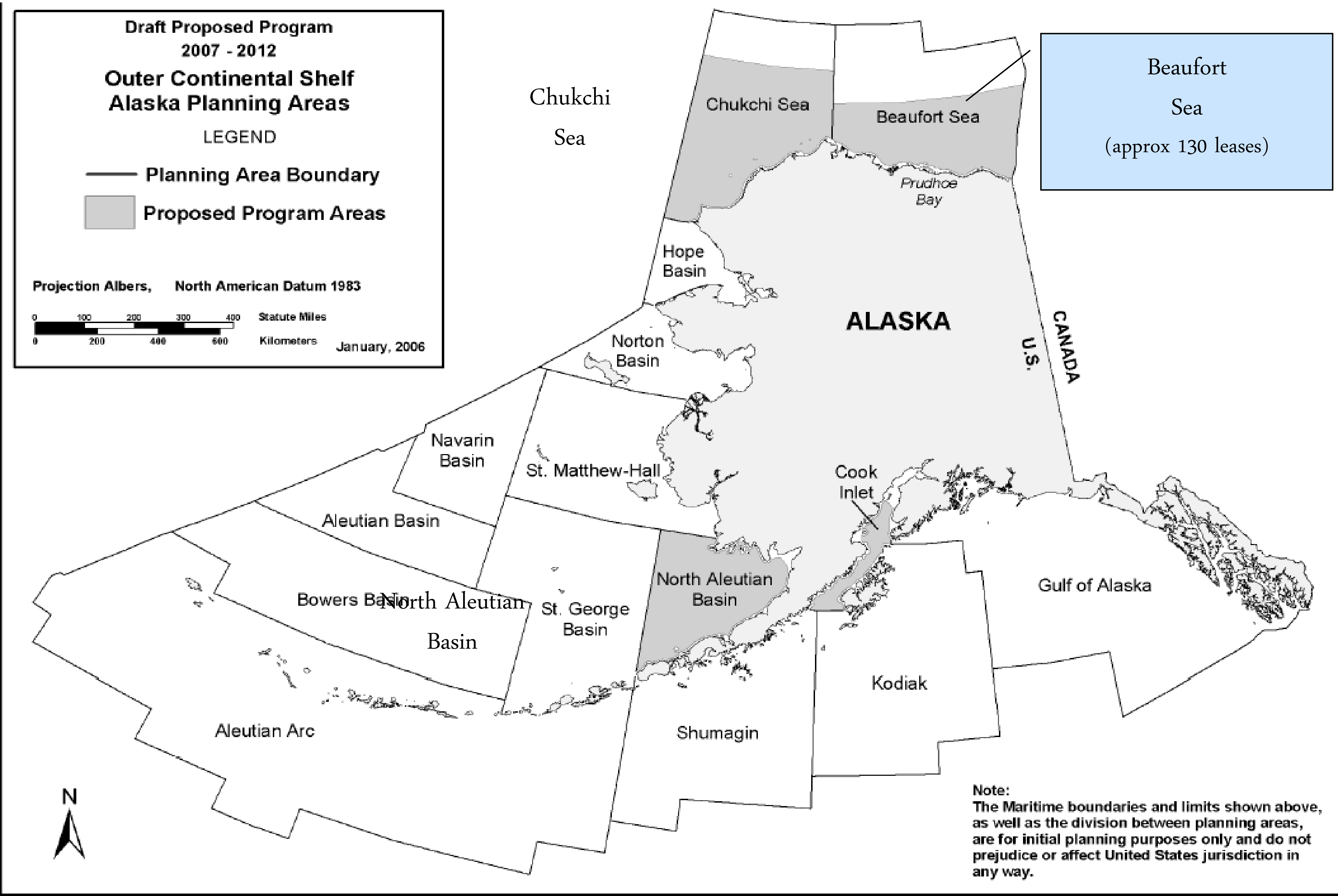
Best Management Practices

- Best Management practices specify best available housekeeping rules for maintaining drilling fluids, minimizing fluid-associated waste generation, and avoid exposure to spills
- Typical elements covered in BMP’s:
  - General rig housekeeping rules
  - Mud pit best practices
  - Solids control equipment best practices
  - Contingency plans (e.g. to cover equipment failures)
  - Rig staff training requirements & log
- BMP’s developed for WBM housekeeping on Kulluk

2007 Alaska Exploration

- Extensive preparation activities in 2006
  - ✓ Supply chain matrix addresses sourcing, logistics and local content
  - ✓ Excellent supplier support sofar for preparation activities
- Continued pro-active support necessary in 2007
  - ✓ 60-day window for 3 wells: deliver the right support at the right time
  - ✓ Local stakeholder management /local content are important issues
  - ✓ Start-up activities on Kulluk and Frontier Discoverer to be managed safely
  - ✓ Environmental compliance requires special attention

Minerals Management Service Five Year Plan



2007 Open Water Season: Key Activities

3-D Seismic – Gilavar (& support)

Oil Spill Contingency – OSRV Endeavor, Arctic Tanker

Ice Class-Drill Ships – Kulluk & Frontier Discoverer

Site Surveys – Henry C.

Geotech Boring – vessel TBD

Strudel scour – Annika Marie

Note: Excludes on-ice seismic pilot (Mar) and additional support vessels for crew change, etc.

2007 Season: Drilling Support

Ice Management –
Kapitan Dranitsyn
Vladimir Ignatjuk (formerly *Kalvik*)

Anchor Handling & Ice Management –
Tor Viking
Fennica

Support –
Jim Kilabuk

Marine Mammal Monitoring & Mitigation Plan

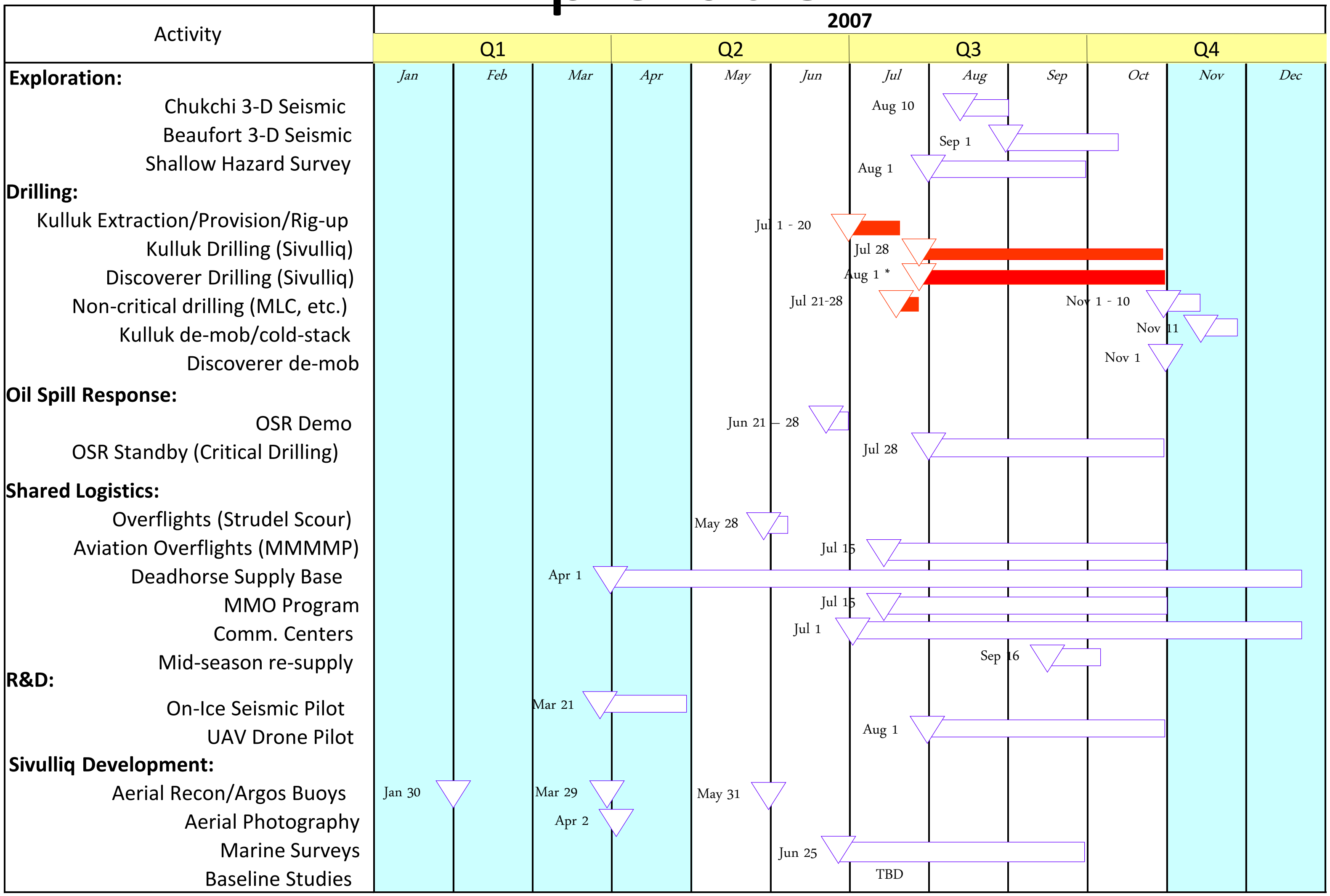
- Focus is protection of the animals.
- Collection of distribution data, patterns, and evaluation of potential deflection
- MMO's on-board most vessels
- Incorporation of local expertise
- Aerial surveys & pilot program for unmanned drone
- Acoustic recorder arrays

Herbert Tagarook, MMO from Wainwright

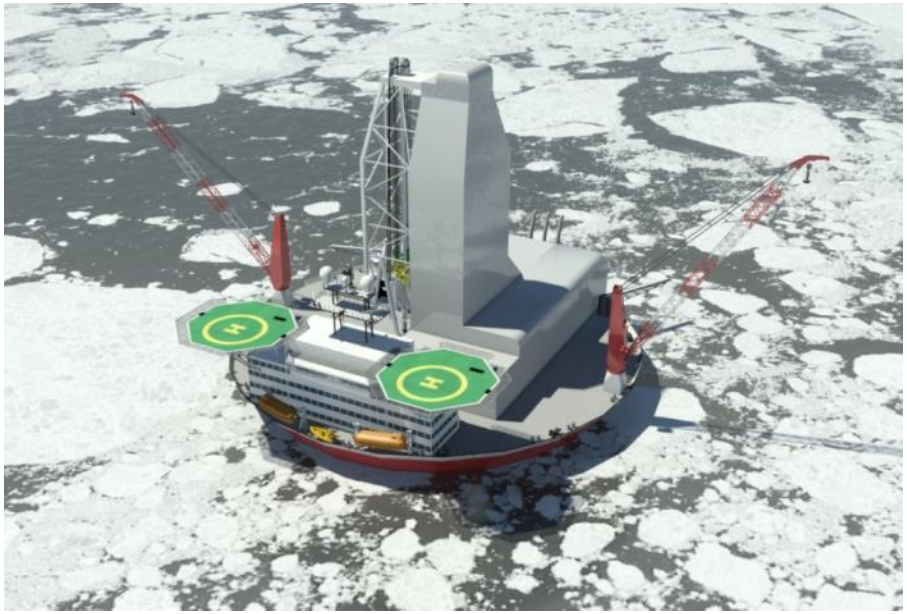
Billy Gordon, MMO from Kaktovik

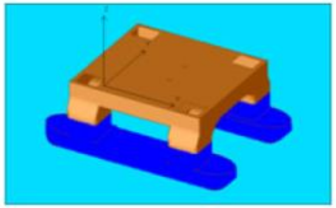
Jesstin Patterson, MMO from Barrow

Timeline for 2007 Season – Alaska Exploration

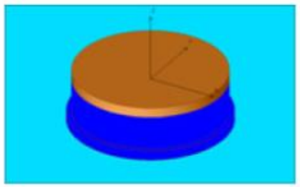


Fall Whaling:



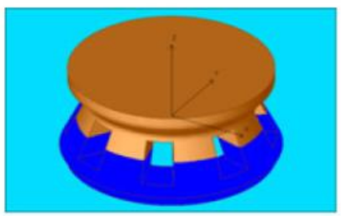


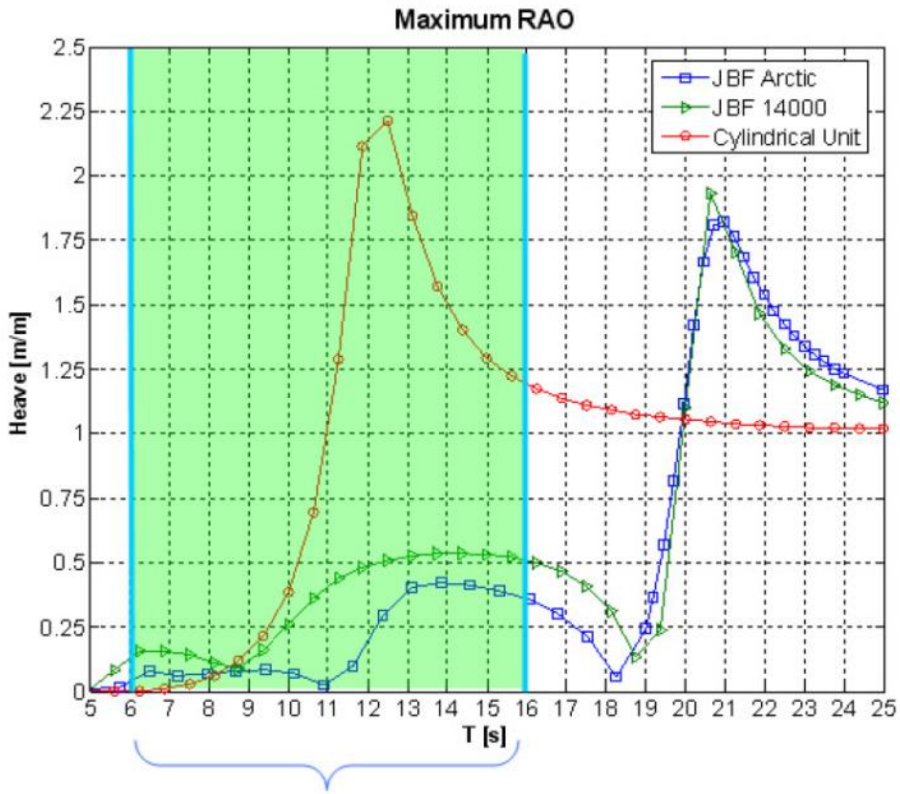
JBF 14000 (typical semi)



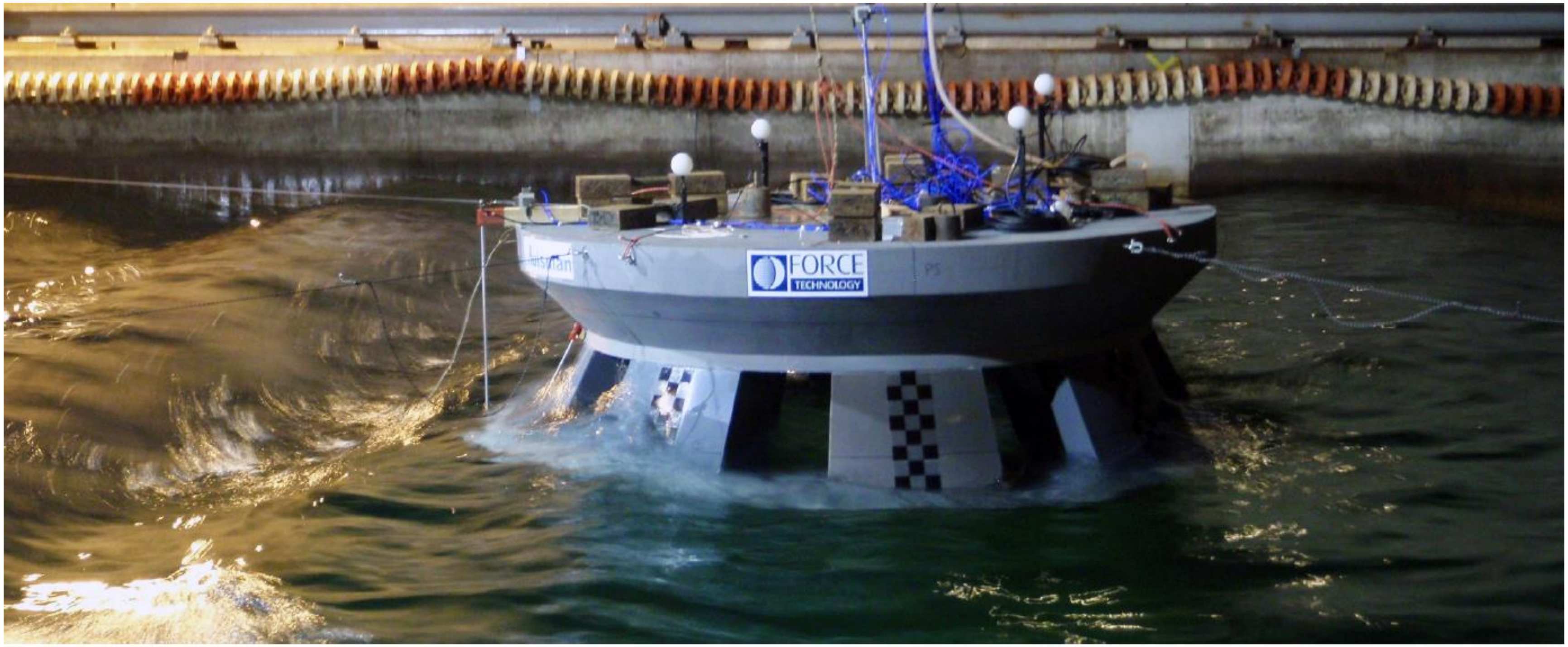
Cylindrical Type Unit

JBF Arctic

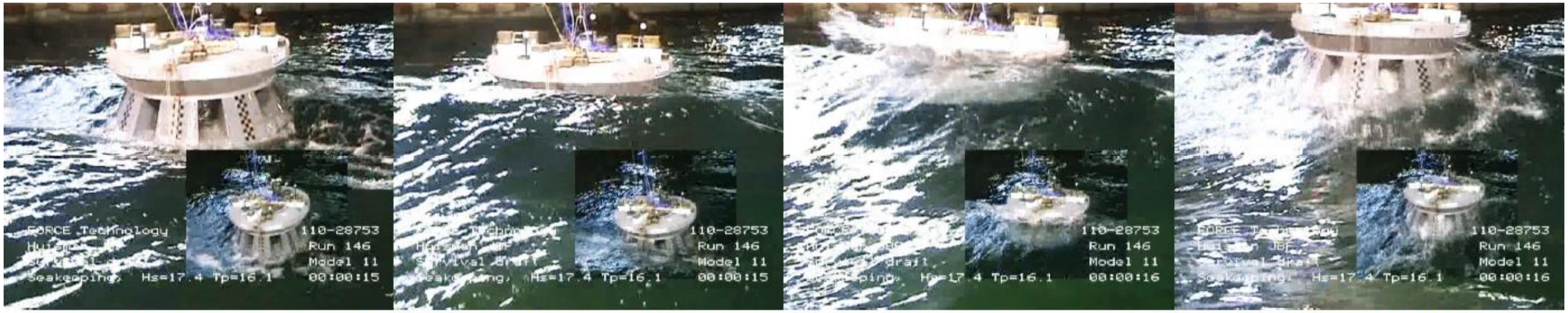




range of typical wave periods



Model tests of JBF Arctic in irregular waves at open water operating draft



Model tests of JBF Arctic in irregular waves in survival condition meeting the wave H_{sig}=17.4m

Model tests of JBF Arctic in ice (ice draft and transit draft)

Improvement – Continuous Loop

- Technology Drives Improvement
- Field Tested – Lab work only gets you so far (more variables)
- Waste is Just That "Waste"