Arctic Drilling: Economic Opportunity or Environmental Disaster?

Most students believe deepwater development in the Arctic was premature.

Hell no, this should never happen

It is too early, we are not ready

Proceed, but with caution

Drill, Baby, Drill
Kulluk Towing Problems
Shell’s Artic Presence / Ambitions
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.).

3 Wells Planned as early as 2007
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 $H_{\text{sig}} = 17.4$ m
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

**Anchor Handling & Ice Management** – Tor Viking, Fennica

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

**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

Streamline-isotach analysis in westerly storm September, 1970
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

Dimensions:
- 30” – 300-500’
- 20” – 1-2000’
- 13-3/8” – 6000’
- 9-5/8” – 7000’
- TD – 10000’
Comparison of Arctic & GOM Deepwater Pore Pressure Environment

- Alaska OCS:
  - 5,000 feet: Normal Pressure
  - 10,000 feet: Near Normal Pressure
  - 15,000 feet: High Pressure
  - 20,000 feet: Very High Pressure

- Deep water, GOM:
  - Empire State Building

- Deep water
- High pressure
- More challenging well control
Arctic & GOM Deepwater Emergency Riser Disconnect – Effect of Riser Margin

Alaska OCS
Typical shallow water

Deep water, GOM
Typical deep water

94 PSI
Pressure Change Minus 27 psi

67 PSI

4160 PSI
Pressure Change Minus 1924 psi

150 feet

5000 feet

2236 PSI
Arctic & GOM Well Designs

Conventional DW Well Plan

Typical Alaska Well Plan

TD > 25,000'

30”

20”

13 3/8”

TD ~ 10,000’
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
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.

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

- 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

Visualization Center

Drill the Well on Paper (DWOP)

Risk Identification & Mitigation
Prevention Layer II - Early Detection & Response

Real Time Operations Center

Alarm notice and acknowledge
Channel alarm profiles
Tanks / Pumps screen for tripping out rods
Tong Torque screen for tripping
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

Riserless Drilling
Focus on Hole Cleaning:
Sea Water & Viscous Sweeps

Risered Drilling
Focus on Well Control, Hole Cleaning and Shale Stability:
Inhibitive WBM

Mud Line Cellar ~ 40 feet
30 Inch Casing ~ 200 feet
20 Inch Casing ~ 1000 feet
Surface Casing ~ 2500 feet, and below
“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

<table>
<thead>
<tr>
<th>Additive</th>
<th>Function</th>
<th>Also Found in:</th>
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</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>Base Fluid</td>
<td>Naturally Occurring</td>
</tr>
<tr>
<td>Xanthan Gum (poly-saccharide biopolymer)</td>
<td>Primary viscosifier</td>
<td>Gravy, Soups, Milk Shakes</td>
</tr>
<tr>
<td>Bentonite Clay</td>
<td>Secondary viscosifier &amp; fluid loss control agent</td>
<td>Make-up, shampoos, facial creams and lipstick</td>
</tr>
<tr>
<td>NaOH (caustic), NaHCO₃ (sodium bi-carbonate, Citric Acid)</td>
<td>pH control agents</td>
<td>pH regulation in food preparation</td>
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</table>
# WBM Composition

<table>
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<tr>
<th>Additive</th>
<th>Function</th>
<th>Also Found in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>Base Fluid</td>
<td>Naturally Occurring</td>
</tr>
<tr>
<td>NaCl (sodium chloride)</td>
<td>Clay inhibition &amp; density control</td>
<td>Naturally Occurring, Table Salt</td>
</tr>
<tr>
<td>Xanthan Gum (poly-saccharide biopolymer)</td>
<td>Primary viscosifier</td>
<td>Gravy, Soups, Milk Shakes</td>
</tr>
<tr>
<td>CMC / PAC (carboxy-methylated cellulose, poly-anionic cellulose)</td>
<td>Fluid loss control agent</td>
<td>Soups, Sauces, Ice Cream, Donuts</td>
</tr>
<tr>
<td>PHPA (partially hydrolyzed poly-acrylamide)</td>
<td>Clay inhibition</td>
<td>Water treatment</td>
</tr>
<tr>
<td>Barite (barium sulphate)</td>
<td>Weighting agent</td>
<td>Naturally occurring mineral, Barium meal for X-ray imaging</td>
</tr>
<tr>
<td>NaOH (caustic), NaHCO₃ (sodium bi-carbonate, Citric Acid)</td>
<td>pH control agents</td>
<td>pH regulation in food preparation</td>
</tr>
<tr>
<td>Na₂CO₃ (sodium carbonate, soda ash)</td>
<td>Hardness control</td>
<td>Food additive (E500), anti-caking agent, sherbets, noodles</td>
</tr>
<tr>
<td>Bentonite Clay</td>
<td>Secondary viscosifier &amp; fluid loss control agent</td>
<td>Make-up, shampoos, facial creams and lipstick</td>
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</table>
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

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

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

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

[Diagram illustrating the forces involved in hole cleaning, including downward force due to gravity and upward force due to fluid flow.]
Drilling Challenges: Shales

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

Calcite/PHPA/NaCl, 24hr.

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 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 policy 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 (CO₂, NOₓ, SO₂, 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 so far 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

Draft Proposed Program
2007 - 2012
Outer Continental Shelf
Alaska Planning Areas

LEGEND

— Planning Area Boundary

Shaded Areas: Proposed Program Areas

Projection Albers, North American Datum 1983

Note:
The Maritime boundaries and limits shown above, as well as the division between planning areas, are for initial planning purposes only and do not prejudice or affect United States jurisdiction in any way.
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
### Timeline for 2007 Season – Alaska

#### Exploration

<table>
<thead>
<tr>
<th>Activity</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
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<tr>
<td><strong>Exploration:</strong></td>
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<tr>
<td>Chukchi 3-D Seismic</td>
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<td>Beaufort 3-D Seismic</td>
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<tr>
<td>Shallow Hazard Survey</td>
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<td><strong>Drilling:</strong></td>
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<td>Kulluk Extraction/Prov/Rig-up</td>
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<td>Kulluk Drilling (Sivulliq)</td>
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<tr>
<td>Discoverer Drilling (Sivulliq)</td>
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<td>Non-critical drilling (MLC, etc.)</td>
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<td>Kulluk de-mob/cold-stack</td>
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<td>Discoverer de-mob</td>
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<td><strong>Oil Spill Response:</strong></td>
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<td>OSR Demo</td>
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<td>OSR Standby (Critical Drilling)</td>
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<td>Overflights (Strudel Scour)</td>
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<td>Aviation Overflights (MMMMP)</td>
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<td>Deadhorse Supply Base</td>
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<td>MMO Program</td>
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<td>Mid-season re-supply</td>
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<td>On-Ice Seismic Pilot</td>
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<td>UAV Drone Pilot</td>
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<td><strong>Sivulliq Development:</strong></td>
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<td>Aerial Recon/Argos Buys</td>
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<td>Aerial Photography</td>
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<tr>
<td>Baseline Studies</td>
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**Fall Whaling:**
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 $H_{\text{sig}}=17.4\text{m}$
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”