A Case Study in Evaluating Technical Options for Well Abandonment in an Aging Offshore Field

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HARRIET JOINT VENTURE (HJV)

- 45 Wells across 9 Unmanned Structures
- 4 Suspended Subsea Wells
- 4 Land Wells
SCOPE OF WORK

• Develop AACE Class IV Time and Cost Estimates for Abandonment
  – Review offset well abandonment results
  – Evaluate local regulatory constraints on abandonment design
  – Develop individual well methodologies for a ‘Conservative’ case & an ‘Opportunity’ case
  – Develop Technical Risk Register
  – Develop individual well durations
  – Develop cost database
  – Undertake Monte Carlo probability analysis of overall Project Cost for both Cases

• Evaluate Opportunities for Cost Minimisation especially the potential for using Rigless Techniques
CHALLENGES & OPPORTUNITIES

Well Characteristics

- Mudline Hangers and Annuli Cemented at surface/mudline
- Sustained B and C Annulus Pressures: Sources Uncertain
- Total Losses to ~ 650m and unknown cement top in B Annulus
- Shallow Gas Bearing Zone(s) with limited flow potential: ~1,000m-800m (Windalia/Gearle)
- Tubing & Wellhead Integrity
- Limited High s.g. Tail Cement Volumes
- Effectiveness of existing Suspension Plugs
- Multiple Production Reservoirs (5 Wells)

Goal-Oriented Regulation

Limited Platform Load Capacity & Water Depth (30m-6.5m)
ABANDONMENT PHILOSOPHY – CONSERVATIVE CASE

- Isolation ‘Barrier’ required across the wellbore
- Single ‘Combination’ barrier permitted
- Hydrocarbon Cross-flow not permitted (deeper formation in 5 wells)
- Tubing and GLM leaks assumed to prevent thru’ tubing operations
- Sustained B and C annulus pressures assumed to originate from reservoir formation
- Remedial cementation of cemented annuli via section milling
- Remedial cementation of casing with uncertain cement and liners, by perf and wash technology
- Plugs below tailpipe only when hole angle < 75deg
- Cementing of 7” liner in 12 ¾” hole: unreliable at high hole angle
- Windalia and Gearle require isolation from surface at 13 3/8” shoe due to loss formations above this point
Conservative Case

- Kill Well and Plug Tailpipe
- N/D XT & N/U BOP
- Pull Tubing & Set BP in Liner Hanger
- Section Mill Casing & Set Cement Plug #1
- Set Squeeze Packer at 13 3/8” Shoe
- Circulate or Squeeze Annulus
- Sting Out and Set Cement Plug #2 on Top
- Cut & Pull Inner Casings
- Set Bridge Plug
- Set Plug #3

Well Status: Inactive

Wellhead Test Failures
- No recorded issues.

Annulus Pressure
- Sustained B Annulus Pressure

Cement Note
- No cement details in report.
- TTOC from Completion Schematic.

Well Name: Artreus-1

Conservative Case P&A Schematic

ML to KB: 49.8 m
Water Depth: 8.1 m

Drilling Rig: Ensco 56
Spud Date: September, 2005
Rig Release: September, 2005

Wellhead Test Failures
- No recorded issues.

Annulus Pressure
- Sustained B Annulus Pressure

Cement Note
- No cement details in report.
- TTOC from Completion Schematic.

Primary Data Source for this work: Well Summary and Integrity Review
Changes from Conservative Case

• Sustained annular pressures assumed to be from Windalia/Gearle
  — Still need Annular Reservoir Barrier in 7 wells
• Quality of unknown casing cementation can be verified successfully by logging
• Small tubing leaks do not prevent through tubing cementation operations
• Cross flow between hydrocarbon reservoirs permitted
• No surface plug required
Opportunity Case

- Kill Well and Plug Tailpipe
- N/D XT & N/U BOP
- Pull Tubing
- Verify Casing Cement
- Set Plug#1 on Bridge Plug & Verify
- Set Squeeze Packer at 13 3/8" Shoe
- Circulate or Squeeze Annulus
- Sting Out and Set Cement Plug #2 on Top
### DURATION ESTIMATES

#### Liftboat based Durations

<table>
<thead>
<tr>
<th>Position Rig</th>
<th>Liftboat based Durations</th>
<th>Low</th>
<th>Most Likely</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>LB Move in on GP and Jack Up</td>
<td>5.0</td>
<td>6.0</td>
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<tr>
<td>LB Skid Cantilever and prepare for operations</td>
<td>7.0</td>
<td>9.0</td>
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<td>LB Instal walkway</td>
<td>10.1</td>
<td>12.6</td>
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<td>P&amp;A Preparations</td>
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<tr>
<td>LB Tubing and Annulus Riser and PCE preparations</td>
<td>21.2</td>
<td>21.8</td>
<td>22.4</td>
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<tr>
<td>Prepare Well</td>
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<td></td>
<td></td>
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<tr>
<td>LB Rig up W/S, PCE &amp; riser lines to tree &amp; annulus</td>
<td>2.5</td>
<td>5.0</td>
<td>11.0</td>
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<tr>
<td>LB Bullhead kill fluid to formation</td>
<td>4.0</td>
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<td>10.0</td>
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<td>LB R/U wireline drift well and lock open SSV</td>
<td>6.0</td>
<td>8.0</td>
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<td>Through Tubing Reservoir Plug</td>
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<td>LB DHFT to Packer &amp; set plug in tailpipe</td>
<td>8.0</td>
<td>10.0</td>
<td>16.0</td>
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<tr>
<td>LB Punch/pave tubing and circulate annulus clean</td>
<td>3.0</td>
<td>6.0</td>
<td>12.0</td>
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<tr>
<td>LB circulate BOP: balanced cement plug via tubing and verify</td>
<td>8.0</td>
<td>10.0</td>
<td>15.0</td>
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<tr>
<td>LB R/H CBL and Log Annular cement</td>
<td>4.0</td>
<td>6.0</td>
<td>9.0</td>
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<tr>
<td>LB R/H and set squeeze packer above perforations</td>
<td>16.0</td>
<td>21.0</td>
<td>33.0</td>
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<tr>
<td>LB Mix and squeeze cement into perfs</td>
<td>4.0</td>
<td>4.0</td>
<td>8.0</td>
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<tr>
<td>LB string out of packer and spot cement plug on packer</td>
<td>6.0</td>
<td>8.0</td>
<td>12.0</td>
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<tr>
<td>Pull Completion</td>
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<tr>
<td>LB sever/punch tubing at shallow depth (Typically @ 13 3/8&quot;)</td>
<td>2.0</td>
<td>4.0</td>
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<tr>
<td>LB set temporary plug in tubing hanger</td>
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<tr>
<td>LB Remove Tree</td>
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<td>LB Hoist up BOPs</td>
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<td>15.0</td>
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<tr>
<td>LB R/H and latch tubing hanger and recover upper tubing set</td>
<td>9.0</td>
<td>15.0</td>
<td>22.0</td>
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<td>LB R/H and latch tubing hanger and lift tubing string</td>
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<td>5.0</td>
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<tr>
<td>LB mix and spot BOP cement plug thru tubing and verify</td>
<td>8.0</td>
<td>10.0</td>
<td>15.0</td>
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<tr>
<td>LB Pull Completion - Normalised to 2000m length</td>
<td>17.9</td>
<td>30.0</td>
<td>40.0</td>
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<td>LB R/H, latch and retrieve packer</td>
<td>24.0</td>
<td>30.0</td>
<td>40.0</td>
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<tr>
<td>Prepare Cased Hole</td>
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<tr>
<td>LB cut out 9 5/8&quot; casing</td>
<td>12.0</td>
<td>15.0</td>
<td>22.5</td>
<td></td>
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<tr>
<td>LB Cut &amp; Pull 13 3/8&quot; casing</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>LB R/H CBL and Log Annular cement</td>
<td>4.0</td>
<td>6.0</td>
<td>9.0</td>
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<tr>
<td>Isolate Cased Hole</td>
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<tr>
<td>LB R/H Bridge Plug, set, string out, spot cement on top and</td>
<td>14.4</td>
<td>18.0</td>
<td>27.0</td>
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<tr>
<td>LB R/H and set Bridge Plug/Squeeze Packer</td>
<td>6.0</td>
<td>7.5</td>
<td>11.0</td>
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<tr>
<td>LB Perforate Casing and Circulate annulus clean</td>
<td>6.0</td>
<td>8.0</td>
<td>12.0</td>
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<tr>
<td>LB Mix and squeeze/circulate annulus cement plug</td>
<td>4.0</td>
<td>6.0</td>
<td>9.0</td>
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<tr>
<td>LB WOC and verify</td>
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<td>8.0</td>
<td>12.0</td>
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<tr>
<td>LB R/H, spot cement plug and verify</td>
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<tr>
<td>Intermediate Isolation</td>
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<tr>
<td>LB cut and pull 9 5/8&quot; casing</td>
<td>12.0</td>
<td>15.0</td>
<td>22.5</td>
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<tr>
<td>LB R/H Squeeze packer and set</td>
<td>6.0</td>
<td>7.5</td>
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<tr>
<td>LB Perforate Casing and Circulate annulus clean</td>
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<td>6.0</td>
<td>8.0</td>
<td>12.0</td>
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<tr>
<td>LB circulate, balanced cement plug via tubing and verify</td>
<td>8.0</td>
<td>10.0</td>
<td>15.0</td>
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<tr>
<td>LB Cut &amp; Pull 9 5/8&quot; casing</td>
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<td></td>
<td></td>
</tr>
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<td>LB Cut &amp; Pull 13 3/8&quot; casing</td>
<td>12.0</td>
<td>15.0</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>LB R/H Bridge Plug, set, string out, spot cement on top and</td>
<td>14.4</td>
<td>18.0</td>
<td>27.0</td>
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</tr>
<tr>
<td>Surface Isolation and Conductor</td>
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<tr>
<td>LB Cut 9 5/8&quot; casing and R/O BOP</td>
<td>5.0</td>
<td>10.0</td>
<td>15.0</td>
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<tr>
<td>LB Skid back Cantilever</td>
<td>4.0</td>
<td>6.0</td>
<td>8.0</td>
<td></td>
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<tr>
<td>LB Cut Casing &amp; Conductor</td>
<td>4.0</td>
<td>5.0</td>
<td>8.0</td>
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<tr>
<td>LB Recover conductor (H/Linds &amp; Wonnich only)</td>
<td>6.0</td>
<td>8.0</td>
<td>16.0</td>
<td></td>
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<tr>
<td>LB Confirm Conductor Severance with Vessel Crane</td>
<td>9.0</td>
<td>12.0</td>
<td>24.0</td>
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<tr>
<td>MOB-DEMOB</td>
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<td></td>
<td></td>
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<tr>
<td>LB Jack Down and move off location</td>
<td>4.0</td>
<td>5.0</td>
<td>8.0</td>
<td></td>
</tr>
</tbody>
</table>

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**Diagram:**

[Diagram showing a triangular distribution with axes labeled X, Y, and Z, and the area shaded in blue to represent data. The labels 10% to 60% are marked at different sections.]
Option 1:
Mob Liftboat first, finish wells with the Rig

Option 2:
Mob Rig first, finish remaining wells (and remove facilities?) with the Liftboat
• Source of Sustained Annulus Pressures
  – Potential impact: Reservoir isolation via section milling
• Unknown Quality and Extent of Annular Cement
  – Failed Cement Barriers, delays Pulling Casing
• Section Milling in High Angle Hole
  – Delays
• Surface Isolation Valve Functionality
  – Circulation Failures
• Casing Leaks
  – Failed Barriers, Compromised Circulation Paths
• Pressure and/or Undetonated Guns below Shallow Cement Plugs
  – Alternative Intermediate Abandonment
ADDITIONAL STRATEGIC RISKS & OPPORTUNITIES

- Regulator Agreement
- Unit Cost Inflation (Rates are Low, but for how long?)
- Alternative (Local) Liftboat
- New & Emerging Technologies/Methods
  - Logging thru’ tubing
  - Reduced cement plug length
  - Alternatives to conventional section milling
  - Alternative barrier materials
  - Removing the need to pull tubing
- Synergies with Facilities Decommissioning
- Suspended Well Risk Assessment
• Single Mobilisation of Each Asset *
• Liftboat and Rig mobilised to/from Singapore*  
  — * Exception: US$ 25k/day amortization for rig opportunity case (based on previous QE experience)
• Significant Inclusions  
  — Safety Case  
  — Liftboat Cantilever Mods  
  — Supply Base and Dedicated Supply Boats & Helicopters  
  — WOW and Cyclone Provision
• Offset Operations Durations & Recent Unit Costs used where Possible
Conservative Case P50: 389 rig days plus 184 liftboat days
Opportunity Case P50: 137 rig days plus 284 liftboat days – 27% cost reduction
Quantification of Risk Impact Required

- Example: Additional Surface Plug (~USD17.4M Impact)
RECOMMENDED ACTIONS & CONCLUSIONS

- Early & Sustained Dialogue with Regulator
- Follow up Risk Register Actions to Reduce Unknowns
- Finalise Most Likely Case
- Liftboat cost savings are limited until rig rate escalates or local liftboat option is feasible
- Investigate Local Liftboat Options & Contractor Model
- Confirm Facilities Strategy before Committing to P&A Strategy
- Significant further cost reduction opportunities through
  - Understanding source of annular pressures
  - Understanding condition of tubulars
  - Alternatives to section milling
  - Challenging multizone isolation, surface plugs etc.
- Declaring suspended wells as abandoned requires further study