Shell U.K. Limited

Relinquishment Report

for

Licence P.2058

(Block 29/7b)
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1. Licence Information

Licence Number: P.2058

License Round: 27th Licencing Round, 2013 award

Licence Type: Traditional

Block Numbers: 29/7b

Equity Holding: Shell U.K. Limited (50%, operator)

Esso Exploration and Production UK Limited (50%)

2. Licence Synopsis

The P.2058 licence, comprising block 29/7b, is located offshore, approximately 210 km ESE of Aberdeen, in the UK sector of the Central North Sea Central Graben (Figure 1). The licence was awarded during the 27th Offshore Oil and Gas Licencing Round to Shell U.K Limited (100%) with a start date of 1 January 2013. Subsequently in March 2013, in keeping with a 50 year old partnership in the North Sea, Esso Exploration and Production UK Limited obtained after the award a 50% interest with Shell U.K. Limited retaining 50% and remaining as operator. The initial licence term expires on 31 December 2016.

Figure 1. Location of Licence P.2058. Block 29/7b is highlighted in yellow.
The licence application was premised on unlocking the stranded Tertiary Curlew-A oil accumulation discovered by well 29/7-1 (Shell, 1979), by drilling a down-dip appraisal well. The objective of the appraisal campaign was to penetrate the Odin and the Cromarty sandstones to prove up a longer hydrocarbon column and thicker reservoir development.

Appraisal of the Curlew-A accumulation was part of a wider strategy to unlock stranded discoveries to deliver new hydrocarbons with cost-efficient subsea production concepts to increase local export capacity via the proposed Fram FPSO development. The Curlew-A application was aligned with the application for the nearby Acorn and Beechnut East undeveloped discoveries 10km to the east in Blocks 29/8b and 29/9a, and had further potential synergies with the Puffin discovery 30km to the east.

![Figure 2. Palaeogene lithostratigraphic column.](image)

The Block had been relinquished in 2007, following the Curlew-A discovery, due to insufficient volumes for a commercially-viable development: the primary Jurassic target was proven water-
bearing and the discovery in the secondary Tertiary target was evaluated to have a too high a chance of being under-filled. The new insights that backed up the 2012 application came from a re-evaluation of the subsurface data, following on from learnings from appraisal wells on the Stella and Fram Fields. The lead was expected to be configured of laterally extensive Odin and Cromarty overlapping toe-of-slope or basin-floor sandstones (Figure 2), in a simple 4-way salt-cored dip closure without significant fault-related compartmentalisation, sealed by the Horda Claystone with a fill-to-spill oil column charged from the Kimmeridge Clay. The trap and reservoir were deemed sufficiently large to supply the 9MMbboe minimum economic volume for tie-back to Fram.

3. Work Program Summary

The firm commitment work programme for the initial licence term comprised drilling a well on the Curlew-A prospect to a depth of 2640m or to the Top Chalk, whichever is the shallower, to evaluate the Tertiary (Cromarty).

The commitment appraisal well was secured on the 2013 drill sequence for the Ocean Guardian rig, under contract to Shell, with a planned spud date in November 2013. Immediately post-award, in early 2013, full evaluation activities were underway to plan and to deliver safely the well operations. The subsurface evaluation was finalised in March 2013; detailed well design, well-picking, logging programme creation and the site survey execution were all completed by May 2013.

The first Fram development wells were drilled whilst the Curlew-A appraisal well planning work progressed in early 2013. The significance of the results of the re-evaluation of the subsurface architecture in the Fram reservoir and the aquifer led directly to an immediate consideration of application to the Curlew-A structural and depositional models. The direct learnings from Fram were that the thin Tertiary reservoirs were more complex than originally evaluated with poor cross-fault fluid communication with consequently variable fluid contacts. Fluid contacts in structures in similar geological settings are likely difficult to predict. All Curlew-A well planning preparation work was paused in August 2013 to allow time to re-evaluate the Tertiary target reservoir and to deliver a recommended course of action.

A total of 410 km2 of newly acquired 3D broadband seismic data were licensed from CGG in 2014 (Quad 30, Phase 8 extension), over and above the commitment work programme, to ensure that the most modern data were used for the re-evaluation.
4. Database

The seismic and well data available for the resource assessment of licence P.2058 is summarised in Figure 3 and presented in Table 1 and Table 2.

![Map of seismic and well database.](image)

<table>
<thead>
<tr>
<th>3D Seismic Survey</th>
<th>Type</th>
<th>Year acquired</th>
<th>Processing</th>
<th>Area covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quad 30 Phase 4</td>
<td>Conventional 3D</td>
<td>2004</td>
<td>2011 HPHT PSDM</td>
<td>Entire Curlew field cluster, Curlew-A and majority of block 29/7b</td>
</tr>
<tr>
<td>Cornerstone 3D Tomo ML</td>
<td>Conventional 3D</td>
<td>2004</td>
<td>2015 CGG PSDM</td>
<td></td>
</tr>
<tr>
<td>Cornerstone 3D Quad 30 Phase 8 Extension</td>
<td>Broadband 3D</td>
<td>2014</td>
<td>2015 CGG PSTM</td>
<td>Entire Curlew field cluster, Curlew-A and majority of block 29/7b</td>
</tr>
<tr>
<td>Cornerstone 3D Quad 30 Phase 8 Extension</td>
<td>Broadband 3D</td>
<td>2014</td>
<td>2015 CGG PSDM</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Summary of 3D seismic data within the licence.

The newly obtained Cornerstone 3D Tomo ML data was available and interpreted over its extent within the licence area. The later Cornerstone 3D Quad 30 Phase 8 Extension data which became available during the feasibility study was used in the re-evaluation phase. Well calibration within the licence is provided by two exploration wells drilled by Shell (Table 2).

<table>
<thead>
<tr>
<th>Well</th>
<th>Operator</th>
<th>Year</th>
<th>Status</th>
<th>Well Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>29/7-1</td>
<td>Shell</td>
<td>1979</td>
<td>Abandoned, Curlew-A oil discovery</td>
<td>3 tests, Cromarty Reservoir, recovered 36°API oil</td>
</tr>
<tr>
<td>29/7-3</td>
<td>Shell</td>
<td>1987</td>
<td>Abandoned, oil shows, Hugin Fm</td>
<td>None.</td>
</tr>
</tbody>
</table>

Table 2. Summary of well data within the licence.
5. Prospectivity Update

The prospectivity presented in the licence application was focussed on the Curlew-A stranded discovery (Figure 4). Two further leads in the Mesozoic were cited as additional prospectivity: a Chalk lead with a mean STOIIP of 81MMbbls and a Fulmar lead with a mean STOIIP of 14MMbbls.

![Figure 4. N-S seismic section through the Curlew-A discovery.](image)

It was noted in the application that the primary objective of the Licence P.2058 exploration programme was to reduce Curlew-A volume uncertainty, mitigate against the low volume scenario, by confirming reservoir presence, thickness and proving-up the longer column scenario.

The technical focus areas that would have the greatest influence on pre-drill uncertainty reduction were selected for the re-evaluation of Curlew-A that was initiated in August 2013. The focus areas were fault analysis for assessment of compartmentalisation and impact on oil recovery efficiency; review of reservoir depositional models based on regional assessment of Tertiary penetrations; thorough analysis of the seismic data for reservoir prediction; fluid contacts evaluation and a review of the development options. The volumes of the remaining two leads, one in the Chalk and one in the Fulmar sandstone were also re-assessed during the evaluation.
Fault analysis

To ascertain the density of the small- to mid-scale fault network at Curlew-A, the Petrel\textsuperscript{TM} Ant-Tracking\textsuperscript{TM} algorithm and work-flow were applied to the top reservoir seismic event over the extent of the reservoir and aquifer. The algorithm works to identify discontinuities in the pre-conditioned seismic volume, using amplitude contrasts and edge evidence. The result indicates a dense network of structural lineaments that are interpreted to be faults with sufficient throw to offset the thin reservoir units and create baffles to fluid flow within the reservoir and the aquifer (Figure 5). Interpretation of the well results from the analogue Fram discovery indicates fluid compartmentalisation in a similar setting.

The maps shown in Figure 5 demonstrate the intensity of the deformation patterns over the structure. The expectation from these analyses is that the Curlew-A reservoir and aquifer are highly compartmentalised in line with the conclusions from the analogue discovery; the reservoirs are likely to contain variable contacts due to the lack of direct reservoir-to-reservoir juxtaposition of the thin reservoir units. There will be lower recoverable volumes per development well, a need for more development wells to produce the oil, resulting in a higher Capex and higher minimum volume requirement for a commercial development.

![Figure 5](image-url)
Reservoir depositional models

The prediction of reservoir away from the Curlew-A discovery well (29/7-1) was the largest uncertainty at the time of the application. The well itself found gross thicknesses of 17ft of Odin and 25ft of Cromarty sandstone reservoir intervals. The favoured depositional model for the Cromarty Sandstone was of a turbidite lobe system, derived from a provenance to the West, covering the majority of the structural closure. The Top Sele to Top Chalk isochron was observed to be of uniform thickness across the structure and so the Odin Sandstone thickness was also believed to be uniform.

The bulk isochron of the Top Sele to Top Chalk interval, derived from the 2013 remapping exercise, shows the variability in thickness of the unit (Figure 6). A review of all nearby Tertiary penetrations
in the nearby wells was undertaken for the 2013-2014 re-assessment (Figure 7). The interpretation indicates that the Cromarty sand occurrences are separated by zones of no sand presence, and that Curlew-A is located at the eastern termination of the sand system (Figure 8). The conclusions drawn from observations from the wells and seismic data are that the Cromarty Sands are only of a limited extent in the area, and composed of thin sand pulses separated by shale units (Figure 9), deposited as narrow, ribbon sands of uncertain width and variable thickness. The Odin Sands are only present at the Curlew-A well itself.
Figure 7. Correlation panel of key wells in Figure 8. The Cromarty Sand occurrences are highlighted with the red dashed line.
Figure 8. Map of Tertiary sand occurrences in the Curlew-A area (refer to Figure 7 for the correlation panel).

Figure 9. Observations of Cromarty Sand thickness from offset wells.
Reservoir prediction from seismic data

Shell’s in-house processing products from the CGG 2014 3D broadband seismic acquisition were available for interpretation in March 2015. Shell’s proprietary Spectral Decomposition methodology was used to evaluate the Tertiary interval for regional reservoir interpretation and reservoir prediction at Curlew-A. The result indicates that reservoir sands remain seismically unresolvable at Curlew-A itself but the proven water-wet channel feature that cuts through the Acorn-Beechnut area is visible. Curlew-A is depositionally up-dip from that feature, so it is unlikely that the Cromarty Sand over Curlew-A was deposited as a turbidite lobe, and more likely that it is the feeder channel system for delivering sands to the east (Figure 10). The outcome of the interpretation is that the reservoir sand thickness is not uniform across the Curlew-A trap, and restricted to discrete channels.

![Figure 10](image)

(a) (b)
Figure 10. Image from the Spectral Decomposition analysis. (a) without interpretation, and (b) with interpretation. The numbers in yellow ovals refer to the wells in Figure 7.

Fluid contacts

A petrophysical review of the Curlew-A discovery well, 29/7-1, was carried out in 2013. Data from oil saturations in nearby discoveries were used to determine a saturation-height function to assess the most likely free water level in Curlew-A. The very best match to the calculated oil saturations in the stratigraphic interval from the Balder Fm to Sele Fm was achieved with a free water level at 8248ft.tvdss (Figure 11), but an irreducible uncertainty range of 8170-8250ft.tvdss was carried forward as it was an analogue-based approach. The successful pressure measurements in the well were recorded in the oil leg and also are too close in depth to determine a meaningful local aquifer gradient to narrow the prediction. The key depths derived from the petrophysical analysis were:

- 8100ft.tvdss: ODT in 29/7-1 discovery well.
- 8210ft.tvdss: Mid-point of the assessed 8170-8250ft free water depth range.
- 8474ft.tvdss: Curlew-A structural spill-point taken from the Top Cromarty depth map.
An exercise to identify fluid contacts from quantitative interpretation of the reflectivity character of the near-offset and far-offset data cubes from the 2014 3D broadband seismic was undertaken to independently research the oil water contact depth. The Sele reflectivity character is enhanced, from the images from the 2011 data, with lower frequency contributions. The expectation from modelling of the offset well logs was that thin Cromarty Sands are acoustically hard relative to the Tertiary shales, and reflectivity should dim with hydrocarbon fill. However, the sand bodies are below seismic resolution. The observations from the analysis were (a) that there is a dimming at and above the picked seismic event at Top Sele Fm that is conformable with the east-west fault trend but not conformable with the 4-way structural closure, (b) there is a brightening below the Top Sele Fm pick, and it does show a possible direct-hydrocarbon indicator that is intersected on the eastern edge by well 29/7-1, in the range of the expected free water level, and (c) the AVO responses are weak but visible (Figure 12). Although conclusions should be drawn with caution, this analysis does provide support for only a small hydrocarbon column in an under-filled trap due to either insufficient areal distribution of viable reservoir or due to compartmentalised fluid distribution in a structurally complex reservoir.
Further prospectivity

The current view of the P.2058 licensed area is that it contains the Curlew-A Tertiary oil discovery and only one further viable Mesozoic lead. The Chalk lead is not a viable lead with an assessed risked recoverable volume of only 0.07MMbbls (mean STOIIP 30MMbbls, UR 3.75MMbbls, chance of success of 2%).

The Fulmar lead, Curlew-N, is a poorly-definable structural/stratigraphic trap combination reliant on fault seal and lateral pinch-out. The unrisked volumes in the current evaluation are consistent with those at the time of application (mean STOIIP 14MMbbls), but the lead is deemed non-viable as the chance of success is only 9%.

6. Further Technical Work Undertaken

Development options

The development concept at the time of application was to tie into the predicted Acorn-Beechnut development plans for export via the Fram proposed FPSO. The Curlew-A oil volumes are now
evaluated to be only a fraction of the pre-application minimum economic volume, and as such a commercial development is not possible. The ability to define a commercial development concept is hampered by the very low expected ultimate oil recovery per well in the highly compartmentalised Cromarty interval, and by the down-grade of the neighbouring Acorn-Beechnut volumes (Licence P.2038, Blocks 29/8b and 29/9a).

7. Resource and Risk Summary

A summary of the volumes and risks evaluated for the leads within the Licence P.2058, Block 29/7b is shown in Table 3.

<table>
<thead>
<tr>
<th>Prospect/Lead name</th>
<th>P</th>
<th>L</th>
<th>D</th>
<th>Stratigraphic level</th>
<th>Unrisked recoverable resources</th>
<th>Geological chance of success %</th>
<th>Risked Mean MMboe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oil MMbbls</td>
<td>Gas bcf</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
</tr>
<tr>
<td>Curlew-A</td>
<td>L</td>
<td>Tertiary</td>
<td>0.30</td>
<td>1.07</td>
<td>3.26</td>
<td>0.37</td>
<td>1.79</td>
</tr>
<tr>
<td>Curlew-M</td>
<td>L</td>
<td>Jurassic</td>
<td>0.31</td>
<td>1.74</td>
<td>4.68</td>
<td>0.21</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Table 3. Summary of recoverable resources within the licence. P = prospect, L = lead, D = discovery.

8. Conclusions

This report details the relinquishment of the P.2058 licence following the completion of feasibility assessments based on newly purchased 3D seismic datasets and integrated technical studies. The technical work described in this document led to a down-grade of the hydrocarbon volumes, and an increase in risk of finding extensive reservoir within the Curlew-A structure. A summary of the outcome of the evaluation is shown in Table 4.

<table>
<thead>
<tr>
<th>Element</th>
<th>PRE-APPLICATION EVALUATION</th>
<th>CURRENT EVALUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Seal</td>
<td>Horda</td>
<td>Horda</td>
</tr>
<tr>
<td>Trap</td>
<td>Simple salt-cored antiform, lightly faulted.</td>
<td>Salt-cored antiform, with pervasive faults, compartmentalised reservoir.</td>
</tr>
<tr>
<td>Reservoir</td>
<td>Odin and Cromarty in basin-floor or toe-of-slope setting, draping entire structure.</td>
<td>No Odin. Thin-bedded Cromarty, deposited in restricted channel setting.</td>
</tr>
<tr>
<td>Oil column</td>
<td>580ft mean (fill-to-spill)</td>
<td>430ft mean (under-filled)</td>
</tr>
<tr>
<td>Recovery factor</td>
<td>25% mean</td>
<td>11% mean, compartmentalised reservoir and aquifer.</td>
</tr>
</tbody>
</table>

Table 4. Subsurface evaluation summary.
The licence will be relinquished due to the lack of sufficient volumes in Curlew-A to warrant further exploration activity, and a lack of alternative viable prospectivity. Further drilling on the licence will only erode value, and is not considered to be in the interests of the stakeholders.

9. Clearance

Shell U.K. Limited confirms that the Department for Business, Energy and Industrial Strategy is free to publish the contents of this report.