Pipeline Inspection by Low Logistics Autonomous Underwater Vehicle with Particular Emphasis on High Resolution Geophysical Data and Access in Very Shallow Water

Bryan M. Keller
Travis Hamilton
Paul Olsgaard
Simon Hird
UTEC Survey

Diranne Lee-Renwick
Quadrant Energy Australia Limited
Introduction

- UTEC operates the largest fleet of low logistics AUV in the world with over 40 projects completed on six continents.
- Today we will focus on a subsea inspection project carried out in Australia in July 2014.
- UTEC’s client was Quadrant Energy.
- 43 pipelines of total length 571km.
- 20 platform site surveys.
- Carried out using two Teledyne-Gavia AUVs.
- Deployed from support vessel MV Yardie Creek.
Scope of Work

• All Varanus Island hub subsea facilities and platforms.
• Stag and Reindeer fields.
• Sales Gas pipeline to the mainland.
• 43 pipelines, 20 platform and structures.
Teledyne-Gavia AUV

- UTEC owns and operates a fleet of seven Gavia AUVs.
- Operating depth range from <2m to 1,000m.
- Small footprint - < 3m long; < 120kg with compact spread layout
- Low logistics – Modular and easy to ship via air freight, mission configurable, small on-deck footprint, lightweight for launch and recovery.
Project AUV Configuration

- Twin battery pack configuration for long duration mission capability
- Camera & Obstacle Avoidance Sonar
- INS/DVL navigation
- LBL/USBL Acoustic Comms
- DGPS navigation
- 1800kHz & 900kHz high resolution SSS
- Propulsion Module
- Interferometric multi-beam bathymetry
- SBP Module Not Shown
- Twin battery pack configuration for long duration mission capability
Support Vessel – MV Yardie Creek

- 34m LOA Multi-Purpose Vessel.
- 2.2m draft.
- Large back deck.
- 6 tonne A-frame.
- Hiab deck crane.
- 21 berths.
- Large survey room.
- 5.8m rigid-hulled inflatable boat.
Launch and Recovery

• Stern launched using winch and A-frame in deeper water.

• Manually deployed from the RHIB in shallow water.

• Used RHIB as standard recovery method – manual lift into custom chocks in the RHIB, then AUV lifted by vessel crane to deck.

• In marginal weather RHIB would tow AUV to stern and place it in purpose-built lifting cradle for A-frame recovery – four occasions.
Field Operations

- Our AUV capability is global with Centres of Excellence in Houston and Aberdeen – completed 40 projects on six continents.
- We have encountered challenges and learned from these.
- Our first AUV job in Australia – drew on that expertise and applied the global learning.
- The people were the catalyst for the success of the project.
- Nine man team drawn from global UTEC AUV pool:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x Party Chief</td>
<td>1 x Data Processor</td>
</tr>
<tr>
<td>3 x AUV Operators</td>
<td>1 x Geophysicist</td>
</tr>
<tr>
<td>1 x AUV Engineer</td>
<td>2 x Online Surveyors</td>
</tr>
</tbody>
</table>
Health, Safety and Environment

- Total Operational Man Hours = 3,408.
- No injuries to any marine, AUV or survey personnel.
- No Environmental Incidents.
- No Asset Damage.
- No Near Misses during operations.
- Risk Assessments / Job Safety Analyses completed and reviewed daily.
- Safety Briefings / Drills = 53.
- Tool Box Talks = 45.
Productivity

• 27 day project averaging 45km of AUV line survey per day.

• Average includes non-productive time - weather, transits, calibrations and equipment downtime.

• Set a new UTEC record on July 11th with 80.5 line km of survey.

• Surveyed a total of 1,142 line km on pipelines plus 20 platform and structure site surveys.
Key to Productivity

- UTEC used two AUVs ‘back-to-back’ for the first time.
- While one AUV was deployed the other was readied for its mission.
- Each mission duration was between 5 and 6 hours.
- Reduced the on-deck turnaround time from >2 hours for single vehicle ops to <1 hour, which included data download, battery change-out, INS re-alignment.
- The increase in productivity more than offset additional costs.
- Productivity approached that of larger, more expensive AUVs which offer longer mission time due to battery capacity.
Platform Site Surveys:

• Greatest risk in AUV missions – surfacing under a platform, colliding with platform legs or subsea structures.
• Ran reconnaissance missions at higher altitudes and offsets prior to primary mission to identify hazards.
• Gained understanding of speed and direction of currents.
• Turned down sensitivity of object avoidance sonar to reduce number of aborted missions due to extensive marine life (fish) under platforms.
Challenges Faced (2)

Shallow Water – Near Shore:

- Several pipelines terminated at Varanus Island or mainland.
- Scope called for surveying as near to shore as possible.
- RHIB enabled us to get very close to shore while vessel stayed in deeper water.
- Missions planned to coincide with peaks of high tide.
- Ran AUV on surface at ½ speed.
- Successfully collected high quality data in water depths of 2m and in a couple of cases in less than 1m.
Challenges Faced (3)

**Shallow Water – vertical accuracy:**

- AUV is a submerged survey platform - acoustic depths must be combined with AUV depth to resolve final sounding depth.

- Waves and swells introduce pressure fluctuations = modulate pressure sensor output without any vertical movement of AUV = vertical offsets in seabed profile; looks like the AUV is ‘porpoising’.

- In shallow water even small waves cause significant artifacts in seabed profiles.

- The Z (vertical) coordinate from the INS is recorded in the raw sonar file and we use that to correct these artifacts.
Data Processing Workflow

- Data processors, geophysicists and charting specialists create comprehensive data sets for reporting and charting.
- Four stage iterative process:
  - Process Bathymetry Data
  - Navigation processing to remove INS drift and surface swell artifacts
  - Re-process Bathymetry Data. Process Side-scan Sonar data
  - Perform Geophysical Interpretation
Ocean Imaging Consultants
‘CleanSweep’ software:

- Corrections for any positional drift from Inertial Navigation System.
- Filters for Navigation and Attitude.
- Filters for cleaning any ‘outlier’ soundings.
- Algorithms for applying tides, including interpolated tides between multiple stations.
- Angle Varying Gain corrections for the backscatter.

Example of AUV GeoSwath bathymetry data depicting Spud Can Depressions
Removing INS Drift

- A small linear drift over time or distance traveled is expected from the Inertial Navigation System.
- We use InterNav (part of CleanSweep) to correct.
- This matches adjacent swathes and applies a weighting to positions near the start of a mission in preference to those near the end.
- By overlapping start and end of consecutive missions we constrain the uncertainty.
- Horizontal uncertainty was constrained to less than 2m over the project.
Removing Swell / Wave Artifacts

- Caused by pressure fluctuations from surface swells and waves.
- Makes it look as if the AUV is ‘porpoising’ when it is in fact stable.
- A secondary record of the INS ‘Z’ (vertical) co-ordinate is captured in the raw GeoSwath files.
- Apply a smoothing filter to the pressure sensor depth gives a long period trend of AUV depth.
- Applying a high-pass filter to the INS ‘Z’ coordinate leaves a zero mean high frequency record of vertical movement.
- Combining the two processed records provides an accurate AUV depth record free of swell and wave artifacts.
Swell / Wave Artifacts Removed

Digital Elevation Model with pressure sensor depth only, revealing the artifacts of 40cm wave heights and 30m wave lengths.

Combined depths with artifacts filtered and removed
Processing Side-Scan Sonar Data

- MST SSS operates at 900kHz - an appreciable increase in resolution over GeoSwath SSS.
- GeoSwath navigation is more accurate.
- By using CleanSweep’s import/export tools we applied the GeoSwath navigation and altitude data to improve the MST data.
- High resolution MST SSS mosaics were used for areas requiring a high level of detail.
Processing Side-scan Sonar Data

GeoSwath SSS (Left) vs MST SSS (Right)
Geophysical Interpretation

- Fully processed GeoSwath and MST SSS data exported in XTF format to Chesapeake Technology ‘SonarWiz’ software.
- SonarWiz used to identify freespans, pipeline burial and other contacts.
- SonarWiz includes tools for identifying, measuring and cataloguing events into a database for export to spreadsheets. This includes a freespan tool specially built for UTEC for this project.
- The freespan tool combines point contact attributes with a linear feature allowing the feature to be catalogued with height of freespan.
- Databases then exported to Excel and used for event listing and Pipeline Alignment Charts.
Data Presentation

- Field reports identified areas of concern while still in the field.
- Interim reports identified critical freespans and cross-checked these against prior year surveys.
- Fully processed data exported to Geographical Information System (GIS) for final QC checks.
- Having all items in a single GIS allows consistency checks prior to charting.
- Each event target is checked against the digital elevation model and the mosaics to ensure correct identification and position.
- Final report provided Pipeline Alignment Charts (plan view and pipeline events) and full Pipeline Events Listings (freespans, debris, sections of burial etc.)
Pipeline Charts
Platform Charts
Geographic Information System - GIS
2 SUMMARY OF RESULTS

The features created and mapped, for the 2014 survey, for each asset are quantified in the summary table below. Specifically, each pipeline asset was surveyed for their features (with RAMS digitized), specific engineering features, defined which lies in proximity to the pipeline and condition of the seabed that may interfere with pipeline structure. Each platform asset had their surrounding seabed mapped for debris and remedial engineering features. Further details of each asset are in section 13.

2.1 Pipeline Assets

The table below shows a quantified breakdown of events for each pipeline as per survey objectives:

<table>
<thead>
<tr>
<th>Asset</th>
<th>Asset Code</th>
<th>Pipeline</th>
<th>Survey Length</th>
<th>Number of Events</th>
<th>Number of DEBRIS</th>
<th>Number of KM</th>
<th>Mean Event</th>
<th>Number of KM</th>
<th>Event Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Main</td>
<td>2.779</td>
<td>32.000</td>
<td>61</td>
<td>2</td>
<td>2</td>
<td>13.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 39 RE Preeospan/Puto Xping No. 66S (KP49.246 to KP49.370)

The table below shows Debris Items mapped along and in close proximity to the Receival 10" ("Debris Gas pipeline (RG).

<table>
<thead>
<tr>
<th>Event No</th>
<th>Item</th>
<th>Event Code</th>
<th>Event</th>
<th>Event Code</th>
<th>Event</th>
<th>Event Code</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>2</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>3</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
</tbody>
</table>

Figure 100 JB Platform Debris Overview

The table below shows Debris Items mapped in close proximity to the John Brookes (JB) Platform.

<table>
<thead>
<tr>
<th>Event No</th>
<th>Item</th>
<th>Event Code</th>
<th>Event</th>
<th>Event Code</th>
<th>Event</th>
<th>Event Code</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>2</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>3</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
</tbody>
</table>

Table 49 JB Platform Debris List

<table>
<thead>
<tr>
<th>Item No</th>
<th>Item</th>
<th>Event Code</th>
<th>Event</th>
<th>Event Code</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>2</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
<tr>
<td>3</td>
<td>Debris Item</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
<td>628463.23</td>
</tr>
</tbody>
</table>
Meeting Quadrant’s Expectations

- Project met Quadrant’s expectation as set out in the Scope of Work.
- AUV operations in very shallow water meant that 92% of all pipeline kms were surveyed.
- Total of 571km of pipe surveyed with one-pass each side i.e. 1,142 km of AUV track-line.
- Twenty platforms and subsea structures surveyed, which was 100% of subsea assets specified in Scope of Work.
- Total duration was 27 days in mid-winter including mob, demob and transits.
- Less than 2% operational downtime and only 18% weather downtime impacting launch and recovery.
- On a per kilometre basis AUV surveys are calculated to be less than 50% of the cost of an ROV survey.
- AUV surveys substantially contribute to subsea integrity management strategies.
Questions?