Introduction

The Partitioned Zone (PZ) is located on the Arabian Peninsula between the State of Kuwait and The Kingdom of Saudi Arabia. In 2014-16 Wafra Joint Operation (WJO), a joint operations venture between Saudi Arabian Chevron (SAC) of the Kingdom of Saudi Arabia and Kuwait Gulf Oil Company (KGOC) of the State of Kuwait completed acquiring one of the largest onshore single sensor 3D seismic data using the UniQ seismic data acquisition system. The PZ area of operation covers approximately 4612km² (5,346 km² including the 2 zippers) (Figure 1).

Figure 1: Partitioned Zone (PZ) Location Map  Figure 2: Data acquisition operational path

The entire Partitioned Zone was divided into two blocks, namely PZ 3D East Which was an exploration area, while PZ 3D West was a development area based on the presence of proven oil field and density of wells. For data acquisition, this had an impact on the number of source points per square kilometer, and therefore the equipment roll ratio per source point. Further for seismic data acquisition purpose, the area had to be split into three blocks, namely Block 1, Block 2 and Block 3 with nominal width of 30.6 km. The blocks had 6 km combined source and receiver overlap (zipper) to maintain the fold when joining the data sets together at the processing stage, as illustrated in Figure 2.

The two-year survey started in the southwestern area of the PZ moving northward in Block 1, then crossing over to Block 2 north, moving to the south, then crossing into Block 3 south, and finally moving to the north to complete the survey. The sequence of the operation was adopted to minimize the potential complications that might be encountered when crossing multiple environments. To complete the survey more than 1.49 million vibrator source points and over 18 thousand explosive shot hole source points were collected.

Within the PZ there are many infrastructures/oil facilities such as: multiple oil fields, pipelines, refineries, residential cities, tourist resorts, nature reserves, and a power plant, where an easy access is not always possible, beside dynamic nature of the environment (movement of sand dunes/high wind) always increases the safety risks on higher side. Despite numerous previous UXO/ERW clearance projects there still remains a likelihood of encountering landmines and UXO/ERW within PZ area, which are often exposed due to wind-shifted sands.

To mitigate safety risks from UXO/ERW a two-phase method was designed. In the first phase, an initial assessment was conducted in the form of a desk-top study followed by a field study. In the second phase, two main activities were undertaken, namely Battle Field Clearance over the prospect, and Mine Field Verification.

Procedure

Phase-I : This was conducted in the form of a desktop study with information gathered from archived material and other sources with the objective to gather as much material prior to any field study being conducted. The desktop study involved a brief investigation into the history of the area of the PZ and
its surroundings, accessing archived material from public domain and from military sources, evidence of the level and nature of explosive ordnance contamination, weapon characteristics etc.

Followed the desk-stop study, a 14 days vehicle mounted visual field survey/reconnaissance (Figure 4) of the entire PZ was conducted (Figure 3).

**Figure 3: Reconnaissance GPS tracks**  
**Figure 4: Identified Risk Areas**

- The Phase-I study identified that the main risk to seismic survey operations and its supporting personnel within the PZ would come from:
- Vehicles driving over surface UXO/ERW in a dangerous condition.
- Vehicles driving over anti-tank and anti-personnel mines.
- Personnel standing on anti-personnel mines.
- Vibrators impacting the ground on top of unexploded munitions.
- Personnel playing with and removing the items of UXO/ERW as souvenirs.
- Personnel picking up suspicious looking objects.

Phase-II: Because of complexity of the task and operational requirement this phase was divided into two sub-units.

**Battle Field Clearance (BFC)**

A 100% visual search (Figure 5) was carried out over the source, receiver and Power Insertion Unit (PIU) lines with occasional subsurface searches utilizing the Large Loop Metal Detector (Ebinger 740M LLMD) (Figure 6), when any sub-munitions were located. Source lines were cleared to a 20m width, receiver lines were cleared to a 10m width and PIU lines were cleared to a 6m width with the cleared corridors marked with illuminating material to support day-night operation.

**Figure 5: Visual search by crew**  
**Figure 6: Sub-surface search by Metal Detector**

Whilst using visual search techniques, whenever an item of ordnance was discovered, depending on the type of the UXO, a subsurface search was carried out particularly if there was a threat of more subsurface munitions being found i.e. sub-munitions or cluster bombs. The number of personnel per line was dependent on visual obstructions and terrain. Areas that had increased ground vegetation required additional personnel. It was normal practice that each spotter had 2-3m spacing between them.
so an adequate overlap was achieved, again this was increased or decreased due to terrain. When vision was obscured (i.e. during a sandstorm) visual verification was ceased until visibility was sufficient to continue. Once a suspect item was found, it was inspected, marked, recorded and reported for disposal by Kuwait Ministry of Defense (KMOD) teams. Upon finding a submunition, the team searched at a minimum 100m either side of the last found UXO on both the source and receiver lines that were affected.

Mine Field Verification (MFV)

The minefield areas are located in the northern side of PZ (Figure 7) and main purpose of this task was to ensure that all define lines through the former mine areas were verified as free of mines prior to personnel and equipment entering these areas, ensuring a safe working environment.

Figure 7: Potential mine field areas of PZ

Figure 8: Armored Vehicle for mine clearance

MFV operations was carried out mostly through an armored Kamaz vehicle (Figure 8), however in congested areas a Mine Detecting dogs squad was deployed for sniffing out the mines and other UXO in the area. No live mines were located, however at two separate locations remnants of mines were identified and these were confirmed as scrap and removed from the line. All former minefields were verified by the MFV team prior to the BFC teams entering these areas. It should be worth noting that the moving sand and weather changes can expose mines exposed on the surface posing real threat to vehicles and personnel roaming around the desert for daily work.

Outcomes

As the survey was executed on 24/7 mode, beside dynamic nature of the area, the risk level was obviously high. A strict procedure, continually upgraded, was established for the crew to deal with this hazard and kept high on the agenda on every safety meetings as below:

- A comprehensive hazard and risk assessment using “Hazard Analysis and Risk Control” (HARC) methodology and documented on HARC forms
- Prior to approaching the possible contaminated area all departmental heads held a meeting
- Cleared tracks and identified UXO locations were marked with sandbags
- Movement of crew, vehicle and equipment were strictly restricted to designated path
- No Personnel outside of the demining company were allowed to approach the contaminated areas unless the area had been previously cleared by the demining teams.
- The passing of the demining teams was logged on the maps and provided to the various departments, plus visual confirmation on the ground using sandbags in a set formation
- Restricted and also NO on-foot movement during night operations.
- Due to the inherent high potential of these hazards, separate procedures were put in place to mitigate the chances of an incident occurring

The survey utilized 168,000 UniQ channels, with 20 DX-80 vibrators, shooting flip flop with four fleets. The spread consists of 60 live lines, 200 m apart, with a live patch of 57,600 channels. Total spread on the ground exceeds 1,800 linear km with a sensor unit planted on every 12.5 m.
The lay-out/pick-up of equipment was done only in day-light and strictly remaining within the designated UXO cleared path thus minimizing risk. No incident nor any UXO was located by the lay-out crew. A total of 82 UXO/ERW found (Figure 9) and destroyed.

Conclusions

A high fold, multi-azimuth, 3D Seismic Survey was successfully completed over entire PZ in 24/7 mode, covering a surface area of almost 4612 sq. km. A two-phase de-risking strategy facilitated safely acquiring a very high-resolution data volume without any data gaps/holes. A total of 551 days was spent for UXO identification, which amounted to 28,915.912 linear kilometres covering all source, receiver, PIU and infill lines. The Project was completed without any incidents or accidents and a high standard of verification was maintained throughout the project.

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