By Martin Bett, Senior VP Reservoir Solutions, TGS

The Value of PRM in Assuring Your Investment in Increased Oil Recovery

Innovative uses of seabed seismic technology will help operators glean billions from new and mature fields. High potential returns with low risk and lower lifetime cost of ownership are increasingly attractive. The active promotion of reservoir surveillance will directly impact a country's economy where responsible stewardship of national petroleum resources is a priority.

Increasing the hydrocarbon recovery factor from a producing reservoir will make a significant economic contribution. In Norway, for example, "it is estimated that a 1% increase in the recovery rate for fields that are currently operating will increase oil production by approximately 570 million barrels of oil". Assuming an oil price of NOK 570 (1 USD = 5.98 NOK) per barrel, the gross sales income from such an oil volume is approximately NOK 325 billion.[1]

It is widely acknowledged that many of the enabling technologies deployed on fields on the Norwegian Continental Shelf that have contributed to the high recovery rates have been developed through close cooperation between international seismic companies and regional operators. The use of 4D, or time-lapse seismic on the Gullfaks field alone has been estimated by Statoil to have created value of NOK 6 billion, with the total value creation from 4D seismic over the last 10 years estimated at more than NOK 22 billion.[1]

Such value creation is not confined to the North Sea alone. Published case studies combined with his own experience lead David H Johnston, SEG 2013 Distinguished Instructor, to believe that 4D seismic can have a strong impact in deepwater areas, including West Africa, Brazil, and the Gulf of Mexico. In these areas, "such fields often have critical reservoir issues that affect sweep efficiency and that can be addressed by using 4D seismic – issues such as compartmentalization, connectivity, and baffling." With high drilling and intervention costs relative to seismic costs, and subsea drill centers often limiting the use of conventional reservoir monitoring tools, he sees 4D seismic as "a primary tool for surveillance."[2] However, although the results achieved on mature fields are most widely recognized, it will be necessary to plan ahead if the value of 4D seismic is to be maximized and its potential realized on new deepwater field developments.

It is anticipated that the number of seabed seismic permanent reservoir monitoring (PRM) systems will increase in the years ahead as existing and new systems (*Table 1*) fulfill their promise to deliver substantial additional recovery and operators realize that PRM provides the highest quality data for the lowest through-life cost. Asset managers who have studied the results also know that the benefit of "on demand" 4D seismic over the life of the field far outweighs the cost. To help overcome the inertia that can block operators in other regions from accessing these benefits, TGS offers unique planning tools: operational and geophysical feasibility, seabed risk mapping, and illumination studies that are designed to ensure effective project delivery and mitigate the potential geoscience and operational risks associated with a PRM installation.

A PRM system typically requires about the same level of investment as one deepwater well. Yet although PRM has been shown to reduce the cost of drilling and production, and increase reserves while minimizing a wide variety of subsurface risks, PRM investments are often seen as major projects with high technical and commercial risk. In fact, early adopters now understand that a PRM system is considerably

Year	Km	Operator	Region	Field	Comments
1995	30	BP	N Sea	Foinaven	Experimental
2002	8	ConocoPhillips	N Sea	Ekofisk	Test line
2003	120	BP	N Sea	Valhall	Operational
2004	10	Shell	GoM	Mars	Test line destroyed in Hurricane Katrina in 2005
2006	40	BP	N Sea	Clair	Operational
2007	120	BP	Caspian	CARSP	Operational
2007	1	Multiple	N Sea	Tjeldbergodden	Test line
2008	4	ConocoPhillips	N Sea	Ekofisk	Test line
2008	1	Multiple	N Sea	Tjeldbergodden	Test line
2009	25	Statoil	N Sea	Snorre	Test line
2010	200	ConocoPhillips	N Sea	Ekofisk	Operational
2012	30	Petrobras	Brazil	Jubarte	Operational
2013	90	Shell	Brazil	BC-10	Operational
2013	260	Statoil	N Sea	Snorre Phase I	Partially installed
2014	165	Statoil	N Sea	Grane	Planned Operational 2014
2015	230	Statoil	N Sea	Snorre Phase II	Planned Operational 2014

Table 1: Chronology of PRM Trials and Implementations

All charts and graphics courtesy of TGS

[1] *Meld. St. 28 (2010 - 2011). An Industry for the Future - Norway's Petroleum Activities. Whitepaper Report to the Storting, published by the Norwegian Ministry of Petroleum and Energy, Norway, 2011*
[2] *Johnston, David H. Practical Applications of Time-Lapse Seismic, SEG 2013 DISC, Distinguished Instructor Series, No.16. Published by the Society of Exploration Geophysicists*

less risky than a deepwater well[3]. They have learned that a well-designed PRM system will deliver a substantial reward. A PRM project can reach an ROI of 5 to 25 times the cost of the investment, with "super high definition" field-wide reservoir attributes being delivered quickly and frequently such that they can impact all aspects of managing and optimizing improved oil recovery (IOR) programs.

PRM systems impact IOR programs so significantly because stationary arrays of sensors offer geoscientists a new dimension to time-lapse seismic. Simply by ensuring that no sensor movement takes place between subsequent surveys, and that the data is full azimuth, data resolution and accuracy are greatly improved. This reduces processing time, and costs, while enabling data-driven reservoir management decisions that impact five significant drivers of improved recovery:

- Better in-field exploration;
- Improved well planning and placement;
- Optimized completions;
- Fracture monitoring from active and passive micro-seismic; and
- Flood front monitoring.

Geoscientists and engineers managing fields with PRM systems are experiencing these benefits because they are not limited to the data quality of a towed survey. By leveraging 4C/4D data they can map minute pressure changes, monitor saturation and phase changes, and manage reservoir drainage. With these inputs, production can be optimized with better planning of in-fill drilling locations, improved sweep efficiency, and most importantly, accurate knowledge of what is going on between the wells. Drillers are even taking advantage of permanent seismic array data to understand geomechanical rock properties and to monitor cuttings disposal beds to avoid overcharging them.

The telecommunications industry has relied on optical systems for more than 30 years and the latest PRM systems now leverage this experience to deliver reliable subsea sensing systems with a 25+ year design life. Designed for 4D, the proven optical sensors in TGS' Stingray® arrays benefit from a simple design, a low component count, a low noise floor, and a 180 dB dynamic range. Cables are lightweight, with simple and reliable connectivity rigorously tested and qualified to meet the industry's most demanding standards. With no subsea electrical power requirements, the seabed array is connected through a riser cable to a compact acquisition and recording unit situated on surface facilities, an FPSO, or tied back to a remote host facility up to 500 km away.

	Towed	OBC	Node	Permanent
Man-hours/200 sq km survey	36,000	235,000	72,000	10,000
Major risk	Towing	Cable lay	Node lay	Gun work
CO_2 emissions per survey	High	High	Medium	Low

Table 2: Qualitative HSE risk comparison of four types of 4D surveys. Adapted from Seismic Surveillance for Reservoir Delivery, Education Tour Series, EAGE 2012

Unlike all other alternative methods, permanent sensors installed on the seafloor minimize the impact on existing oilfield infrastructure and enable highly repeatable time-lapse seismic imaging in and around obstructed zones. PRM systems are much less costly over the life of the field and present a significantly lower health, safety and environmental risk (*Table 2*).

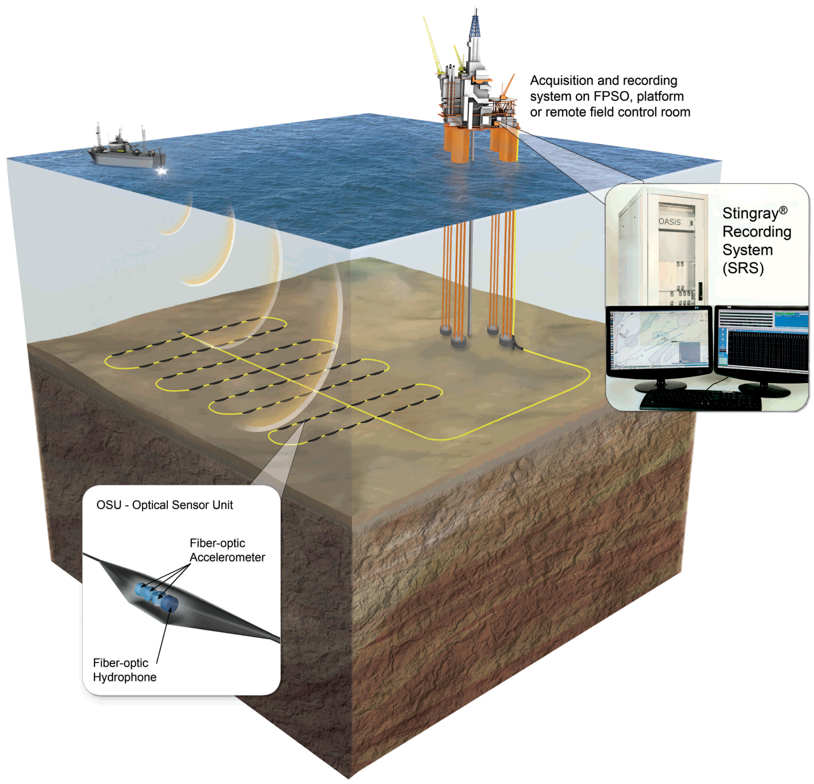

Figure 1: A typical PRM system installation

Operators are always keen to reduce development costs and risk by making timely interventions in depletion and reservoir management strategies. With the opportunity to acquire frequent data to inform such decisions, the question savvy asset managers ask is no longer "Why PRM?" – but instead "Why *not* PRM?" and "Where is the data to optimize my production strategy?"

About the Author

Martin joined TGS in 2011 and has over 30 years of experience in the oil industry working in operational and management positions for Schlumberger, Landmark, I-NET, Trade-Ranger and QinetiQ. He has established and grown businesses in Europe, USA, South America and Africa, and has a track record for closing large transactions for new and pioneering products and services. He has a BSc in Geophysics from Southampton University, UK, and an MBA with Distinction from the International Institute for Management Development (IMD), Lausanne, Switzerland.

[3] *Johnston, David H. Practical Applications of Time-Lapse Seismic, SEG 2013 DISC, Distinguished Instructor Series, No.16. Published by the Society of Exploration Geophysicists*