Wintershall Noordzee Production Optimisation Initiative

Value Creation through Innovation

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1. Summary

Wintershall Noordzee B.V. (WINZ) is an E&P operator within the Dutch, British, German and Danish parts of the North Sea. Historically reserves replacement has primarily been obtained through exploration and development, with less attention having been given to the producing fields. As the region has matured it has, however, proven increasingly difficult to maintain production levels with this strategy, and by 2009 end of economic field life was rapidly approaching for a number of the assets. A "Production Optimisation" initiative was consequently implemented to address this situation.

The objectives of the initiative were to get the WINZ organisation to increase its focus on the producing assets, hereunder addressing the issues of integration and increasing the technical level. To achieve this, a Production Optimisation Department was formed by re-organising existing staff and hiring new talent to augment existing skill sets. Additionally, a technology group was created under the department to increase technical innovation, and develop tools to both increase reserves and to protect production against future threats.

Over the last 4 years reservoir management strategies have been firmed up and some 40 projects implemented based on the results of new integrated models. As a result of these projects some 4 Bcm of reserves and € 0.3 Bln of value (post-tax) have been created. Furthermore, economic field life of the main assets has been extended by between 2 and 7 years. The production optimisation initiative has had a significant contribution towards arresting the production decline experienced by WINZ since 2007 and turning this around to an increase, contributing some 60% of the company's annual proven reserves additions.

The approach adopted for the initiative in WINZ, was based on production optimisation requiring a dedicated effort and having full integration of all disciplines. As the process is labour intensive sufficient resources had to be made available, although this in some cases was in competition with other parts of the business in a resource constrained environment. Finally, as demonstrated by the paper production optimisation solutions are never unique and in general success requires a high degree of innovation.

2. Company Overview

Wintershall Holding GmbH, based in Kassel, Germany, is a wholly-owned subsidiary of BASF in Ludwigshafen. The company has been active in the exploration and production of crude oil and natural gas for over 80 years. Wintershall focuses on selected core regions where the company has built up a high level of regional and technological expertise. These are Europe, North Africa, South America, as well as Russia and the Caspian Sea region. In addition, these operations are complemented by the company's growing exploration activities in the Arabian Gulf. Today, the company employs more than 2,000 staff worldwide from 40 nations and is now Germany's largest crude oil and natural gas producer.

Wintershall Noordzee B.V. (WINZ) is the Wintershall subsidiary responsible for the company's E&P activities within the Dutch, British (Central & SNS), German and Danish parts of the North Sea. With some 550 personnel the company operates 22 gas and 2 oil platforms, 5 sub-sea gas wells, 700 km of off-shore pipelines and an onshore process/compression terminal. Furthermore, the company participates, as non-operator, in a significant number of oil and gas fields within the region.

The operated portfolio includes assets within the full value chain from exploration through to abandonment. Currently, 3 jack-up rigs are under contract, employed in the drilling of exploration, development and production optimisation wells.

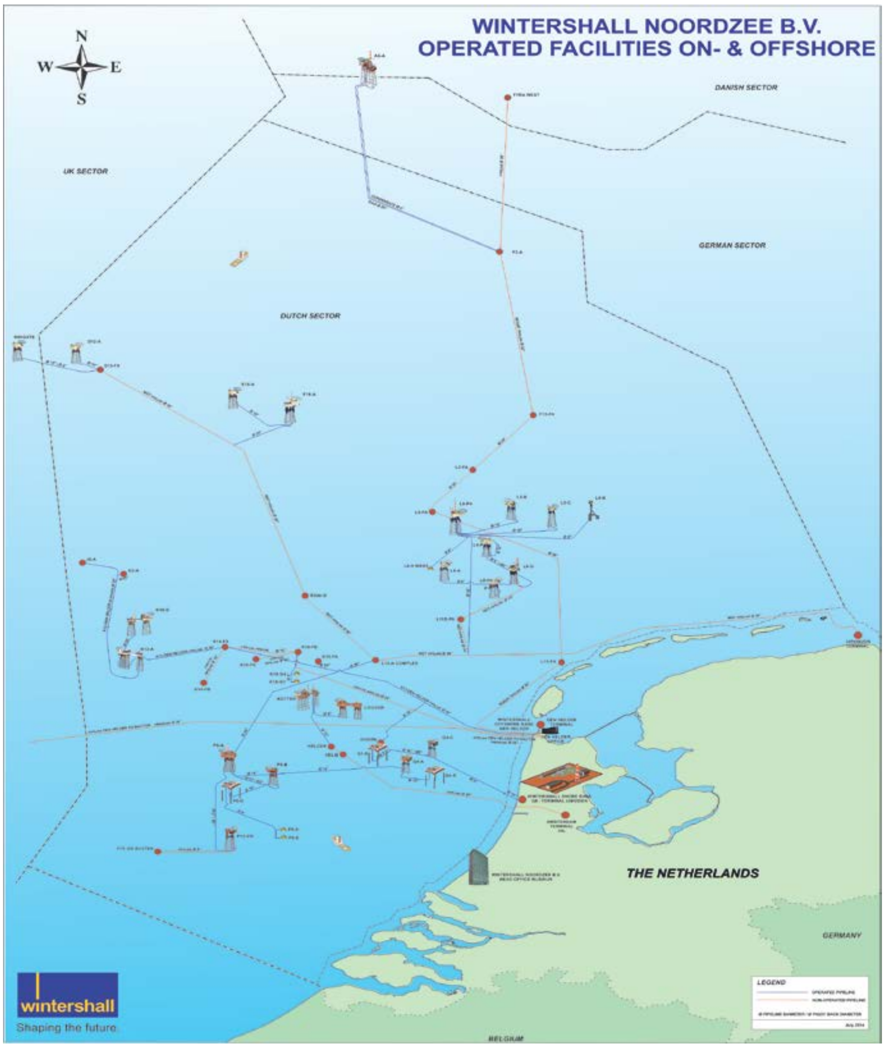


Figure 1 – WINZ Operated Facilities

3. Production Optimisation Initiative

Historically the WINZ business model had primarily been based on growth through exploration and development, with less attention having been given to the producing fields. As the region has matured it has, however, proven increasingly difficult to maintain production levels with this strategy. As such, the company's production was halved in the period between 2007 and 2010, and by late 2009 end of economic field life was rapidly approaching for a large number of the assets. A "Production Optimisation" initiative was consequently implemented to address this situation.

The high level objective of the initiative was to maximise the value of the existing fields, by increasing production and reserves, reducing costs, extending economic field life and safeguarding the assets against potential future threats. To achieve this, an innovative methodology has been applied, whereby one or a combination of the following tools was utilized.

1. Re-organisation
2. Technical Excellence
3. Integration
4. Technology
5. Commercial
6. Vision

The following Sections describe examples of how these tools have been applied to achieve results.

3.1 Re-organisation

To make the production optimization initiative effective, a step change in performance was required. Furthermore, given the urgency of the situation, as described in Section 3, effective implementation had to be rapid. Consequently, it was decided to undertake a re-organisation, which if successfully implemented, could create the required transformation. As such a Production Optimisation department was formed, independent of the Development Department, to ensure that a dedicated effort was applied to the producing assets. Furthermore, the Production Optimisation Department was tasked to focus the entire WINZ organization on the producing assets, improve the technical competency of staff, and promote a more integrated approach.

The re-organisation was done under the motto "One Team – One Course – One Goal", using the analogy of sailing where an obvious requirement exists that all crew need to work together as one team with a common objective.

Implementation was successfully achieved and key projects were implemented within a relatively short timeframe. The technical level has been increased as planned and a new recruitment strategy has led to the hiring of 14 high quality production and reservoir engineers within a tight market. Furthermore, a technology group was created within the department in order to develop key technologies, both to increase value through innovation but also to pro-actively have solutions in place to address potential future threats.

Figure 2 – Production Optimisation Analogy

However, the re-organisation was also associated with a number of difficulties. These were mainly focused around a low degree of change readiness of the organization; the urgency of the situation resulting in priority being given to executing projects at the cost of addressing the softer factors; initially having insufficient experienced staff to address the new challenges resulting in a high workload; attrition of staff due to the re-organisation, although at normal levels, worsening the workload situation; and finally under-estimating the complexity of the re-organisation.

3.2 Technical Excellence

Whereas in the past the producing assets had been managed by use of relatively simple analytical methods, including decline curve analysis, material balance, etc., it was clear that a number of assets required more complex tools in order to understand their behaviour and thus to be able to optimise them.

One such example is a complex Carboniferous gas field which had ceased production with a recovery factor of only some 50%. The issues surrounding the field included water breakthrough not being understood as a significant aquifer had not been mapped, severe salt precipitation in the wells and reservoir impeding flow, use of long (sub)-horizontal wells with multiple layer completions causing cross flow between zones and making fresh water washes from surface ineffective in dissolving the salt and finally the minimum facilities platform not allowing coil tubing access.

To understand field performance a detailed G&G model was constructed. Different stochastic realisations of this model were subsequently iteratively used to history match the reservoir simulation model. This led to the discovery that in some realisations, reservoir layers could be vertically isolated in the gas zone while leaking below the gas water contact. Consequently, in case an individual gas layer was not connected to a producing well, this could lead to a “U-tube” effect whereby expansion of non-connected gas would displace aquifer water into an adjacent producing layer.

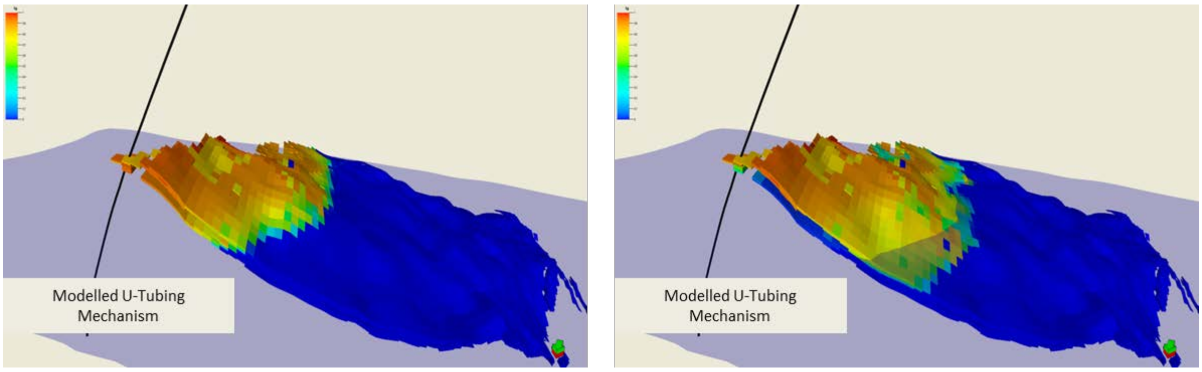


Figure 3 – Modelled U-Tubing Mechanism

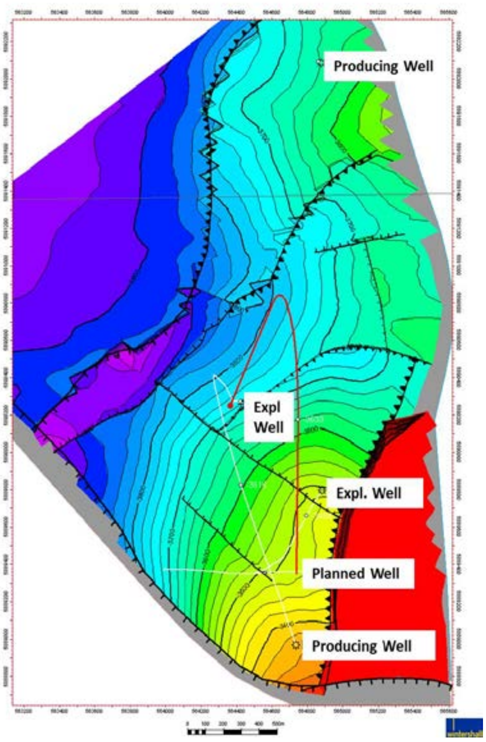
Based on the insights gained from the modelling a re-development was successfully implemented comprising: A 950m horizontal side-track through high permeable reservoir layers with pressure differences of 250 bar; installing an insert liner in another well to seal-off the depleted zones and re-establish production in a salted up zone. To save cost the liner was hung-off and salt precipitation used to create the annular seal; A third well had a plug installed to stop cross-flow occurring between zones due the U-tube effect continuing after the well's production had ceased. As a result of the re-development the field's recovery is predicted to increase to 60% and the field life to be extended by 6 years.

As a result of the study, the completion strategy for the company's Carboniferous fields has been changed so that individual layers are sequentially produced as long as there is no risk of U-tubing. Plugging-off and additionally perforating has been done by tractors while clean-up prior to the job has been successfully executed by a frac boat bull-heading viscous pills alternating with abrasive slugs to clean the wells.

3.3 Integration

The effectiveness of integration, although a common theme for all projects, was illustrated in the optimization of a tight Rotliegend gas reservoir. This field has a very high geological uncertainty including gas-in-place, areal property distribution and potential vertical and lateral compartmentalisation. Furthermore, the field has been developed sub-sea and has limited rig access due to its location within a military exercise area. The two producing wells on the field have shown very different production behaviour and the southernmost well, drilled as a multi-fracced horizontal well, has the added uncertainty that clean-up of the bottom fracs was not possible during completion whereby production contribution from the lower most reservoir layer is uncertain.

An integrated subsurface study was undertaken of the field. As expected the high degree of uncertainty resulted in a range of history matches being possible. Based on the modelling, the field was predicted to yield a low recovery factor of some 45% at the current level of development. Targets for infill drilling however differed depending on the history match scenario, and drilling horizontal wells were not viable due to the limited time allowed to access the area for drilling.



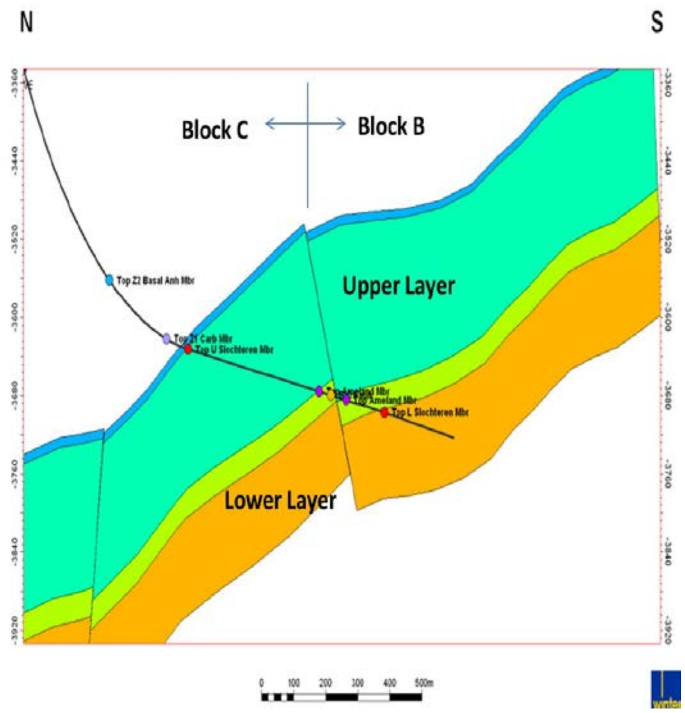


Figure 4 – Top Structure Map

Figure 5 – Planned Well Trajectory

As a result a special procedure was developed with the Ministry of Defence to allow concurrent drilling and military exercise operations, whereby the drilling window could be extended. This allowed a multi-fracced horizontal well to be planned which not only covers two blocks, addressing the areal compartmentalisation, but also the upper and lower reservoir layers, addressing the vertical compartmentalisation. In this way the well was tailored to maximise the chance of finding un-depleted gas within the full range of history matches obtained. The well is planned to be spudded late 2014 and to increase the field recovery factor to 55%.

3.4 Technology

As part of the re-organisation a new technology group had been formed as described in Section 3.1. One of its key projects were to come up with a strategy to manage salt precipitation which was occurring in both wells and reservoirs, adversely affecting more than 50% of the WINZ production.

A large number of the WINZ reservoirs contain connate water which at initial conditions is almost fully saturated with salt. As the pressure drops in the reservoir, gas can adsorb more water vapour and connate water is boiled off depositing free salt. Due to the capillary un-equilibrium from the resulting reduction in water saturation, capillary forces pull-in additional water from the surrounding area whereby a continuous transportation of salt (water) occurs towards the wells. The process is non-linear and increases exponentially with depletion. If measures are not undertaken the wells will cease flowing completely due to plugging of the pores and/or tubing with salt crystals. The process from near full productivity to fully plugged has been found to occur within hours.

Historically this problem has been solved by shutting in the affected wells every few days and bull-heading fresh water into the wells to dissolve the salt within the tubing and near well-bore area. The timing of this is very critical. If injected too late the wells will be fully plugged and the fresh water unable to access the salt by bull-heading.

Figure 6 - Picture of tubing at 4.1 km Depth

To optimize the salt management, a capillary coil system has been developed which will allow the introduction of fresh water across the perforations on a continuous basis, thus avoiding the downtime associated with shutting in the wells. A pilot project has been successfully performed whereby a well could be produced for a month without decrease in productivity, whereas previously it had to be shut-in for 6 hours every few days. A tracer introduced as part of the injection water demonstrated that capillary forces are high enough to overcome the viscous forces during production to imbibe the fresh water into the near well-bore region to wash the formation. On a longer term-basis it is hoped that this technology will stop the transportation of salt towards the wells, assuming the injection water will maintain capillary equilibrium in the reservoir.

As part of the project an insert system has been firmed up which will allow the operation of the sub-sea safety valve with a capillary coil installed, the metallurgy of the coils have been optimized as current fabrication methods of capillary coils to duplex steel standards are insufficient, and a 3-D simulation model has been developed to describe salt precipitation under dynamic conditions, supporting that the precipitation mainly occurs in the near well bore region.

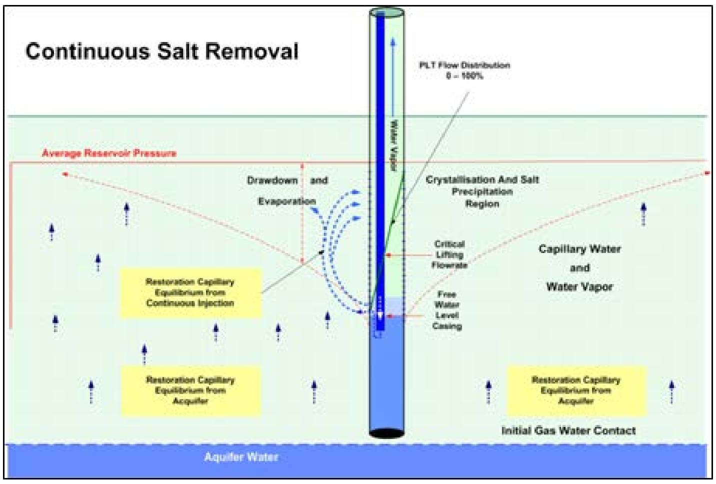


Figure 7 – Salt Removal Principles with Capillary Coil

3.5 Commercial

A high permeable Bunter gas field experienced unexpected water breakthrough in 2009. Subsequent breakthrough in other reservoir zones and wells has caused the production to severely decline. An integrated sub-surface study highlighted that residual gas in the aquifer could account for the unexpected aquifer energy, as an extensive aquifer had not been mapped. Prediction runs showed that production would continue to decline to a low level followed by an extensive tail-end production period at low rates.

This was a major issue as the cost of the field's current high capacity export system was very high, resulting in a significant loss of technical reserves due to these being below the economic threshold. The study highlighted that by re-routing the production to a low capacity and low cost on-shore terminal, these reserves would remain economic.

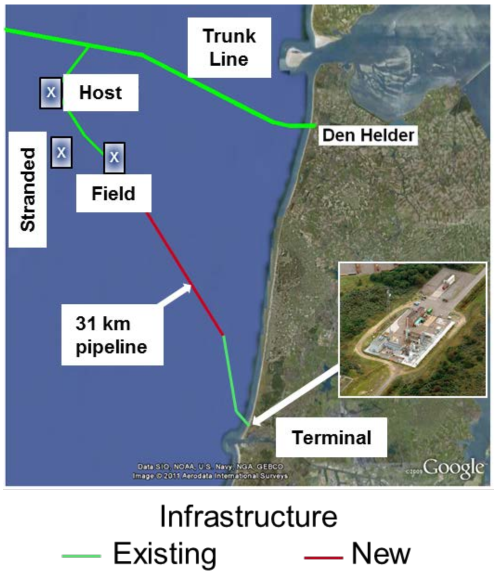


Figure 8 – Re-routing of Bunter Gas Field

The project was successfully implemented in 2012 and field life is predicted to have been extended by 6 years as compared to the do-nothing case. Additionally, a stranded gas discovery in the area, the development of which was non-economic through the original host export route, became economic through the low cost terminal. This development has been successfully completed in 2014.

3.6 Vision

A Rotliegend gas cluster, comprising three gas fields, a main process/compression platform and two satellite platforms had been run in harvest mode for a number of years and was reaching the end of field life by 2012. Obvious measures to remedy this situation did not exist.

A vision approach was therefore applied whereby a target was set to keep the asset producing for an additional 5-10 years, but without initially having a specific plan as to how this could be achieved. An opportunity portfolio was subsequently developed covering the full range of possible activities from near-field exploration to facility modifications.

Figure 9 – Main Process/Compression Platform for Gas Cluster

The portfolio was ranked and the attractiveness of a number of individual projects improved by considering them as part of a bigger portfolio. The status to date is that production from the field has been re-routed to a new host thereby removing the need for compression and processing. As such the main platform has been converted to a satellite. The compression facilities on the host have been upgraded to allow 3 bar suction pressure, thereby avoiding a lowering of the suction pressure at the cluster. A non-producing well has been fracced and successfully cleaned up in spite of a very low reservoir pressure. A development plan for a stranded gas field has been firmed up and is currently being screened for attractiveness and risk.

As a result of the above measures the field life has been extended to 2016 at the current level of development, with the possibility of further extending this to 2020 in case the new development is undertaken.

4. Results

The Production optimization initiative has had a very significant effect on the WINZ business over the last four years.

The re-organisation has been successfully implemented and the Production Optimisation Department has been expanded to some 25 people. Significant expertise and experience has been developed in the company to address the optimisation of the producing assets and reservoir models and management plans have been developed for all main reservoirs.

On the implementation side a total of some 40 projects have been executed including field re-developments, infill drilling, work-overs, gas compression re-configuration to lower suction pressures, converting process platforms into satellites, and re-routing production to more cost effective host facilities. On the technology side continuous down-hole water injection in gas wells has been developed to address salt precipitation issues, on-line monitoring to increase effectiveness and reduce downtime, and foam lift to address liquid unloading problems.

The projects have in general been on time within budget and with results in line with expectations. As a result of these projects some 4 Bcm of reserves and € 0.3 Bln of value (post-tax) have been created. Furthermore, economic field life of the main assets has been increased by between 2 and 7 years.

Since 2010 WINZ's production decline has been arrested and turned around to a production increase. The production optimisation initiative has had a significant contribution to this performance. As such some 60% of annual proven reserves additions have originated from production optimisation.