Montanuniversität Leoben

Master Thesis

Drilling rig design for a unique oil field application – field redevelopment in Ruehlermoor "peat mining field"

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AFFIDAVIT

I hereby declare that the content of this work is my own composition and has not been submitted previously for any higher degree. All extracts have been distinguished using quoted references and all information sources have been acknowledged.

Datum

Simon Stolte

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Abbreviations

300	Cabot Franks 300/11 drilling rig
EMPG	ExxonMobil production Germany
FEED	Front End Engineering & Design
FID	Final investment decision
HP/HT	High pressure / High temperature
HPU	Hydraulic power unit
HSE	Health & Safety Execution
HTV	Horizontal to vertical
MD	Measured depth
PULD	Pick up/lay down machine
RLMR	Ruehlermoor; Abbreviation of the wells in the field Ruehlermoor
TDS	Top drive system
TVD	Total vertical depth
Unimog	Mercedes-Benz Unimog
VFD	Variable frequency drive

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1. Abstract / Kurzfassung

1.1 Abstract

A major part of the German oil and gas consumption is covered by imports, thus it is important that Germany strengthen the domestic production. The oil field "Ruehlermoor" with more than 500 existing wells is Germany's largest onshore oil field and is operated by a joint venture of GDF Suez and ExxonMobil. It was discovered in 1941, is located in a peat mining area at the German-Dutch border and covers 24 square kilometers. Its infrastructure is unique in the world. Due to the unstable underground in the field most transports are done with a narrow-gauge railway (track width 900 mm). The peat mining industry and the oil production operate simultaneously. Parallel arranged dykes, which are several meters high and up to 40 m wide serve as area for the sucker rod pumps, the infrastructure and for drilling and workover operations.

The oil field is in production for 60 years and has an exploitation of 27 % (2015). Since the 80s, the reservoir is stimulated with hot steam injections. Meanwhile, the pipelines of the field and the steam generation plant have to be replaced. The redevelopment of the field needs over 100 new wells in 500 - 700 m depth in the next 5 years, the construction of a cogeneration plant and the consequent increase in steam injection and oil production has to ensure the economic viability of the field.

The last wells in the Ruehlermoor oil field were drilled with a company's own carrier rig built in 1982, which could compensate the small space conditions by its compact design, but is not capable to drill such a drilling campaign.

The future drilling rig needs a hook load of 150 tons except load to pull casings according to the thermal effects in tension. It must be able to transport by rail and the individual parts must not exceed 60 tons. There is no ability to skid in Ruehlermoor, because the surface locations of the new wells are located in between of the existing wells. The small size of the well site and the narrow dykes on which only a road and one rail are available as infrastructure, transport and the rig up/rig down procedure is a major challenge. The rig must be able to drill a minimum of wells, before the cogeneration plant goes into production in 2020, in order to ensure efficient operation of the project. The acquisition of a new rig is therefore essential. Through a Europe-wide tendering process 11 drilling contractors were invited to propose their rig concepts and 4 of them submitted tender documents.

This thesis accompanied the tendering process, deals with the peculiarities of the oil field Ruehlermoor and shows why the construction of a new rig is needed to meet the circumstances of the field and why the transport of the rig has a decisive impact on the

success of the project. Furthermore, the thesis describes the concepts of the contractors and evaluates them technically. For this, matrices have been developed with differently weighted evaluation criteria in accordance to the circumstances, which are needed to do an efficiency analysis. A recommendation for the best concept is then developed using the analysis.

1.2 Kurzfassung

Ein Großteil des deutschen Erdöl- und Erdgasverbrauchs wird durch Importe gedeckt und darum ist es wichtig, dass Deutschland die inländische Produktion stärkt. Das Erdölfeld „Rühlermoor“ mit über 500 bestehenden Bohrungen ist Deutschlands größtes Erdölfeld auf dem Festland und wird von einem Joint Venture aus GDF Suez und ExxonMobil betrieben. Entdeckt wurde es 1941. Es liegt in einem Torfabbaugebiet an der deutsch-holländische Grenze, erstreckt sich über 24 km² und ist in seiner Infrastruktur einzigartig auf der Welt. Aufgrund des instabilen Untergrundes werden die meisten Transporte im Feld mit einer Schmalspurbahn (Spurbreite 900 mm) erledigt. Die Torfabbauindustrie und die Ölproduktion arbeiten simultan. Parallel angeordnete Deiche, die mehrere Meter hoch und bis zu 40 m breit sind dienen dabei als Bereich für die Gestängetiefpumpen, die Infrastruktur und als Handlungsfläche für Bohr- und Workovermaßnahmen.

Das Erdölfeld ist seit 60 Jahren in Produktion und weist eine Ausbeutung von 27 % auf (2015). Seit den 80er Jahren wird das Reservoir mit Heißdampfinjektionen stimuliert. Mittlerweile müssen jedoch die Pipelines des Feldes und die Dampferzeugungsanlage ersetzt werden. Die Neuentwicklung des Feldes mit über 100 Neubohrungen in 500 – 700 m Tiefe in den kommenden 5 Jahren, dem Neubau einer Kraft-Wärmekopplungs-Anlage und dem daraus resultierendem Anstieg an Dampfinjektion und Erdölproduktion soll die Wirtschaftlichkeit des Feldes weiterhin garantieren.

Die letzten Bohrungen im Rühlermoor Erdölfeld wurden mit einer konzerneigenen Carrieranlage aus dem Baujahr 1982 gebohrt, die die geringen Platzbedingungen durch ihre kompakte Bauweise kompensieren konnte, aber nicht in der Lage ist solch eine Bohrkampagne zu bohren.

Die Anschaffung einer neuen Anlage ist daher unverzichtbar. Die zukünftige Bohranlage benötigt eine Hakenausnahmelast von 150 Tonnen, um Casinge entsprechend der thermischen Einwirkungen in Spannung zu ziehen. Sie muss auf der Schiene transportierbar sein und die Einzelteile dürfen 60 Tonnen nicht überschreiten. Die Möglichkeit zu Skidden besteht in Rühlermoor durch existierende Bohrungen zwischen den Neubohrungen nicht. Durch die geringe Größe des Bohrplatzes und den schmalen Deichen, auf dem lediglich eine Straße und ein Gleis als Infrastruktur vorhanden sind, sind der Transport und der Umbau der Bohranlage eine große Herausforderung. Die Anlage muss in der Lage sein ein Minimum an Bohrungen fertig zu stellen, bevor die Kraft-Wärmekopplungs-Anlage 2020 in Produktion geht, um eine wirtschaftliche Nutzung des Projektes zu gewährleisten. Durch ein europaweites Ausschreibungsverfahren wurden 11

Bohrfirmen aufgefordert ihre Bohranlagenkonzepte zu präsentieren bei der 4 von ihnen ein Angebot abgaben.

Diese Arbeit begleitet den Ausschreibungsprozess, befasst sich mit den Besonderheiten des Erdölfeldes Rühlermoor und zeigt auf, warum der Neubau einer Anlage nötig ist, um den Gegebenheiten des Feldes gerecht zu werden und warum der Transport der Anlage einen entscheidenden Anteil an dem Erfolg des geplanten Projektes hat. Des Weiteren werden die Konzepte der Firmen beschrieben und technisch bewertet. Hierfür wurden Matrizen mit unterschiedlich gewichteten Bewertungskriterien dem Umständen entsprechend entwickelt, die einer Bewertung mit Hilfe einer Nutzwertanalyse dienen. Anhand der Analyse wird dann eine Empfehlung für das beste Konzept erarbeitet.

2. Introduction

Germany is not capable of compensating the demand of oil with its own production. [1] Although the consumption has been slightly decreasing over the past 15 years, [2] the development of the inland oil exploration and production has to be enhanced. The oil production has been stagnating over the last 20 years due to various reasons. The existing oil fields resources are more and more exhausted. The exploration of new fields is a challenge in Germany. The urban landscape makes it difficult to find spots for exploration wells or large-scale underground investigations. In addition to that, topics like hydraulic fracturing resulted in the resistance of the population to respective drilling of new wells. Additionally to that the effort to authorize new drilling activities gets more extensive. Different state authorities want the proof of a safe working environment for people, flora, fauna and habitat. Therefore, the production of oil has to be enhanced in existing fields and production wells. There are diverse possibilities to achieve a higher efficiency while increasing safety for all stakeholders. Workover of existing wells, new wells in existing fields, re-entry wells or the stimulation of the reservoir with heat or chemicals are only a few possibilities.

The oil production in Lower Saxony Basin is the second highest in Germany. However, the overall production of oil covers only 2-3 % of the total consumption (Figure 2.1 and 2.2).

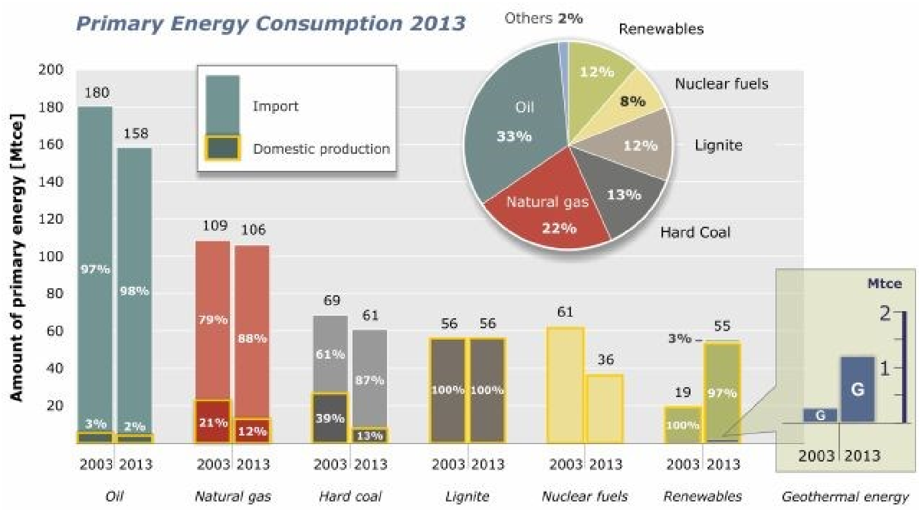


Figure 2.1: Comparison of the use of primary sources of energy and of the ratio of domestic supply to imports for Germany in 2003 and 2013, and relative shares in 2013 (based on AGEB 2014, LBEG 2014) [3]

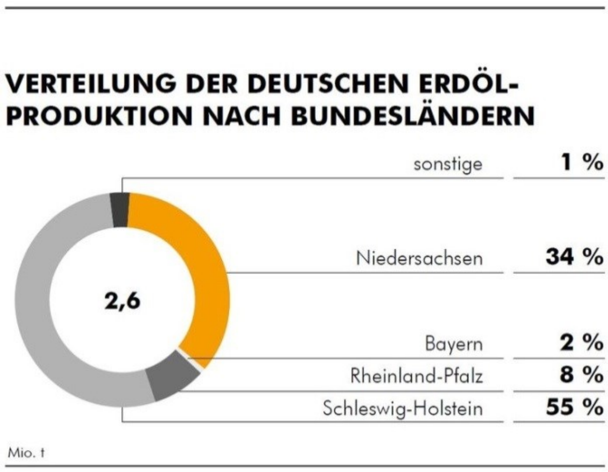


Figure 2.2: Distribution of the German oil production separated in the states of Germany [4]

One of the existing oil fields in Lower Saxony in the Emsland region is the “peat mining field” or “Ruehlermoor oilfield” located at the north western part at the border to the Netherlands (Figure 2.3 (red arrows)).

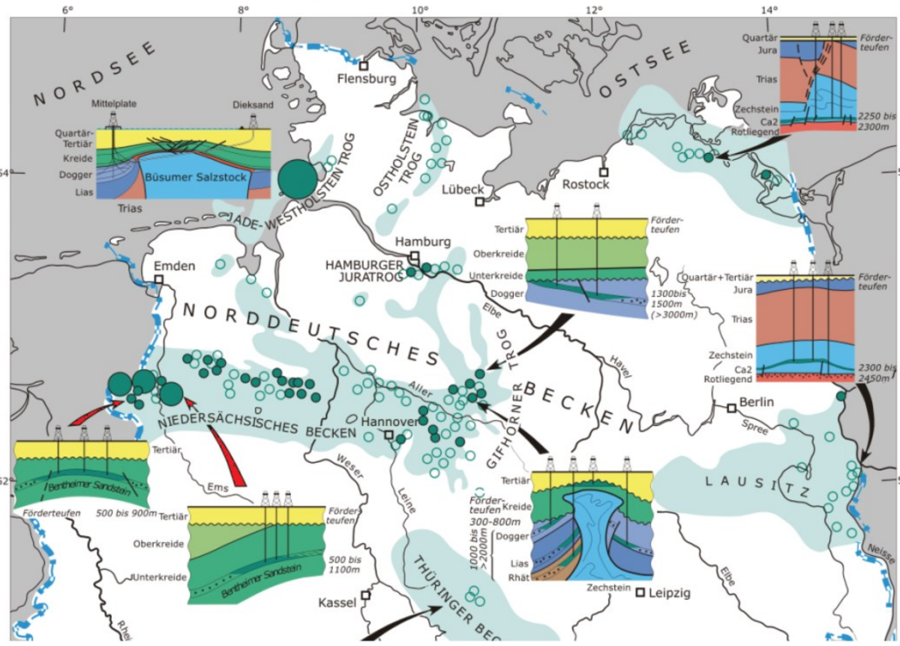


Figure 2.3: Oil fields in northern Germany [3]

It covers a 24 km² area and is separated into two different production areas - the western part Ruehler Twist and the eastern part Ruehlermoor. It contains a 7.08 km² nature reservoir. The Ruehlermoor oilfield was discovered in 1941 and developed from the middle of 1949 to be the biggest oil field of GDF Suez. A joint venture of ExxonMobil Production Germany (EMPG) and GDF Suez E&P Deutschland GmbH operate the field together with 50 % share each. GDF Suez is the drilling operator and

EMPG is working as the production and field operator. The field contains 128 million tons of oil in place in the “Bentheimer sandstone”. The immense challenge in producing the oil is the infrastructure in combination with the nature reservoir and the simultaneously ongoing peat mining operation. Under an 8 – 13 m thick peat layer, the sucker rod pumps are producing oil out of 500 – 700 m deep 2 - dimensional J-shape wells. The pumps are placed on small dykes, which are roughly 40 m wide. They can be reached with a small train or with a car. The rail way system within the field has a 900 mm gauge, is over 100 kilometres long and is necessary for an improved load distribution.

In the past 65 years the field with over 500 wells went through different stages of production. In the first years the oil production was operating due to the natural flow. Until 1964, 372 wells have been drilled and produced by conventional oil recovery. Since 1956 water injection wells have been drilled additionally to pressurize the reservoir in order to cover the decline in production and to hold the reservoir pressure. In the 70s additional 80 wells were drilled because of the increasing oil price. Since the beginning of the 80s the first steam injection wells started to support the production of high viscous oil (ca. 120 cP (Water: 1 cP)). With temperatures of the steam up to 320 °C and production temperatures up to 100 °C the viscosity was able to be reduced and the production proceeded. Due to persisting decline in the 90s older wells with malfunctions were plugged and re-drilled with side-tracks. In the 2000s an additional drilling campaign was initiated to stop the decline of oil production. Currently there are 159 production wells, 8 steam injection wells and 28 water injection wells in operation (August 2013).

2013 GDF Suez E&P Deutschland GmbH and ExxonMobil Germany GmbH started to discuss about a complete redevelopment of the field to ensure a prolongation of production for additional 30 years. Even though the undertaking was understood as a challenge, the motivation of this project was the prediction of a high amount of oil still being producible. The redevelopment project was started.

Regarding the problems of the oil production in Germany and the infield situation the project is confronted with big challenges. The project plan includes the construction of a cogeneration plant, which will be set in production in 2020. Additionally the drilling over 100 new production, water and steam injection wells is planned. The water injection wells with a length of up to 1500 m MD each will be drilled on 2 sides outside the peat mining area to dispose the produced water. Nowadays the water cut is > 90% all over the field and in the future it will most likely not decrease. The field produces over 500 t oil every day. The cogeneration plant uses the produced water to generate steam and electricity. This is required, because it is not possible to inject the complete produced water back into the formation due to the capacity limits. Additionally the generated electricity can be used in the operation and the surplus can be sold.

The steam injector wells will be placed within the field to heat up the reservoir and reduce the viscosity of the oil. The well head temperature has to be raised to 200 °C. Therefore, new production infrastructure like pipelines and wellheads must be installed, because the present equipment does not handle these high temperatures. Also the completion design will be changed to withstand extreme conditions with the occurrence of high temperatures, CO_2 and H_2S. Up to 150 °C H_2S is high corrosive. Above this temperature CO_2 gets highly corrosive. Thus, during the life time of the producer with a rising of the temperature of the produced fluid, it will mostly be a corrosive medium in place.

Water production wells will be drilled at the border of the field, which will reduce the pressure in the production zone and build a low pressure barrier against the water injection wells outside of the field. Observations have shown, that with pressures around 30 – 40 bars the oil transport in the pores is better than with the current pressure, which is around 60 bars. If the pressure is too high during the injection of the steam, the possibility occurs that the steam changes into the fluid phase and blocks the flowing channels of the reservoir rock which will result in a decrease the oil propagation. Also the water cut can raise and a steam break through is possible. Therefore, the water production wells will be placed around the field. The overall investment for the consortium will be around 1.2 billion Euros.

3. The peat mining field Ruehlermoor

This chapter informs about the history of the Ruehlermoor oilfield from the beginning until today. Well schemes will be shown to get an idea of how wells were drilled and cased in the past. Afterwards the geology of the field is presented. The process and stage of the redevelopment is discussed and later on the infield infrastructure with train, carrier, road transport and logistics is explained.

3.1 History

On the 24.08.1949 the Ruehlermoor 1 (RLMR1) well found oil in the Bentheimer sandstone at 670 m vertical depth. It was the 4th oil finding in the Emsland within 7 years. (1942 in Lingen-Dalum, 1943 in Emlichheim, and 1943 in Georgsdorf) After the second successful oil finding in Ruehlermoor in 1949 the consortium of Deutsche Schachtbau und Tiefbohrgesellschaft mbH – today GDF Suez – and Gewerkschaft Elwerath – today ExxonMobil developed the field Ruehlermoor in 1950 with additional 13 wells. The wells got serial numbers which can be sorted in a timeline including an abbreviation RLMR for "Ruehlermoor". The wells with numbers from 1-399 were drilled until the beginning of the 60s. Wells with numbers from 500-799 were drilled afterwards until the beginning of the 90s and have a comparable casing design to the wells of the redevelopment project. Later drilled wells got numbers between 400 and 499 or 800-899. Also then all equipment was transported on rails because of the unconsolidated underground. The production of 880 t per year in 1949 raised up to 30,000 t per year in 1950.

Due to drilling of additional 17 wells in 1951 the production increased up to 96,000 t oil per year. Consequently, in 1966, the development of the field with building pipelines and drilling of new wells resulted in over 1,000,000 t per year of oil production out of 274 wells. At that time 366 wells were already drilled, including 15 wells that were only used for water injection and 77 were abandoned wells. The water cut rose during the following years but a constant production was perceived. The attempt to increase the oil production by installing lager pumps failed and in the beginning of the 70s the oil production decreased for the first time. This trend would be stopped with drilling of 80 new wells from 1976 to 1980. Additionally to that in 1980 the steam injection started which caused the occurrence of H2S but somewhere tripled the oil production in the invaded zone.

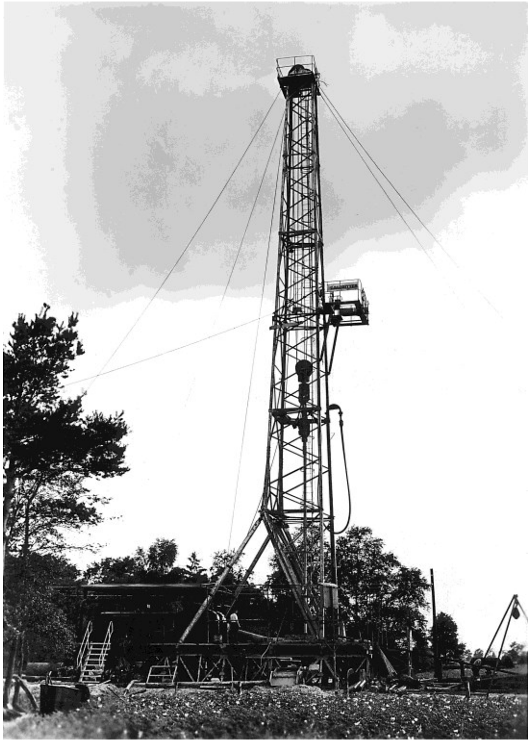
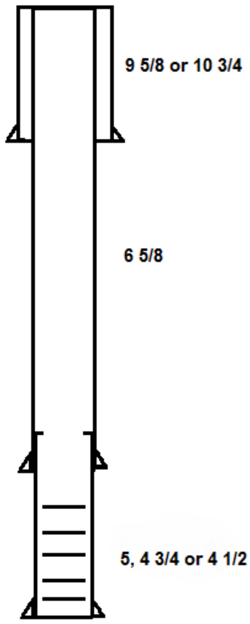


Figure 3.1: Rig 42, Ruehler Twist 1950 [5]

3.2 Old wells (0-99, 100er, 200er, 300er)

As mentioned before the field was developed in the 50s. The RLMR 1 was drilled from the 15.6.1949 until the 18.8.1949 with the following casing design:

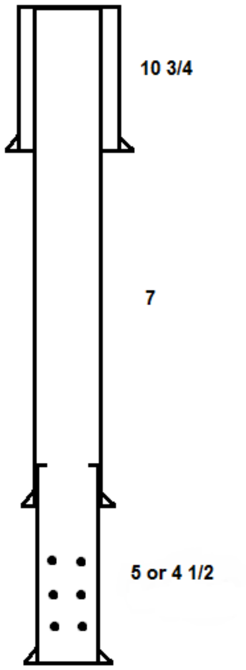
- 13 3/8” up to 263 m,
- 9 5/8” up to 574 m and a
- 6 5/8” pre drilled Liner from 566 – 671 m.



For the following wells in the 50s and 60s it is a nontypical design. Later on almost every well was completed with a 9 5/8” or 10 ¾” up to around 130 m, a 6 5/8” up to around 620 – 830 m and a 5, 4 ¾” or 4 ½” Liner up to the end depth which is a more economic casing scheme. The liners were slotted, perforated or pre-drilled and in some wells additional 2 7/8” sand screens were installed to prevent sand production.

3.3 Thermal wells (500er and 600er)

These kind of thermal wells were drilled in the beginning of the 80s when steam was used for the first time to enhance the flow properties of the oil in place. These wells got a brief change in the casing design. The 9 5/8” surface casing was changed to the 10 ¾” casing, the 6 5/8” was changed to the 7” casing and a liner completion with a 5 or 4 ½” casing, which were mostly cemented and perforated.



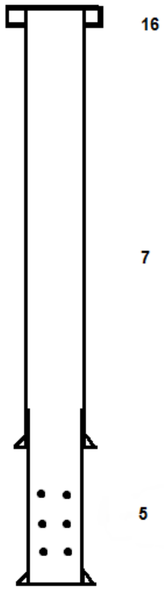
3.4 Wells drilled since the 2000s (400er, 800er)

The RLMR 413 was drilled 4 years ago from 07.01.2011 to the 18.01.2011. The well is 644 m MD (623 m TVD) deep and has the following casing design:

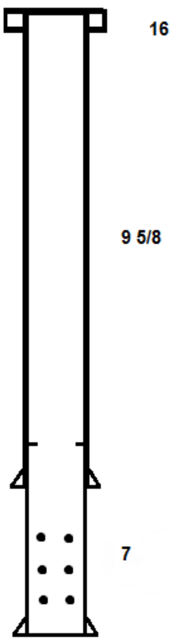
- 16” Conductor up to 36 m
- 7” Casing up to 482 m
- 5” Liner from 429 to 644 m

The well was drilled with following bits:

- 12 ¼” up to 75 m
- 9 7/8” up to 485 m
- 6 1/8” up to 644 m
- 8 ½” Underreamer from 490 to 639 m
- 4 1/8” BHA: Landing Collar, Float equipment



This so called “slim well design” is typical for the field Ruehlermoor since the beginning of the 2000s. During the drop of the oil price in the 90s this casing design was chosen to reduce the costs. It is designed for production temperatures of 100 C°. For the Redevelopment project this design is not feasible. Due to higher production fluid temperature changes this casing design includes a higher risk of a failing well integrity. GDF Suez and EMPG decided that the risk is too high to use this casing design for injection of high temperature steam. It is not possible to pull the whole 7” casing in tension to withstand the high forces occurring during high temperature changes, because of 2 different cement types. The lower section is covered with tail cement which hardens faster than the lead cement in the upper section. This tail cement section is relatively short compared to the lead cement section and works as an anchor. Thus, the casing could be pulled in tension. The result is that only the part of the casing covered with lead cement can be pulled in tension. Additionally it is not possible to assure a safe well integrity with the 7” casing as the only barrier. Also as a producer this design has some uncertainties. If gas with H_2S and/or CO_2 enters the tubing annulus the 7” casing is the only barrier to the formation. If the casing corrodes it may result in major negative effects to the environment.



The RLMR 801 is a well which was cored additionally to get detailed underground information. It is located on dyke 6 and was drilled from 07.05.2014 – 28.05.2014. It is 636 m MD and 617 m TVD deep with the following casing design:

- 16” conductor casing up to 36 m,
- 9 5/8” casing up to 475 m
- 7” Liner set in 2 steps from 0 to 636 m

(first 428 m – 636 m, second 0 – 428 m)

A 7” tie-back from 0 - 428 m was chosen, that the work over team can use their stocked 7” tools. The second fact for the extraordinariness of the casing design is that the geological department needed a 4” core. This is only possible to achieve with an 8 ½” coring tool which fits a 9 5/8” casing. It is the last producer well drilled in the field until today.

The RLMR H 25 is a steam injector well located on dyke 7 and was drilled from 02.06.2014 – 17.06.2014. It has a depth of 614 m MD and 599 m TVD. Its casing design is the following:

- 16” conductor casing up to 36 m
- 9 5/8” Casing up to 288.5 m
- 7” casing from 0 to 534 m
- 5” Liner from 476 to 603.5 m

This casing design is a good reference for the wells of the redevelopment project, which is discussed in more detail in chapter 3.6.2 “The future wells schemes”.

Figure 3.2 and 3.3 show a time analysis of the drilling process of RLMR 801 and RLMR H 25 distinguished in the different working procedures. It is developed with information out of daily reports. For the redevelopment project no coring is planned, but all other processes shown in the figure can be a reference to analyze the effectiveness of the new rig.

In the appendix the detailed time analyses can be found. (Appendix 13.4)

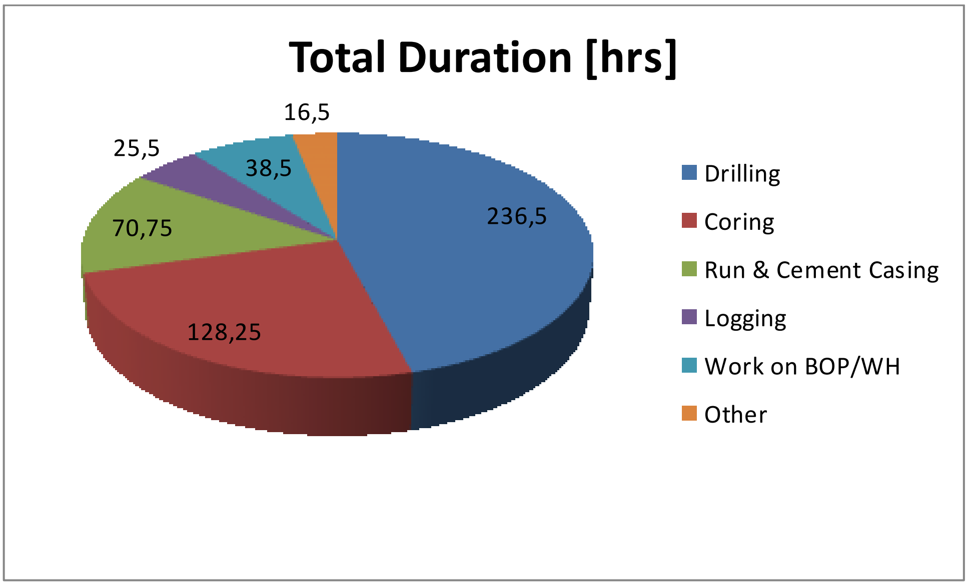


Figure 3.2: Time Analysis of well RLMR 801

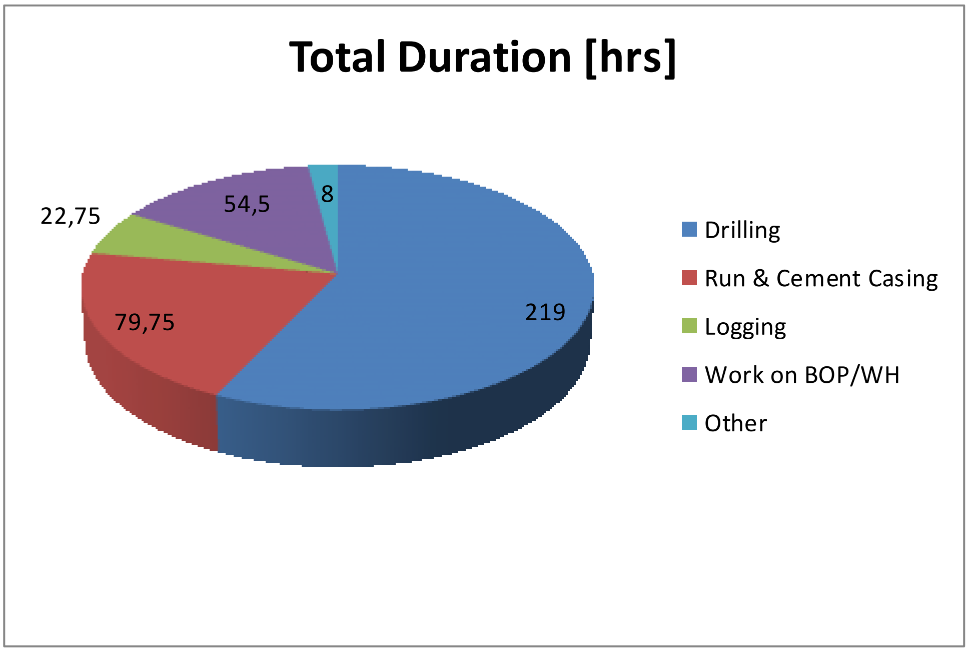


Figure 3.3: Time Analysis of well RLMR H 25

3.5 Geology

The Ruehle structure is characterized by an EW-trending elongated anticline. Geologically the reservoir contains the structure of the Bentheim Sandstone (“Oil sand”; Lower Valanginian, Lower Cretaceous) with a thickness between 10 to 80 m. The top of the structure (Upper Layer of the Bentheim Sandstone) ranges from -510 m TVDSS to more than -1000 m TVDSS. The initial OWC is approx. at -870 m TVDSS. Faulting within the Ruehlermoor structure, due to extensional tectonics, is dominated by normal faults with vertical throws ranging from less than 5 m to 40 m. Several faults exist in the reservoir with different orientation, though trends from 90° to 180° prevail. The convex layered reservoir provides a very good trap situation (Figure 3.4)

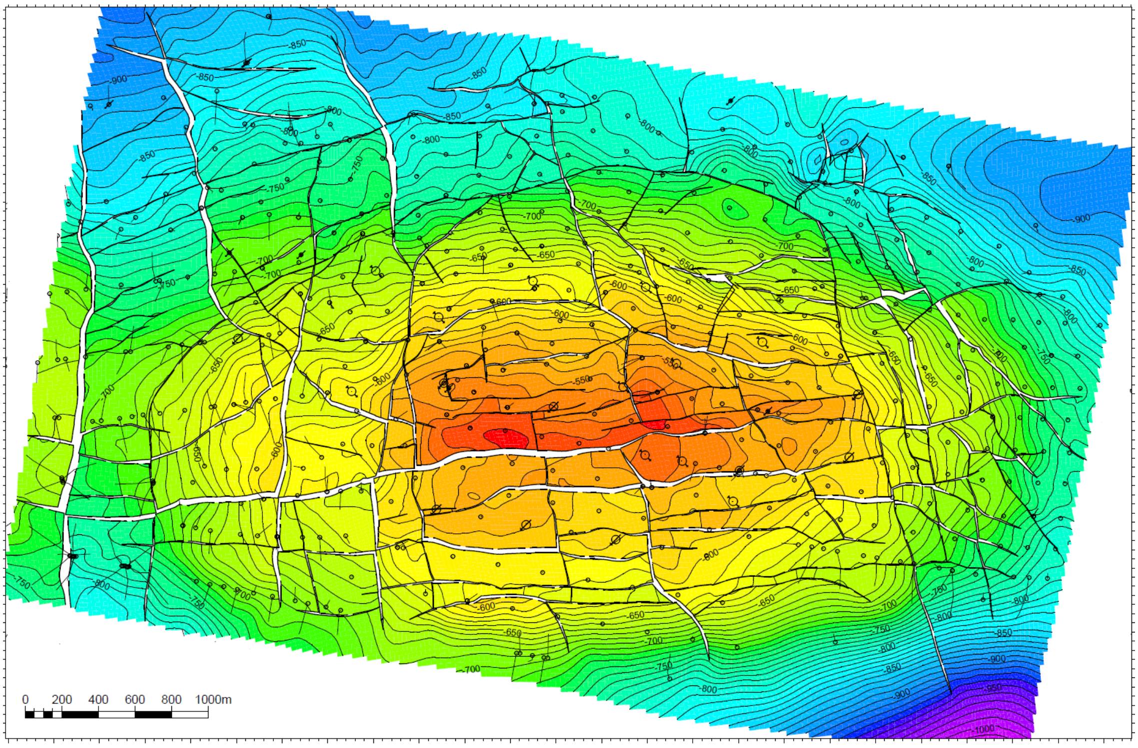


Figure 3.4: Geology structure Ruehlermoor

The oil bearing sandstone is subdivided into two different layers - the upper layer with thicknesses of 10 to 20 m and the lower layer with thicknesses of 8 to 26 m. In between them is a small shaly intercalation of 1 to 4 m. (Figure 3.5) This makes it possible to produce independently from both layers. The temperature gradient in this area of the Lower Saxony basin is 3.1 °C per 100 m. The actual average temperature in the reservoir is 35 °C and the oil has a viscosity of 120 cp. One major problem producing reservoir fluids in Ruehlermoor is H_2S with partly up to 10 Vol-percent for a short period during a steam break through. A breakthrough of steam occurs, if the pressure of the injected steam is that high, that the propagation of the steam through the pores is faster than the propagation of the oil. The steam “overtakes” the oil inside the flowing channels of the sandstone and comes out of the producer well. The average amount of H_2S production is 1 Vol-percent due to steam reactions in the reservoir. The high temperature dissolves the corrosive H_2S out of the oil. This is called steam distillation. The highest H_2S production occurs, when the gas breaks through with up to 220° C. The steam in the gas phase provides a good reservoir temperature increase. If steam becomes liquid because of the given pressure temperature conditions the propagation velocity of the oil decreases. To avoid this from happening, the pressure conditions in the reservoir and in the steam injection well has to be monitored and controlled at all time.

<table>
<tr><th colspan="4">Lithostratigraphy</th><th>Lithology</th></tr>
<tr><td colspan="4">Quarternary</td><td>Sand, fine gravel</td></tr>
<tr><td colspan="4">Tertiary</td><td>Clay, sand, claystone</td></tr>
<tr><td colspan="5">Transgression</td></tr>
<tr><td rowspan="13">Lower Cretaceous</td><td colspan="3">Albian</td><td>Marlstone, Claystone</td></tr>
<tr><td colspan="4">Transgression</td></tr>
<tr><td colspan="3">Aptian</td><td>Claystone</td></tr>
<tr><td colspan="4">Transgression</td></tr>
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<tr><td rowspan="8">Valanginian</td><td rowspan="3">Upper</td><td>Upper Valanginian (shaly)</td><td>Claystone</td></tr>
<tr><td>Dichotomite Beds (sandy)</td><td>Fine sandstone</td></tr>
<tr><td>Dichotomite Beds (shaly)</td><td>Claystone</td></tr>
<tr><td rowspan="5">Lower</td><td>Flaster Sandstone</td><td>Fine sandstone, Claystone</td></tr>
<tr><td>Bentheim Sandstone, Upper Layer</td><td>Sandstone</td></tr>
<tr><td>Bentheim Sandstone, shaly intercalation</td><td>Claystone</td></tr>
<tr><td>Bentheim Sandstone, Lower Layer</td><td>Sandstone</td></tr>
<tr><td>Platylenticeras Beds (shaly)</td><td>Claystone</td></tr>
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Figure 3.5: Geology profile Ruehlermoor

3.6 The Redevelopment project

This chapter describes the development process of the redevelopment project and the current position in the project plan. Different well schemes are shown and described to give an overview of how the future wells will most likely look like.

3.6.1. General description

The redevelopment project goes through different stages of development. (Figure 3.6) Now the project resides between Gate 3 and 4 in the Front End Engineering & Design (FEED) phase (red borderlines in Figure 3.6). Gate 4 will be in September 2016. Generally the rig selection is finished before Gate 3 starts (blue border lines in Figure 3.6). It was decided that the rig selection should be performed in the FEED phase, because of insufficient information about the future wells.

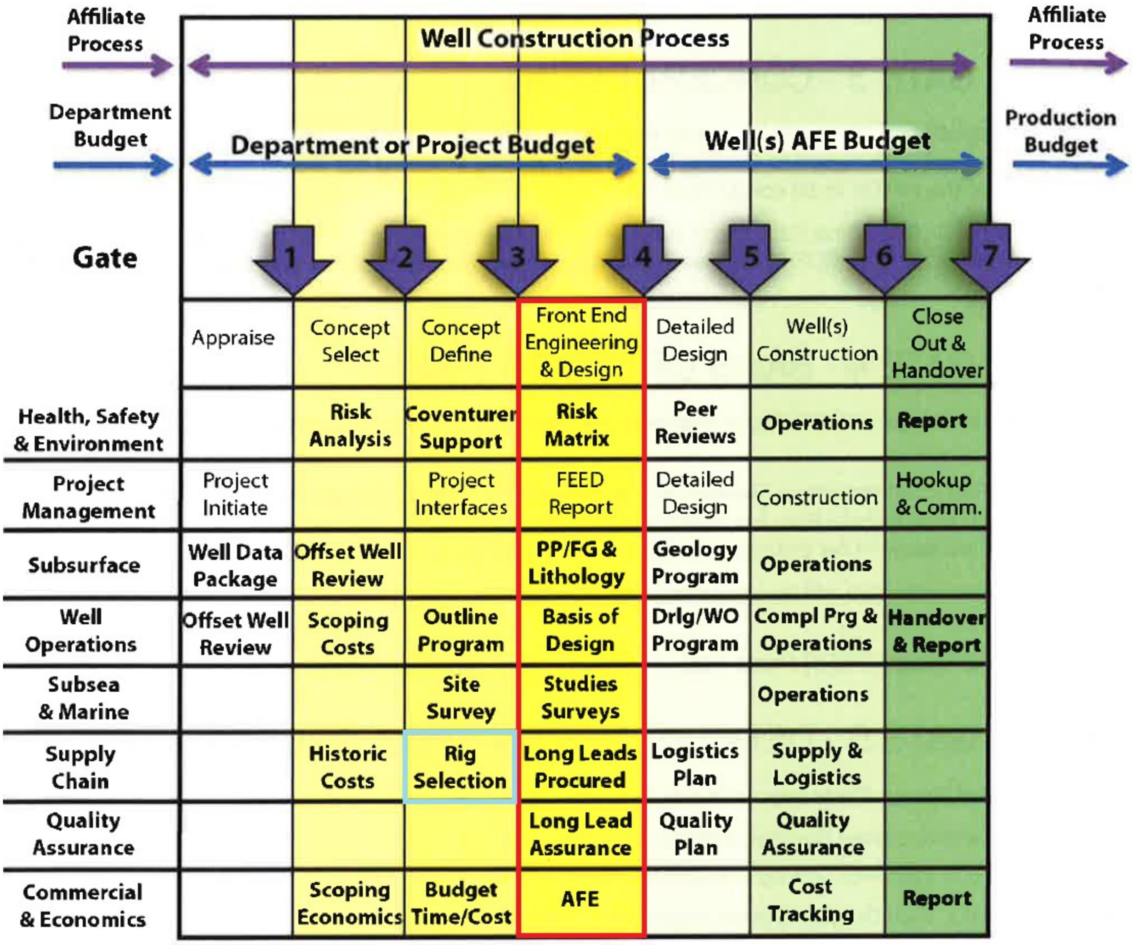

Figure 3.6: Well construction process gates

In 2010 EMPG came to the conclusion that the production pipelines of the field have to get renewed, because of their age and the raising possibility of failures. The existing pipelines are old and partly hardly corroded. The plan to redevelop the field has been started, because the pipelines and the existing steam production plant have to be renewed and on top of that the daily production stagnated. The actual steam production plant uses fresh water which has to be produced with additional water wells. The break-even point of the project is slightly over 60 $/bbl. The current oil price of 47.80 $/bbl [10] makes a decision difficult for such a long term project. It can only be granted if the expectation is that the oil price rises again until 2019, while the price is crucial for the project.

A new cogeneration plant is planned to be built until 2020, which could decrease the energy consumption of the steam production. 2020 is a crucial year, because government subsidies are secured until this year for cogeneration plants and this state support is crucial for an economic project. Also it would be able to use reservoir water, after upstream water processing instead of fresh water. Additionally these investments could be justified with the target to produce more oil with less energy consumption afterwards.

According to the current status the drilling phase of the project will start in January 2017 with building drilling sites, rails and streets to the new surface drilling sites.

It is not finalized, if the streets and rail way system will be renewed before the drilling phase starts and the full funding is triggered by the management with additional money, or if the renewal starts after the full funding. The renewal of the infrastructure takes approximately 3 – 5 month. Also during the project the maintenance of the infrastructure will be done continuously.

Before the cogeneration plant goes into production in 2020 at least 5 steam injection wells have to be drilled and connected to the plant with pipelines, so that the plant can work economically with minimum 40 % capacity. The plant is the biggest investment of the project.

3.6.2. The future wells schemes

At the status of October 2015 112 wells are planned for the redevelopment project: 80 producers, 18 steam injectors and 14 water injection wells. They will be drilled in 3 different phases. The wells of the first phase are responsible for enhancing the production and provide injection wells for steam. One by-product of the oil production in Ruehlermoor is gas. It will be used to supply the cogeneration plant as additional combustible to purchased gas. This reduces the overall working costs. In the second phase additional wells will be drilled to raise the production. After the second phase there is a drilling break to observe the reservoir behaviour and the eventually following

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drilling spots are fixed according the observations. If the pressure conditions, the production and injection behave like expected or the new spots are defined, the third drilling phase will start. The reservoir department has fixed the exact targets and starting points of the future wells. The detailed completion and casing design is still in discussion but the basics are finalized. The harsh environment with CO_2, H_2S and high temperature changes need a detailed casing planning with partly high steel grades. Following casing designs are planned and checked externally with a simulation process. Therefore, Halliburton provides different kinds of Landmark software. For high temperature/high pressure wells the software WELLCAT™ has to be used, because

> "WELLCAT casing design software lets engineers model complex HP/HT conditions and design the most appropriate casing and tubular design, while obtaining both the right well integrity and the best cost configuration". [11]

The alternatively used landmark software StressCheck™

> "…features graphical design tools and algorithms that automatically generate minimum-cost solutions that minimize the cost of well tubularsis not able to consider the high temperature changes". [12]

Therefore, it is not suitable for the future casing design simulation, because of high temperatures conditions. The redevelopment project is planned with the following casing designs:

Producer:

- 16 " Conductor up to 35 m
- 9 5/8" Casing up to 300 m (basis of tertiary)
- 7" Production casing tensioned up to roughly 600 m (basis of the flaser sandstone)
- 6 1/8" open hole with 5 ½" pre drilled liner and swell packer between the 2 reservoir layers

Steam injector

- 16" Conductor up to 35 m
- 9 5/8" and 7 " casing like the producer and with the 7" pulled in tension
- 5" liner with 50 m overlap in the 7" casing (cemented & perforated)

Water injector

- 16" Conductor up to 35 m
- 9 5/8" casing up to 300 m (basis of tertiary)
- 7" casing up to 1100 m (basis flaser sandstone)
- 5" casing up to 1500 m

All wells will be drilled in a 2-D J shape. The water injection wells will be drilled close to horizontal. The producer well will only have an inclination up to 40°.

3.7 Infield infrastructure

3.7.1. Dyke structure

The underground where the wells are located is in a very nontypical condition regarding to a drilling location. Local people call the underground pudding, because of its unconsolidated behaviour facing heavy loads. Figure 3.7 shows a typical dyke of the Ruehlermoor oil field:

1. Sucker rod pump of an existing well
2. Well head
3. Rail to the wellhead parallel to the main rail (Figure 3.7 and 3.8)
4. Main rail
5. Road with gravel or cement/bitumen
6. Renatured peat pit (in this case filled with water)
7. Up to 4 m of different peat & sand layers
8. Empty peat mining area before renaturing
9. Trees as a windbreak and the border and a stabilisation of the dyke
10. Drill cellar
11. Concrete foundation

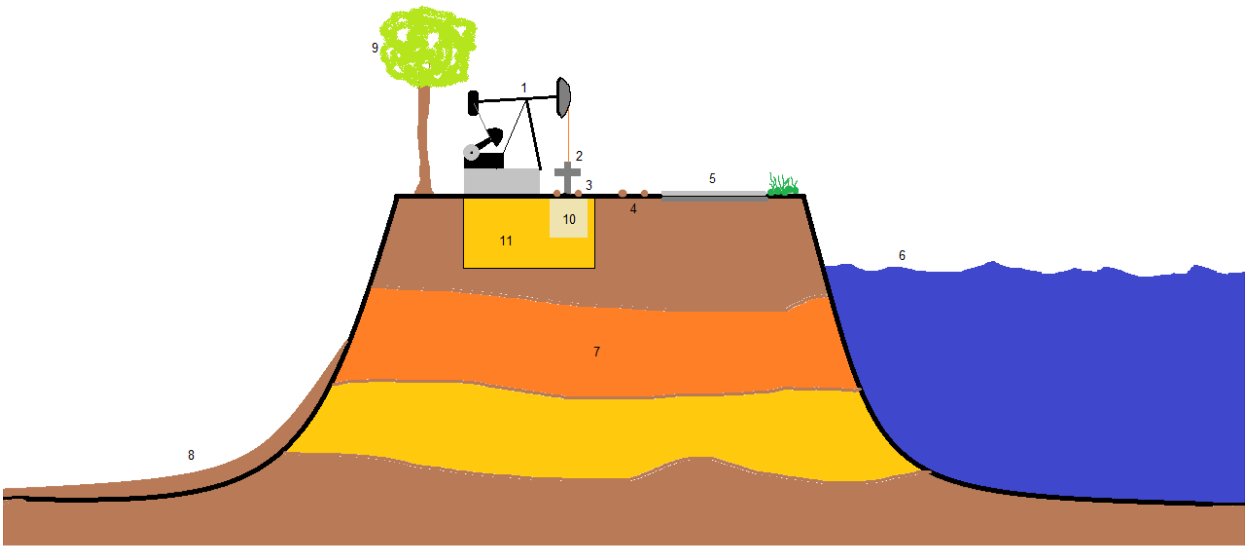

Figure 3.7 Typical dyke structure

Figure 3.8 shows the structure of the underground of the 12 dykes in the southern part of the Ruehlermoor oil field. They are between 27 and approx. 40 m wide. The structure is not very static against heavy loads with several tons, because of the narrow ground water level at around 1.40 – 2.15 m and additionally because of 2 - 4 different layers of sand, peat and humus. Therefore, transports with heavy loads are only allowed to drive in the field with a guide, with very slow velocity and as far as possible away from the slope. Dynamic loads like running pumps have a similar effect to the underground. They can subdivide over time. Figure 3.8 shows an underground study of dyke 4 directly at well RLMR 346. It is shown, that a 2.7 – 2.8 m thick reduction sensitive peaty layer directly under the topsoil covers a thin sandy and humus layer and a 1.8 – 1.9 m sand layer. This combination is responsible for the untypical elastic behavior of the underground called pudding. Several studies about the underground were made and the field personal knows of the behavior of the ground, but also after decades nobody knows exactly how heavy load transports will behave. Sometimes the ground shrinks under pressure and expands afterwards. This behavior may have caused an accident with a heavy load carrier and a transported crane, where the crane slips of the carrier while standing on rail overnight. The field personal found the crane next to the carrier but on the rail and on the underground nothing could be found. The rail was balanced and the determination after the accident found nothing extraordinary. The thickness of the underground layers can change everywhere on each dyke with no predictable behavior.

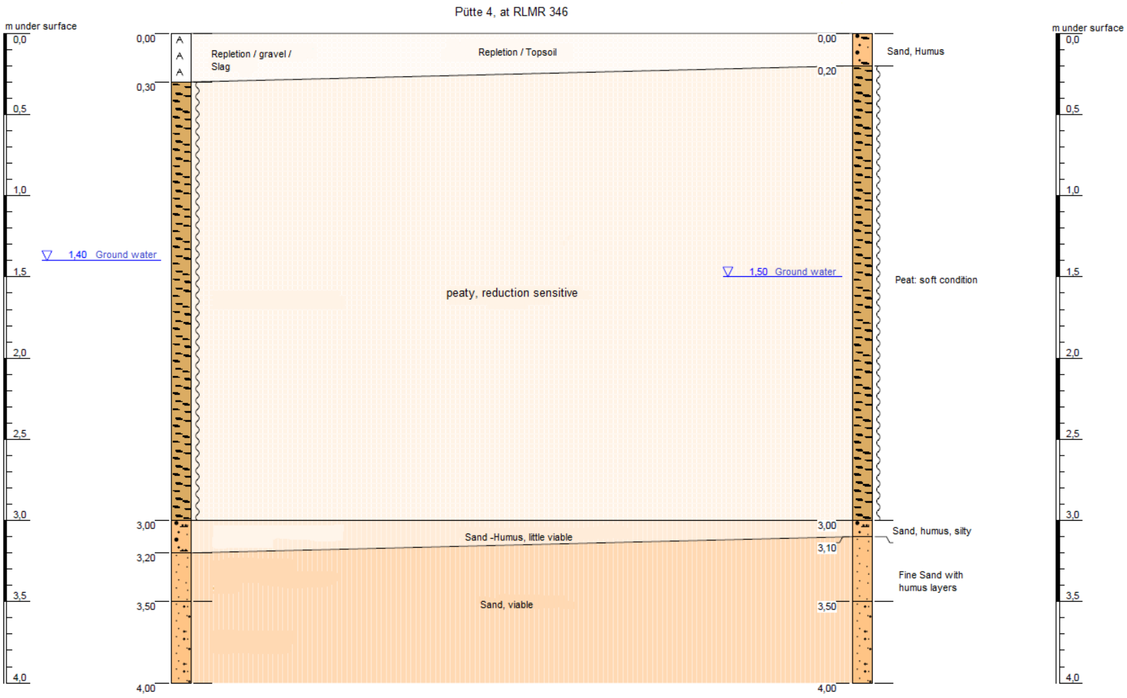

Figure 3.8 Underground of dyke 4

3.7.2. The Train and the rail condition

Figure 3.9: CHL 40 locomotive and a shunting engine

Figure 3.10: Typical Train in the Ruehlermoor oil field [6]

The rail way system in Ruehlermoor is over 100 km long (Figure 3.12) and all wells and drilling locations are accessible with it. The rail infrastructure connects the northern part and the southern part with 2 crossing points of the public road L-47. Also the tool house, the storage area with the mud mixing plant and the head office area in the north east of the field are reachable by rail.

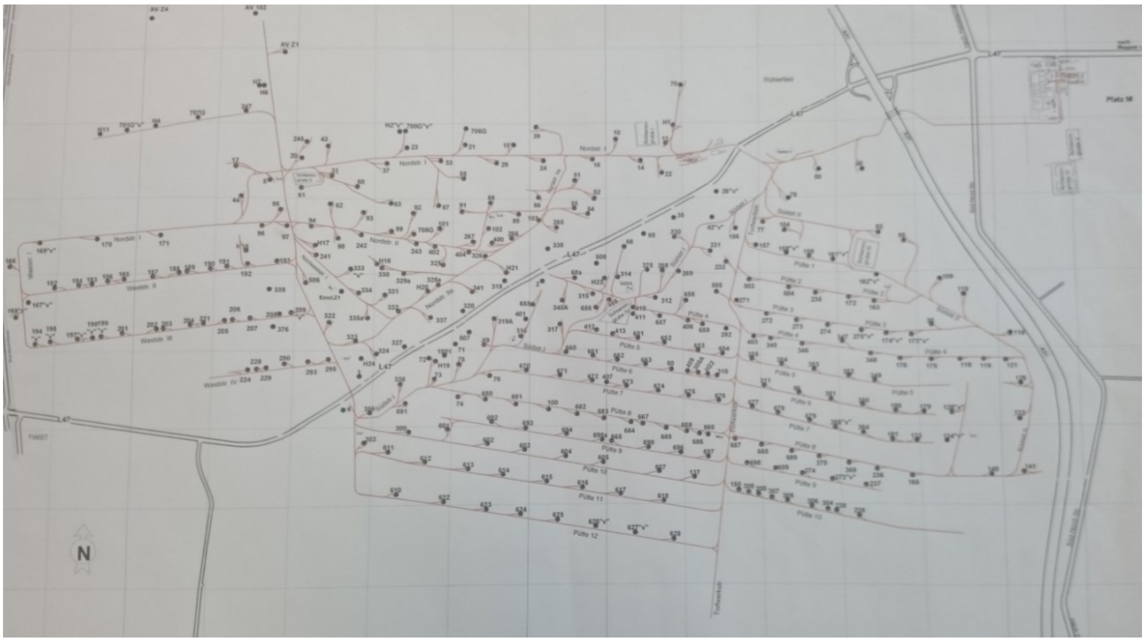

Figure 3.12: Rail way system in Ruehlermoor

GDF Suez operates 11 diesel-hydraulic driven locomotives for the field which are built by the manufacturer “Schöma”. They are separated in 2 different types with different pulling force capacity. The bigger CHL 40 G and the smaller CHL 30 G shunting

engine. They are partly over 30 years old, but still working daily in the field. 2 CHL 40 G were bought in the 90s and 1 was bought in 2013. With 7 t working weight, an axle load of 3.5 t and 63 horse power a maximum speed of 15.3 km/h is reachable. It has a maximum tractive effort of 23.3 kN. With this power - depending of the driving speed - a load up to approximately 238 tons can be pulled horizontally (Figure 3.11).
The driver has the possibility to use the air conditioning and the auxiliary heating. To increase the safety of the people some devices are available. The locomotive can be operated with a remote control to enable one driver operating the train as well as the manual switches safely. Furthermore, the locomotives are connected with a radio set for an easy communication between the crew. If the public street L-47 has to be crossed by a train, the driver has to stop in front of the street, change the traffic lights to red with a key and cross it afterwards.

CHL-40G

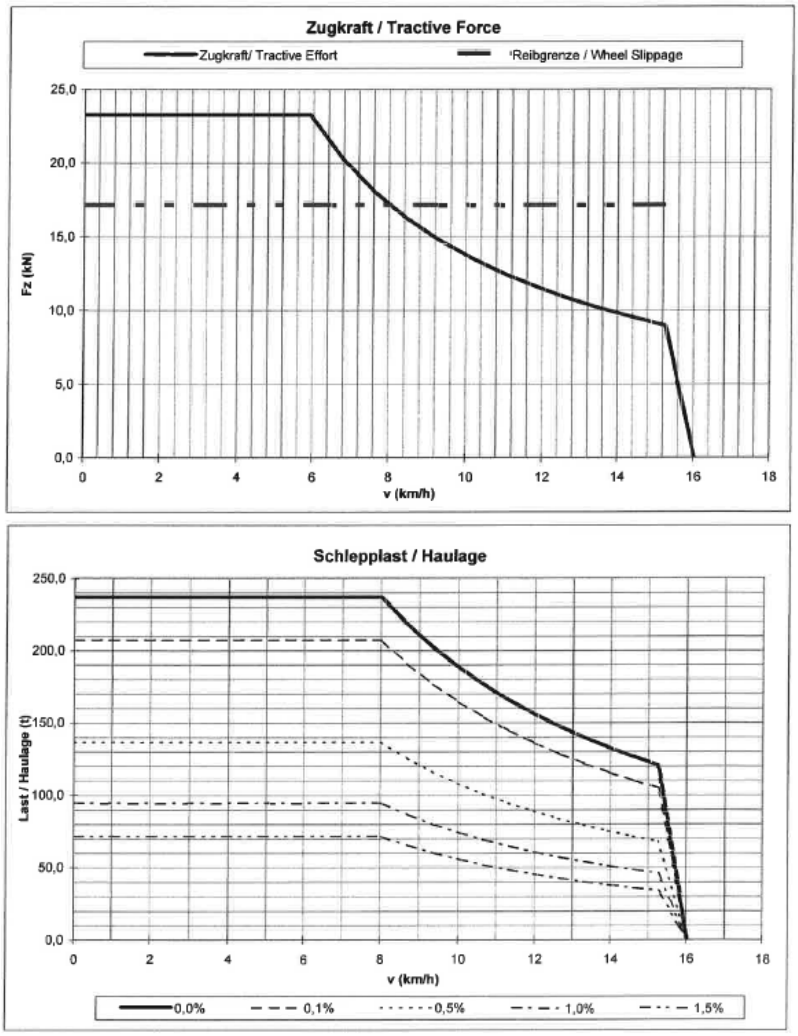

Figure 3.11: Performance chart CHL 40 G

During the redevelopment project GDF Suez will be responsible for all train transport where the load will be restricted to 150 tons total train weight, because of the already mentioned underground conditions. This is also the reason why most of the transport has to be done by rail. The streets and the dykes may do not withstand the huge quantity of transports during the project.
Within the field 2 different rail types for 2 different loads are installed. The S-20 or S-27 rail for loads up to 5 tons per axle (less steel diameter and a brief different structure) and the S-30 rail for heavier transports up to 15 tons per axle (max. 60 tons) and a minimum curve radius of 31.8 m. This radius will be able to change for the redevelopment project, because the value of 31.8 m was developed for the current tasks in the field.
All used rails have to be changed to the S-30, because the expected loads during the rig move will be more than 5 tons per axle, and thus are too much for the S-20 or S-27 rail. A few hundred meters long test rail will be built before the project starts to analyze the behaviour of the underground facing a load of 15 tons per axle and 60 tons total weight. This weight has been declared in the tender documents.
Until now the future moving procedure and the logistic concept is under development. Different possibilities and opportunities for the project are feasible. Maybe a joint venture with the peat mining company, who also uses the rail could support the rig move or provides personal to develop a suitable logistic concept. Also purchasing of new locomotives with different parameters is possible, because the locomotives working in the field are ideal for the current tasks and not for the future ones. This redevelopment forces the organisation team to think “out of the box”, to find new ways to work in the field Ruehlermoor and solve problems which have never been there before.

3.7.3. The Carrier

For the infield transport different kind of carriers are used for the different purposes. 4 of them, which are currently used for the requirements of GDF Suez and EMPG are a good reference for the future redevelopment project and are shown in the following table and in Figure 3.13 – 3.16.

Table 3.1: Different carrier in Ruelermoor

Type	**Dimensions of loading area [L x B x H in m]**	**Possible loading capacity [t]**
1. Multi carrier	8.3 x 2.4 x 0.5	25
2. Pipe carrier	For different pipe length changeable	2 7/8” up to 100 pipes 3 ½” up to 70 pipes
3. Heavy load carrier 1	8.6 x 2.8 x 0.9	40
4. Heavy load carrier 2	9.0 x 1.20 x 0.55	40

The multicarrier (Figure 3.13) provides different load scenarios. The carrier was constructed to take loads up to 25 tons on two double axles in two 10 feet container or one 20 feet container. The containers are fixed at the carrier with a special locking device. Other loads like BOP, stairs, a closing unit, pumps etc. are also transportable. The relatively low height results in an easy loading and safety benefits. If the carrier is equipped with an office or crew container an entrance area is still available. Therefore, 6 foldable stairs and stackable handrails are constructed at different points on the carrier for additional safety if the crew wanted to enter the container. The carriers are manufactured by a company called “Busch”. The construction of the multicarrier carrier takes around 6 month.

For the future project the load scenarios or the carrier and/or the design can change because of different requirements. The advantages of this existing carrier are that the technical drawings exist, and thus can be easily and fast be rebuilt. They are tested and they are a good option for a safe container transport. The risk to take this design is, that they might not be suitable for the future loads and a new design has to be developed which consumes time and money. The new design results in an eventual new concept that has not been audited and contains some uncertainties.

Figure 3.13: Multicarrier

The drill pipe and casing transport is done with the pipe transportation carrier shown in Figure 3.14. In principle it is a combination of two u-shape steel frameworks which are fixed on rail cars and connected with each other with a steel pipe. Inside of the "U" the pipes or casings are placed in several layers and transported to the site.

Figure 3.14: Pipe transportation carrier

Figure 3.15: Heavy load carrier 1

Two heavy load carriers (Figure 3.15 and 3.16) are able to move loads up to 40 t on two double axles with a maximum total weight of 60 t. The distance between the two double axles is 13.5/13.8 m. Heavy load carrier 1 (Figure 3.15) was used to transport heavy machinery such as a cementing unit. This carrier can be used for the future rig move. With a transportation area height of ca. 1 m it can be loaded with a crane or a fork lift. The resulting centre of gravity of transported loads compared to the multicarrier is higher and poses higher risks for accidents or uncertain situations.
60 ton wheel cranes are too heavy to drive inside the field. Therefore, the heavy load carrier 2 (Figure 3.16) has been constructed. With its small transport area of 1.20 m width and a low height of 0.55 m this device can be used for vehicle transport. For preparation of the transport one rail chassis gets dismantled and the vehicle can drive over the loading area. Afterwards the rail chassis gets installed again. To move the vehicle, the loading area is elevated hydraulically and fixed to the framework or the substructure of the vehicle. This carrier is a special device and can only be used for narrow loads or vehicles. Additionally for each vehicle an individual framework has to be built to connect it with the loading area.

Figure 3.16: Heavy load carrier 2

Some other and older carriers are part of the carrier pool of GDF Suez. However these are not suitable for the project because of not enough loading capacity or they are otherwise involved in the daily workover procedures.
All mentioned carriers are planned and constructed for the current circumstances and requirements of the oil field. During the future redevelopment project, additionally to the changing requirements other carriers and concepts are possible. The future contractor has to instruct a manufacturer of rail carrier and work with him together closely. The recommendations of the future rig may change extremely to the recommendations today.

For new planned and constructed rail carrier only a few restrictions are available:

- Max. transported part width: 4 m
- Max. rail trolley distance: 13.5 m
- Max. total weight of carrier and load: 60 tons
- Max. part length: around 20 m
- Rail width: 900 mm

Furthermore, the safety of the transport is very important. A low centre of gravity and an equally distributed weight helps to transport parts easily and safely. The crew has to be instructed before every move. The training of the personal and the communication via radio during the move is extremely important.

3.7.4. Road Transport with Tractor, Crawler crane & Unimog

The unconsolidated underground makes it difficult to be driven on it with heavy loads. For preparing a street on the dyke it has to be covered with gravel and asphalt or bitumen. Because of the high investigation and costs for street preparation, most of the roads in the field are covered only with gravel. Figure 3.17 shows the road net of the Ruelermoor oil field.

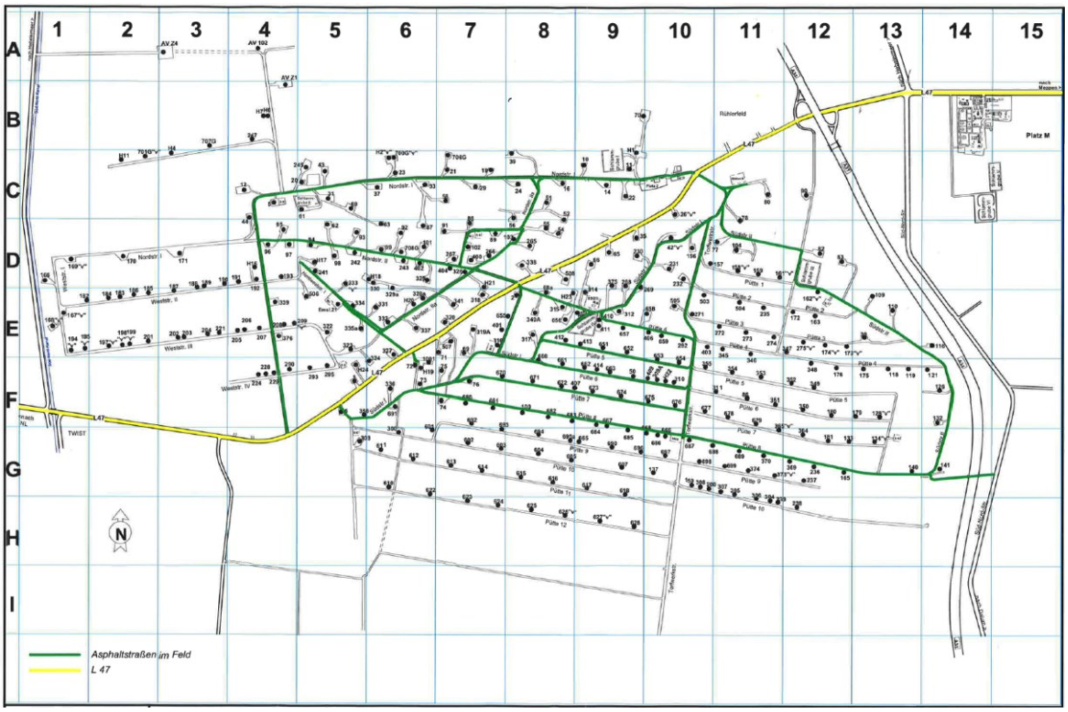

Figure 3.17: Roads in the Ruehlermoor Oilfield

The different colours indicate the various load capacities allowed and the recommended frequencies of utilization. The green line indicates a heavy load road. Once a day you are allowed to drive on it with a maximum load of 40 tons total

transportation weight. These utilization recommendations are not always possible to consider and result in street and/or dyke damage. This street is manufactured with two asphalt layers and a bitumen layer in between. The yellow road is the public road L 47. All other roads are prepared with gravel with a maximum axle load capacity of 1 ton. Transports heavier than 7.5 ton per axle are only allowed to drive on the green marked streets, with walking velocity and only with an additional GDF Suez guiding car. This procedure was developed during the lifetime of the field of infield personal.
The streets are 3 to 4 m wide. This is so narrow that it is difficult to pass with two vehicles simultaneously. Usually one of the vehicles has to wait or drive backwords to an area like a cemented well location to let the other vehicle pass through first.
Different kinds of vehicles are driving through the field: cars, transporters, tractors, the crawler crane or the Mercedes-Benz Unimog or simplified Unimog. Each of them drives within the field with different frequencies and for various reasons. During the redevelopment project the amount of vehicles within the field will increase extremely, because of simultaneously working people.
Cars are mostly used for inspection drives by GDF Suez or EMPG. If something has to be maintained at well site of a producing or abandonment well, the crews of EMPG uses small transporters loaded with equipment. If a bigger problem at a well occurs GDF Suez will work over the well with several available rail mounted workover rigs.
For hoisting of lighter loads at the well site area like BOP´s, Annular Preventer, tongs etc. a Unimog with a Palfinger crane can be used. This crane has a 400° working area and a maximum hoisting capacity of 5700 kg [7]. With increasing distance between the hoisted load and the Unimog the hoisting capacity changes significantly (Figure 3.18).

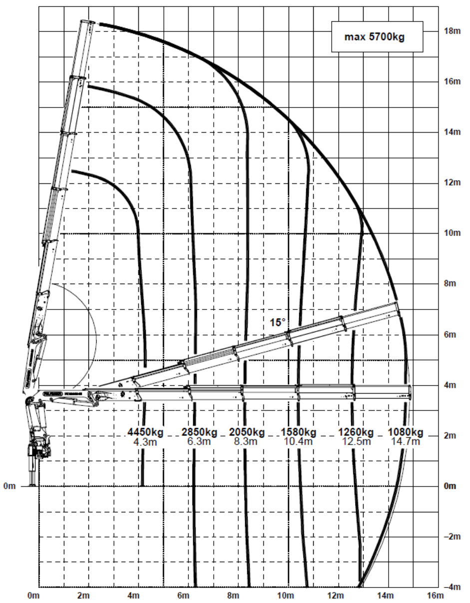

Figure 3.18: Load capacity of the Mercedes-Benz Unimog

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The machine has a small load area behind the driver’s cabin, where loads can be stored or transported with. This diesel driven machine is built to work continuously also with heavier loads of a few tons. Alternatively a 5 – 8 t “Manitou” forklift can assist the drilling and workover team with transport by placing the equipment within the drilling site. Furthermore, during drilling operations this device is used to transport drill pipes and casings to the pipe rack. Basically every time a forklift must be available during drilling operations.

In case of heavier loads the existing crawler crane has to be used. For the rig move during the redevelopment project - depending on which type of concept – one or two crawler cranes have to be used to hoist and load heavy equipment with a maximum possible weight of 42.3 t. Also for the hoisting jobs with the crane it has to be considered that with increasing distance between the hoisted load and the crane the hoisting capacity changes (Figure 3.20).

The main advantage of the crawler crane is that it is allowed to drive in the field due to the equal load distribution through the chains. With a maximum speed of 10 km/h the traveling time of the crane should be considered. At the drilling site the crane can move with small loads on its hook, but this should be voided due to safety reasons. Additionally tractors and carriers can support the moving process.

Figure 3.19: 60 t crawler crane

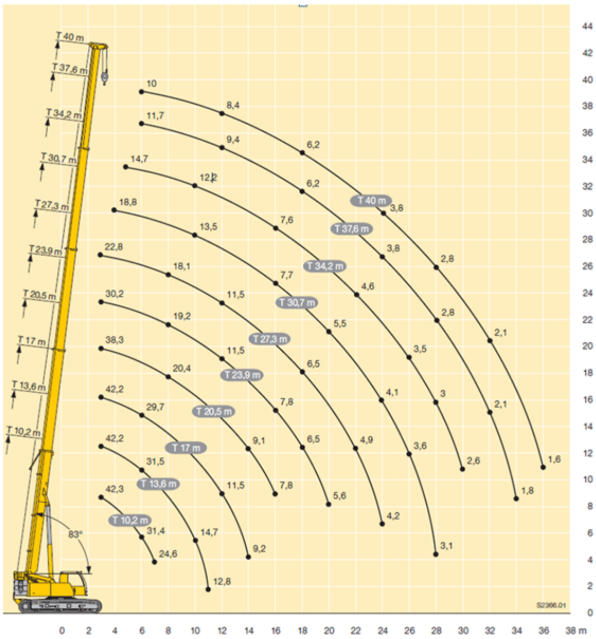

Figure: 3.20: Load capacity 60 t crawler crane

Within the field there are some trailers and tractors available. These agricultural machines are flexibly applicable and in the past loads up to 14 t were transported with the trailers. Also the hydraulic arm of the tractor can be used for hoisting or with a mounted bucket for charging and waste disposal work. Also a fork can be mounted to the hydraulic arm to support the drilling crew like the Manitou fork lift.

3.8 Logistics / Infrastructure utilization

The logistic will be a challenge during the redevelopment project due to the fact that different companies are using the infrastructure at the same time and because of hundreds of people working in the field simultaneously. While organizing the traffic in the Ruehlermoor oil field some specifics have to be considered. It is not possible for vehicles like trucks, tractors or cranes to pass each other on a street. They are too narrow and next to the streets is peat. The danger of getting stuck or slip down the dyke is too high. Subsequently circle traffic has to be established which means time loss for transports. Additionally the frequencies of transports per day are limited on the dykes to ensure the resistivity of the underground and enhance the lifetime of the streets. During the project several companies will work in the field simultaneously: The peat mining company, the pipeline constructors, the drilling site builders, the workover team for the existing wells and the drilling team. They are using the rail and street net. Figure 3.21 shows the future chronological construction process and infrastructure utilization with simultaneously working crafts during the redevelopment project.

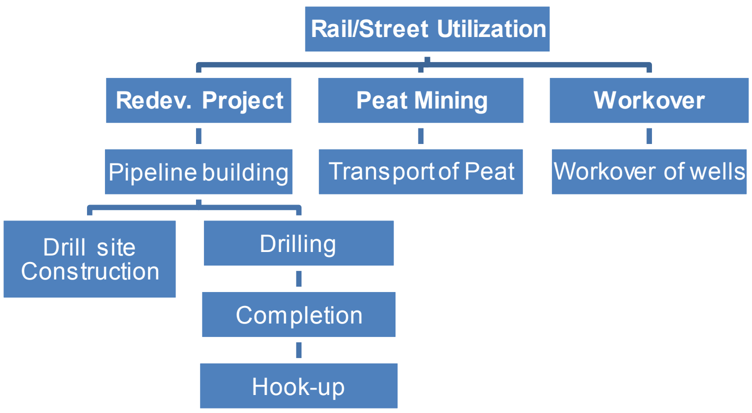

Figure 3.21: Chronological construction procedure

Before the redevelopment project will starts, the logistic has to be planned and the infrastructure has to be capable of supporting the future amount of trucks, cars, trains and cranes. Therefore, the proposal is to assure this traffic with rail and street maintenance or with replacing old rails/streets in advance. After the construction of the first part of the infrastructure all other crafts can use them. For the drilling activities the drilling pad will be built first, which starts after the pipeline construction team and the

infrastructure team finishes their work. (Figure 3.21) That does not mean that all drilling pads have to be prepared before drilling can start. A well operation team of people will be organized at the office facility next to the field to handle the estimated 300 – 500 people. The team contains people which are directly involved in different crafts in the daily work during the redevelopment. They organize the operation and the logistics every day on 7 days a week partly in shifts for 24 hours. The workover will be organized from another department. Old and new wells need workover with small rail mounted workover rigs (roughly 60 t hook load capacity) to work efficiently. At older wells maintenance jobs will be done and at the new ones the completion gets installed.
The peat mining is organized from a different company. At this point of time, it is discussed, if it is necessary to replace the complete rail net to deal with the tremendous traffic effort which will occur during the project.
During the redevelopment project the rig move will have a big influence at the success of the project. Therefore, a rig move scenario was developed to give the contractor the possibility to plan the rig move in detail. This will also provide the opportunity to involve the rig move scenario into the technical evaluation.
Figure 3.22 shows the scenario. The distance between well A and B is 300 m with two existing wells – here called sidetracks - in between with 100 m distance to each other and one additional sidetrack next to well B. These sidetracks are arround 40 m long and can be used to park equipment or to pass other locomotives. If driving over a neigbor dyke is needed, 1000 m has to be taken into account.

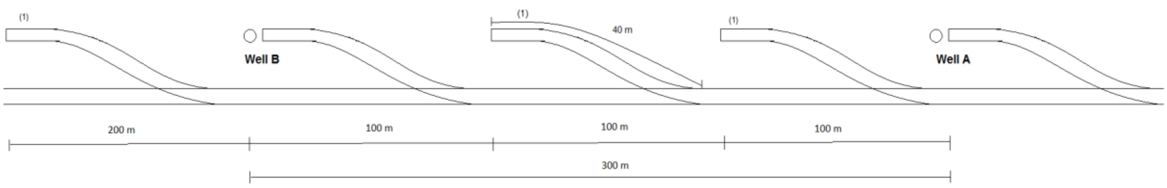

Figure 3.2: Rig move scenario

For the calculation of driving times and rig move organisation following data was provided:

- Distance Well A to Well B (direct): 300 m
- Distance Well A to Well B (indirect over a neighbor dyke): 1000 m
- Length of sidetrack (1): ca. 40 m
- Train speed with load: 4 km/h
- Locomotive speed without load: 15 km/h

- Max. single transport load: 60 t
- Max. single transport length: ca. 20 m
- Max. tractive force of the locomotive: 150 (e.g. 5 x 30 t)
- Max. length of the train: depending on the weight of the single transport weights
- Max. distance between two axles: 13.8 m
- Min. Curve radius of the S-30 rail 31.8 m
- Rail width: 900 mm

With this data the contractors plan their rig move. A detailed analysis of this scenario can be found in chapter 10.1 “The rig move scenario”

4. Drilling Rig Franks Cabot 300/11

This chapter discusses the company´s own rig which was first used for workover operations and later on for drilling operations/activities. Moreover a small overview about the actual drilling site is shown, which can be used for drilling operations.

4.1 Rig Specifications

The drilling operations performed by the drilling rig Franks Cabot 300/11 later on called as the “300” started in November 2002 in the Ruehlermoor oilfield. Before, it was located for workover projects in Hamburg. The 300 is operated and maintained by GDF Suez personal. This kind of carrier based rigs with a pre-installed self-erecting mast is able to drive on public roads without special permits. The 300 is a carrier rig and weights of roughly 38 tons.
For the requirements in the oil field Ruehlermoor remarkable modifications at the 300 have been done over the last 13 years, mainly because the equipment of the 300 workover rig was not capable for drilling activities. Tanks, pumps, the rotary table and the substructure were renewed or modified. The old water pumps were not powerful enough and not able to pump mud sufficiently, a proper substructure which includes the rotary table was brought. During work over a small rotary table was mounted on the BOP which is not allowed for drilling activities. Furthermore, safety inspections were done and critical points like weak structural welds, old ropes or similar issues were repaired or replaced.
The rig is too heavy to drive in the field on wheels. For moving two hydraulically adjustable rail chassis were installed to the framework of the rig - one behind the first double axle and the other one at the end. This hydraulic device allows lowering and increasing of the transportation height. Both rail chassis together weight additional 2 tons. For the first wells the rig was driven on rail in the field. The higher centre of gravity on the 900 mm rail caused by the rail chassis was a problem regarding safety. The transport on rail was a shaky procedure. An emergency button allows lowering the rig on the wheels in a fast manner. After a few transports on rail the crew decided to drive with one side (wheels pairs) of the rig between the rails and with the other side on steel plates which were laid on street. It was an elaborate action but because of safety reason the preferred procedure. Figure 4.1 and 4.2 show the 300 in working position with an elevated and guyed mast, but with the drill floor in down position. A detailed equipment list of the 300 can be found in the appendix under the point 13.2.

Figure 4.1: Franks Cabot 300/11 Pic.1

Figure 4.2: Franks Cabot 300/11 Pic.2

4.2 Drilling site

The redevelopment project plans with over 110 wells which need to be drilled. All these wells need drilling sites which are organized the same to simplify the procedure and ensure a learning curve in rig move and drill site construction time during the project. 3 sites need to be prepared at the same time to fulfil the time plan for drilling 2 wells a month. The drilling area design is adapted to the local requirements. These requirements were part of the rig tender that the future rig is fit for purpose in regards to weight and size limitations in the Ruehlermoor field. If the local conditions do not ensure a proper drilling area the dyke can be changed in a way of enlargement, but this is time and money consuming. For the 300 this enlargement of 3 m was a procedure to have enough space for an emergency exit and for the forklift which needed space to move and transport parts within the drill site. For preparation of the well site first the peat will be excavated for 40 – 60 cm with an excavator on chains, which was transported to site by heavy load rail carrier. The excavated peat will be transported on rail at a central place and reused in the field, for example to repair damaged dykes. For the cellar the peat will be excavated until the sand layer underneath the peat in 3.5 to 4 m in depth. (Figure 3.7)

There are 2 zones at the drilling site. Zone 1 is the zone directly bearing the drilling rig including the cellar. This zone is cemented. The cement was brought by half-filled cement trucks to observe the load restrictions of the streets. In the past, roughly 4 trucks a day were needed to provide enough cement for the cementing job. The second zone is the surrounding area where the other equipment will be placed. This area will be equipped with a geotextile under a layer of sand and wooden plates on top. This combination of materials ensures a better load distribution in the underground.

For the future project the drilling site will be cemented or, to reduce excavation and transportation of peat, steel beams will be rammed into the ground to carry the expected loads under zone 1. This action will help to support the preservation of the dykes because of less sand transports.

Zone 2 is also for the future drilling operation the space where containers, pumps, generators, etc. are placed and where the forklift or other vehicles can drive. If the ground under the wooden plates subsides over time or during high driving frequencies, it gets refilled with additional sand. Zone 1 will be covered with a layer of sand under the cement. The sand will be transported via tractor and carrier. Before preparation of the site a conductor casing will be rammed up to 35 m with a machine transported like the excavator on rail. To coordinate the significant amount of transports per week, a coordination and safety meeting will be hosted regularly. The cement trucks and tractors are allowed to drive very slowly on wheels on the streets. The complete

construction of a drilling site in Ruehlermoor takes around 6 weeks including hardening time of the cement.
Figure 4.3 shows the smallest drilling site in the field Ruehlermoor with 90 m length and 30 m width. This site was prepared for the drilling operation with the 300 of the RLMR 801. The arrangement shows, that the space used for future drilling operations is very limited.

To Figure 4.3:
1: Franks Cabot 300/11
2: Pipe rack
3: 3 x Piston pumps
4: Diesel tank
5: 2 x Fresh water tank
6: Suction tank
7: Shaker tank
8: 2 x Generator
9: Hydraulic power unit (HPU)
10: Closing unit
11: Electricity manifold
12: Tool house
13: 2 x Cutting tank
14: Centrifuge
15: Directional-drilling-service
16: Mud service
17: Geodata container
18: Spare parts container
19: Waste container
20: Office and Sleeper container
21: Washing container
22: Drillers & Team container
23: 2 x Toolpusher containers

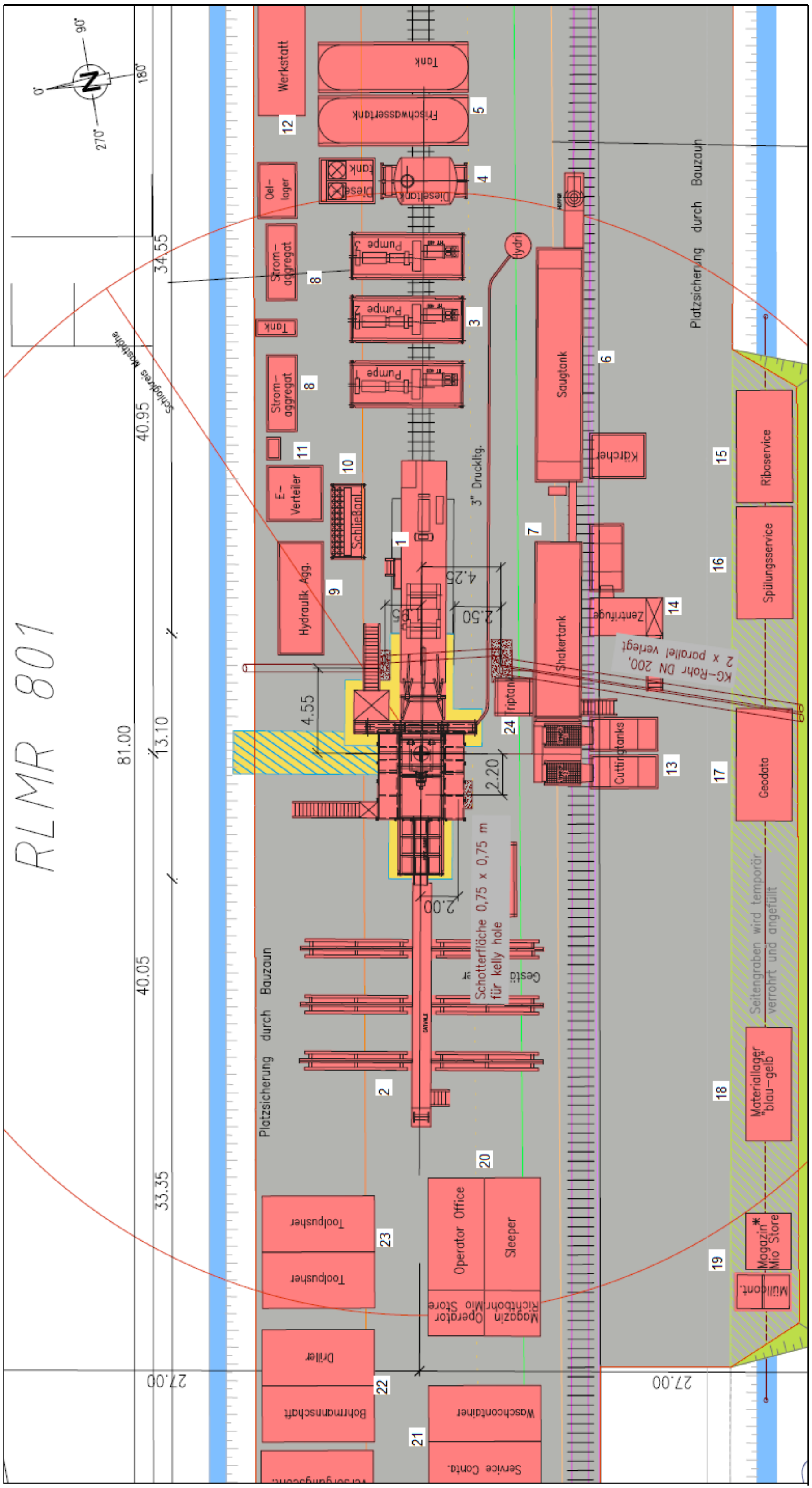

Figure 4.3: Drilling area RLMR 801

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The plan is to have the possibility to place the wells as close to each other as possible or to an already existing one. Therefore, two conditions have to be fulfilled. First the rail – the side track - to the well has to be installed in an unconventional manner (Figure 4.5) to reduce the space between 2 wells. Unconventional because until now the 300 and older rigs used in the field had only the possibility to mount the flowline at one side of the drill floor and because of that the conventional rail organization (Figure 4.4) was established. On most locations there is no possibility to place the cutting box on the side of the rig where no rail is placed, because of the slope of the dyke next to the wells (Figure 3.7). Second the future rig has to have the possibility to install the flow line and the mud tanks on both sides of the mast to avoid the mentioned problem.

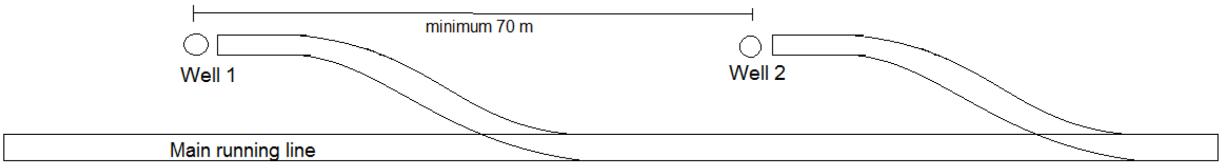

Figure 4.4: Conventional rail organization

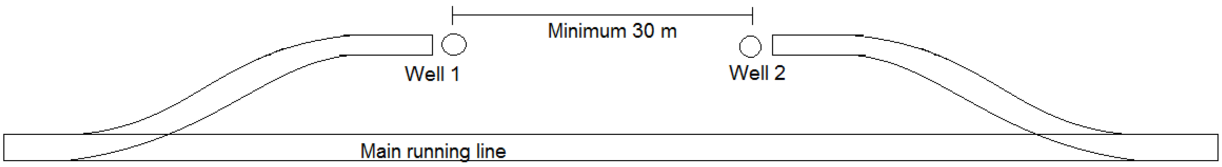

Figure 4.5: Unconventional rail organization

Figure 4.5 shows a possibility to arrange future rails to reduce the space between the wells. The advantage of the organisation of wells with the unconventional rail organization is that the distance between two wells is smaller and the possibilities for the reservoir department to place new wells gets bigger, because less space of the dykes are blocked with rails and drilling sites.

5. Economically view to work with a contractor

The 300 is a drilling rig which was built in 1982. For the work in the field Ruehlermoor it got a range of modifications to fulfil the requirements. Predictable the 300 is not able to drill continuously 20 wells a year, because of its age and the needed maintenance resulting of the continuous work. The risk of failure is relatively high. This was documented during drilling with the 300.

Certainly the pure economy should be considered in this chapter. A real case of the old rig 300 with GDF personal is compared with a new rig which will be operated by a contractor. For a drilling campaign like the redevelopment project the 300 needs an additional upgrade to the upgrade which was done at the beginning of drilling in Ruehlermoor. Table 5.1 shows the view on the upgrade costs which include following points:

- A detailed engineering on mast strength
  - Lengthening of 4 m to accommodate range 2 doubles (including guying pattern) or,
  - Torque tube to accommodate TDS/power swivel with range 3 singles. Also potential lengthening requirement
- Detailed engineering on suitability to use a higher substructure
- Enhanced pipe handling and rotary equipment
- Sufficient mud pump and solid control equipment
- Sufficient power pack (generator)

In addition the following is recommended to increase the overall performance of the drilling operations

- Evaluate maintenance system
- Review drilling program for drilling optimization
  - Casing drilling & directional control
  - Necessity of logging operations
  - Necessity of reaming & check
- Evaluate rig move procedures

Table 5.1: Cost calculation Rig Cabot Franks 300/11

Drilling Rig Cabot Franks 300/11 Calculation of specific rate for Rig Upgrade	
Total Upgrade Costs	2.691.000 €
Depreciation, interest, repairs & maintenance (Ref. Framework rule on governance, financing and settlement of funding operations)	20% per Year
Operating Costs	5% per Year
Operating time	6.720 h/a
Rig Upgrade Rate	100 €/h

Table 5.2 shows the costs of the drilling campaign of the redevelopment project using the 300 including the upgrade costs. The costs in the table consider the real costs of the RLMR 414 drilled with the 300 with a 100 €/h additional rate to improve the 300 technically to withstand the requirements of the redevelopment project – the upgrade costs. An operating rate of 6.720 hours per year is for the condition of the 300 a really optimistic value. The ability for the 300 to work under this condition cannot be guaranteed. This was observed in past drilling activities.

Table 5.2: Cost estimation Rig Cabot Franks 300/11

Drilling Rig Franks Cabot 300/11 - Rig Rate RLMR Re-Development	
Rig with standard Equipment	274 €/h
Drilling Personnel	392 €/h
Rig Upgrade	100 €/h
Total Rig Rate without Energy	766 €/h

A framework agreement is a reasonable possibility to find a comparison to the costs caused by the 300. Table 5.3 shows the costs with all agreed equipment for a 120 t onshore drilling rig operated by a contractor. The total operation rig rate (100 %

(without energy)) is 44 € cheaper than the work with the 300. Additionally the contractor provides the personal and the maintenance system. In this case taking cooperation with a contractor into account is a reasonable procedure to reduce costs during operation because of the lower rig rate and future costs by less personal and no needed maintenance system. Then, GDF Suez will be responsible only for the train and street infrastructure during the redevelopment project.

Table 5.3: Rig cost of a contractor

120 t onshore drilling rig Rig rates per hour for drilling operation	
Rig rate, without energy (100%)	720 €
Reduced rig rate (90%)	648 €
Repair rate (80%)	576 €
Special rate (70 %)	504 €
Standby rate (50%)	360 €

These considerations lead to appoint a drilling contractor for the redevelopment project.

6. The tendering process

The certainty that never before a drilling campaign with over 100 wells in 5 years including the given load and space restriction was done, leads to a rethinking process about drilling in Ruehlermoor. The situation with the 300, the infrastructure, the locomotives and the carrier were developed over decades and are optimal for the current situation. However, this project includes more drilling activities in less time in which the entire process has to be rethought.
At the beginning of the redevelopment project the plan was to take the existing company own carrier rig Franks Cabot 300. Predictable the rig was in its age and condition not able to drill the campaign without any upgrade or major failures and maintenance. Moreover the work with a contractor is even cheaper than working with the upgraded 300.
Purchasing a rig from a manufacturer was the second possibility. Thus, different manufacturers were informed with a first tendering process and 3 of them responded with different concepts. These concepts could not cover the requirements of the field. Additionally if GDF Suez buys a rig they would have to employ a crew for the rig and create a maintenance system with spare parts storage. This is connected with costs even when no drilling activity is done.
Therefore, a third option was considered. The assignment of a drilling contractor avoids additional costs for a drilling crew and provides its own maintenance system.
A second tendering process was initiated were 19 European contractors were informed, 11 indicated interest and 4 of them responded with 5 different concepts which are described in chapter 8. The risk to start this kind of tendering process is, that no concept is able to satisfy the technical team or no contractor respond. Additionally the work with a contractor is always a challenge because two companies are working together to reach one target with maybe different expertise and views. This could lead to discussions between the responsible people of both companies, which maybe delay the process. Also in case of an incident both contractual partners will try to proof their innocence which may result in a lawsuit.
The tender documents of GDF Suez implied rough and basic facts about the future drilling rig. The technical team tried to encourage the contractors to bring in their own ideas. This might lead to a lot of questions. Thus, all contractors were invited to visit the oil field in advance, to learn more about the circumstances and the future problems of the project and clarify the first questions. 8 of them took the opportunity.
For the tendering process an online software tool was used to clarify every question online and for every involved party visible, that the contractors get the same information at the same time. This is necessary to stay legally secure.

The closing date for the contractors to submit their final tender documents was July 31. Figure 6.1 shows the current status of the tendering process.

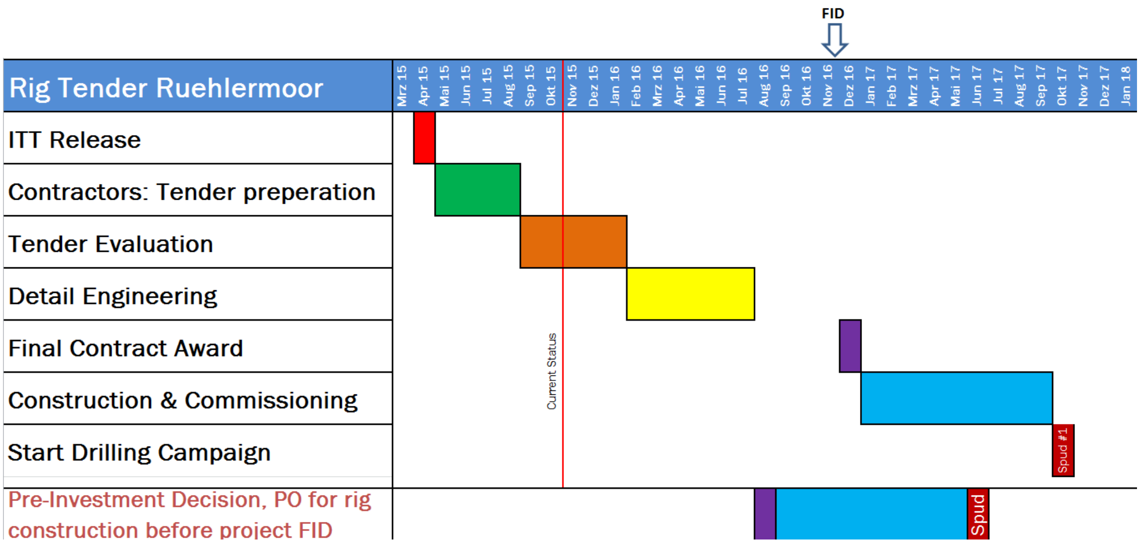

Figure 6.1 Schedule of the tendering process

After a first review of the documents with the legal and the commercial department the technical team decided to consider all 5 concepts. The commercial parts will be opened after the technical evaluation is finished. To ensure that no misunderstandings while reading the tender documents would occur, all contractors were invited to present their concepts at the headquarters of GDF Suez in Lingen - Germany. All of them followed the invitation. After the development of an assessment schema, which is described in chapter 9, the first ranking was done. With this schema the advantages and disadvantages of each concept were determined.

It was perceived that less information about the rig move was available, and therefore a final ranking could not be done. Hence, a second document was created by GDF Suez, where all contractor had to explain their rig move in more detail and clarify other unclear points like transportation and installation of casing during cementing or handling of pipes at the drill site.

The contractors got 2 weeks to submit their documents. Afterwards the evaluation was finished. In a final presentation the results were shown and the decision was made to open the commercial documents of only 3 contractors. 2 concepts were disqualified by exceeding the load restrictions which is explained in chapter 10.2 “Pre-disqualification”.

The following steps will be to open the commercial tender documents and to start a combined ranking process. The tendering process will be finished presumably in January 2017 with a final decision and one contractor will be awarded and can start immediately with the detail engineering for 6 month. After that the construction and

commissioning of the rig can start, when a pre-investment decision is made, otherwise the start will be after the FID (Final investment decision).
To get a better understanding what and how the concepts were ranked the next two chapters will describe the most preferred specifications of a future rig and the concepts of the contractors.

7. The most preferred specifications of a new rig

The oil field Ruehlermoor with its unconsolidated underground layers and the small drilling sites on dykes is unique and a challenge for all operations during the redevelopment project. Following restrictions are pre-existing in the field:
The maximum individual part length of around 20 m, an individual part width of 4 m and a maximum total weight of 60 t must not be exceeded. The S 30 rail has a minimum radius of 31.8 m and allows a maximum rail chassis distance of 13.5 m. The behaviour of the unconsolidated underground cannot be foreseen, when heavy loads where transported through the field. Therefore, the experience of the people working in Ruehlermoor over the past is very important.
This chapter describes a rig, which covers all the recommendation of drilling engineers and supervisors and also provides the possibility to drill the wells for the redevelopment project in a fast and safe way. It has to be considered that the rig which is described in the tender has the possibility to drill deeper wells outside the field. To drill J-shape wells up to 40° inclination and 600 – 800 m (MD) a 150 t onshore drilling rig is a suitable option.
The future drilling rig for the field Ruehlermoor has to be small, flexible and easy to move. Therefore, several additional points have to be considered. To not overcome load restrictions the rig could only be assembled out of components which are light and easy to handle. The fact, that every drilling location is reachable over rails, a drilling rig on rails enables a fast rig move and an easy transportation. Every load transported by rail stands on small load points, the wheels. The distance between the rails is with 900 mm relatively small. The rails provide a good load distribution, but the experience showed that heavy loads on rails can fall off, because of underground subsidence over time. Dynamically repetitive motions during working and transportation of heavy loads should be avoided as much as possible also because of subsidence of the underground. This can occur, when pumps and tanks stay on rail during operation. These movements have to be prevented. It is not easy to find a perfect solution and it is discussable which solution will work the best for the field.
To give a better overview of the best or most appropriate rig, regarding the currently known requirements of the field and the project, some parameters which will maybe be used in the future rig are described in the following.

The derrick

The derrick is presumably the biggest and one of the heaviest loads of the rig during the move. Therefore, the derrick should have the possibility to be drivable on rail in a horizontal way. The longer the distance between the wheels the higher the possibility that the rail car derails when passing a curve. Furthermore, the distance between the locomotive and the railcar should be as short as possible, because otherwise the possibility to derail increases (Figure 7.1). Additionally the load distribution should be as even as possible. Not only for the mast, for all moved loads. If most of the load is at the back or at the front or distributed differently to the sides derailing is more likely.

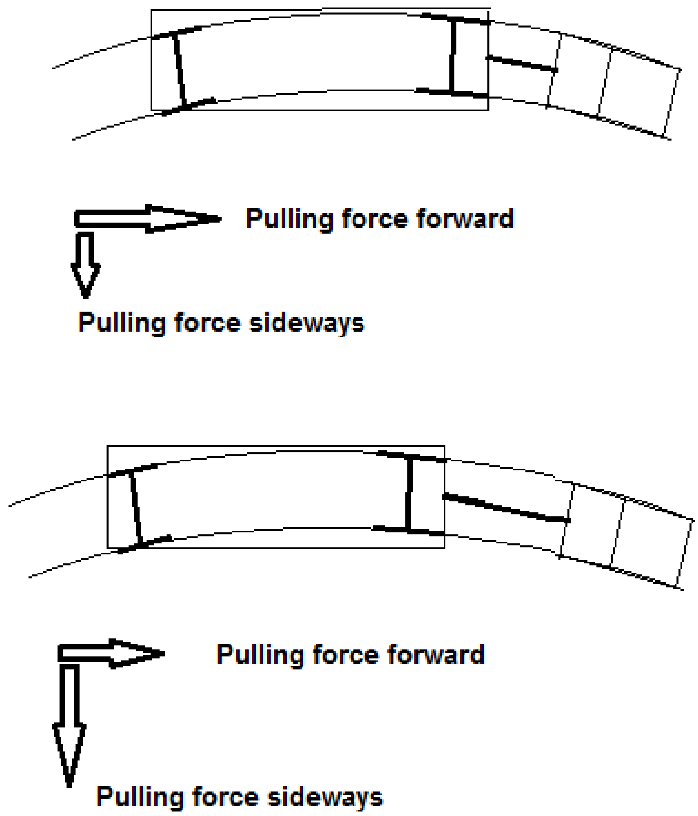

Figure 7.1: Pulling force in a curve depending of the distance between locomotive and load

These facts should be considered. All load movements with carrier, rail chassis and locomotives should fulfil these restrictions. In addition the derrick should be able to telescope to avoid remount the drilling line before move.

Drive, motor

In the field no grid with enough power to operate a rig is available. Therefore, an AC driven rig with power of diesel driven generators will be the best. Modern AC motors are well adjustable with a variable frequencies drive (VFD). A hydraulically drive is not preferable in a nature sensitive area and a mechanical drive is not as easy to control as an AC driven motor with VFD. One power system for the control of the main equipment is preferred. Equipment with additional driving systems like air winches or hydraulic driven equipment has to be neglected. BOP, the closing unit or iron roughneck are indeed driven by a hydraulic system, however, most of the main components should be operated by electric motors to be controlled easily and for a better digital control.

Substructure

The substructure has to comply with the mentioned restrictions as well. The BOP has to be able to be handled with a safe hands-off-system, which can be reached on minimum 2 sides of the substructure to stay flexible at different drilling locations. Also an automatically or winch- or drawwork-supported erection of the substructure is preferred with fewest parts possible.

The mud system

Discussions showed that the best mud system is a system with easily cleanable and light tanks which are easy to install, flexible to arrange and which have enough space for the necessary mud. With easy cleaning is meant that in the best case 100 % of the mud in the tank is usable and nobody has to go inside for cleaning, during the mud change. This is reachable with round tank ground structures. A flexible arrangement of the tank system makes it easier to position the tanks on drilling sites with other circumstances. Therefore, the linkage between the tanks has to be easy and fast. The continuous movement of the mud in the tanks should be provided with electrical driven agitators. They need less maintenance and have proven their worth.

Control equipment

When the rig is an AC driven rig with the mentioned hydraulic parts, specialists like electricians have to be on rig side. The control of the rig has to be as easy as possible to understand and with less expertise able to operate and able to maintenance. Tough screens, cameras and sensors must be working in harmony with working software. A hard drive for storage of all rig data has to be available. An interface for GEO Data should be available to use the data transmission to the office in Lingen providing the drilling engineer all necessary real-time drilling data to occupy the drilling operations from the office. GEO Data is a company who works for GDF Suez and supports with drilling mud and cutting classification and observation. Furthermore, gas detection equipment of GEO Data increases the safety during drilling operations.

Pipe handling

The more hands-off the procedure is the safer the drilling operation. Pipe handler or mechanised catwalks, iron roughnecks and a mechanized derrick man can increase the safety during operation but can also decrease the productivity because of slower working procedure. For the field Ruehlermoor a pipe handler should be capable to handle tools up to 3 t and a length of minimum range 3 (around 14 m). The 8” mud motor for directional drilling is one of the heaviest parts during drilling. The maximum used size of drill collar is 6 ¼”. Operating an automated or half-automated system always consists of different working procedures, which have to be considered. How does the pipe come from the pipe carrier to the pipe rack? How often has the pipe rack to be refilled and how is the pipe handled on the drill floor? These 3 steps cross the working area of people and thus, create danger if the system is not fully automatic. Another point is: How is the system controlled if it is a half-automated? If the driller does it, he has to concentrate on two working procedures. The better way is that one man only controls the pipe handler or the mechanised catwalk and the driller concentrates on the drilling process.

Top drive

A top drive is an expensive tool, but a useful one. With this tool connections are made faster and more comfortable. With a soft torque system an irregular rotation of the drill string can be compensated and the tool joints of the drill pipe undergo less stress. A big advantage of using a top drive is that the drill string can be rotated and mud can be circulated at the same time over a complete pipe length during pulling out of well. It is also possible with a Kelly pipe, but more time consuming and not preferred. This is very important in deviated wells, where a dry pulling of the string can be connected with higher risk of unwanted events like blocked pipe or borehole breakouts. Additionally during directional drilling the whole length of the drill pipe or of a stand of drill pipes can be drilled and no kelly pipe is responsible for loosing hoisting length. This is important the reach the planned dogleg severity. If the derrick has 20 m free working height 2 range II drill pipe can be drilled instead of 1 Range II pipe and a 9 m kelly pipe.

8. Concepts of the contractors

In this chapter the different concepts are described regarding following points:

- Technical concept
- Rig up procedure
- Rig move
- Advantages / Disadvantages without specific weight

This gives an overview, how the concepts will work in the field and which problems maybe occur.

8.1 Company A 1

The company A offered 3 different rig concepts for the field Ruehlermoor. 2 of them (A1 and A2) were described in detail and the last one is only a lighter version of A1, which is capable to drill wells in Ruehlermoor but not deeper ones. However, it is 50 % cheaper than concept A1.

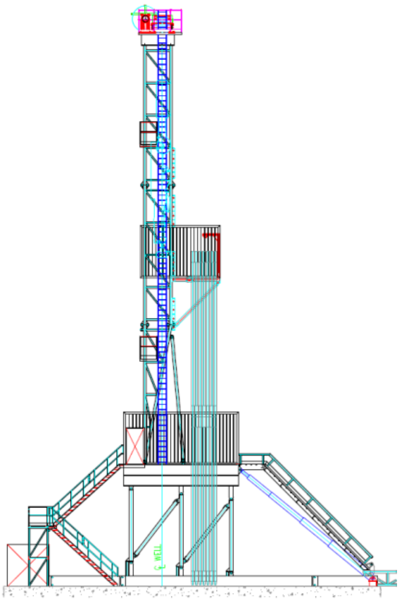

Figure 8.1: Rig A1

Technical Concept

The 1000 horse power rig concept is a conventional rig concept for 2 Range II or 1 Range III drill pipe stored on the surface or on the drill floor. Different scenarios are possible. It is assembled out of different components. It has a hydraulically raised cantilever mast on a parallelogram substructure, which is also raised hydraulically. A pick up/lay down machine (PULD) is responsible for a semi-automated pipe handling. The rig is equipped with a 1,000 HP drawwork, driven by an AC motor. The motor includes the operational electrical break and an additional parking break.

Rig Up Procedure

One decisive factor for the project is the concept of the rig up procedure and the rig move. With a fast procedure, time and money can be saved.

The modular concept of the rig can be disassembled to smaller components which are easier to move and handle, and thus aligned to the conditions in the field Ruehlermoor. The rig concept is designed for a fast, safe and simple assemble and also for a short rig up time, as well as keeping mobilization requirements to a minimum.

The erection of the rig mast and the entire rig floor into its operational position is achieved by hydraulic rams in one single shot. That process is divided into two simple procedures, which requires less of rigging equipment. The parallelogram substructure simply consists of two units which can be moved, for inter field moves, in a complete transport package. The substructure units are spaced and connected with horizontal bracing members, which serve both as erection guides for setting out purposes and structural members for drilling modes. The substructure units are connected with four drill floor modules at their uppermost sections. These modules are interconnected to form a rigid structure, including incorporated wind walls, and to accommodate the driller's cabin. In the ground floor position the substructure units will be assembled together with the drill floor modules. Afterwards the substructure front extension beams are completed with the substructure hydraulic raising cylinders and will be pinned to the off drawworks side of the substructure. To finalize the footprint of the rig substructure the drawworks module will be pinned to the substructure rear extension beams. The mast will be assembled in horizontal position by using a mobile crane. In advance the drawworks module is installed and gives support to the mast lower sections during assembly. A dedicated mast stand will be used to support the mast top section and crown. The racking board will be pinned to the mast in horizontal alignment. Once the mast is completely assembled it will be raised in vertical position by two hydraulic rams. The rams are directly connected to the substructure extension beams in front of the drawworks module. Subsequently the mast will be locked into position with frame legs pinned to the drill floor modules. The parallelogram substructure will then be raised in working height by two additional hydraulic rams built-in to the substructure front extension beams at off drawworks side of the structure. The substructure will be locked by pinned in lock brace members into final position. All components consisting mast and substructure are designed to meet all road transportation restrictions without requiring additional transportation permits. The rig components are further designed to allow an in-field mobilization on rail cars in larger transportation loads by reducing the rig up and rig down time between wells.

<u>Rig move</u>

The rig will be transported via rail like a train in presumable 3 days. It is possible to transport the rig including all needed equipment with 2 locomotives in 20 steps (35 locomotive moves) from one location to the other. Therefore, a significant amount of rail chassis and carriers are needed. Additionally 2 cranes must work continuously during the moving action. The cranes have to change 5 times the location to do all hoisting work. With an hydraulically rail chassis device (Figure 7.2) the mud tanks, generators, the diesel tank and the VFD can change in very short time from transportation to working position. The relatively low transportation height of the heavy loads provides a low center of gravity, which increases the safeness of the rig move. The hydraulically erectable mast will be transported with its length of roughly 20 m on two special rail chassis. Smaller or rather lighter equipment like BOP, the manifold, office and service containers will be transported by carrier.

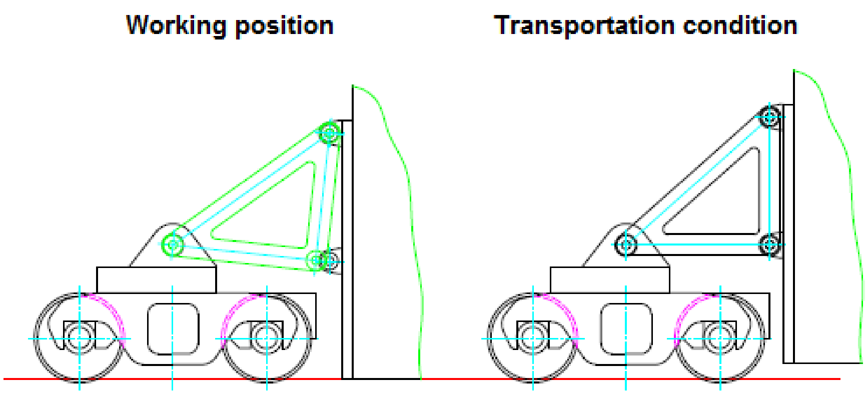

Figure 8.2: Rail car system

During the rig move 4 side rails to other wells are used as transitional storage area for parts which are not used immediately after dismantling at the leaving well site. The combination of mud tanks, generators, diesel tank and VFD will be driven by 2 locomotives in one train to the new location but will be left at the main rail behind the new well location. For this transport one locomotive pulls the equipment and the other one pushes. Because of the blocked main rail after the transport of the train the pulling locomotive has to drive back to the leaving location over a neighbor dyke to continue the moving process.

Advantages

- Rail chassis system provides a fast and safe moving scenario
- Small pieces are easier to handle and could be moved faster
- Vertical drill pipe storage shortens round trips and the BHA Handling
- Mast will be mounted on surface → no heavy and high hoisting works
- Rail chassis provides a low center of gravity during move → safety increases
- Train system provides a predictable fast rig move
- Possible changes on the rig can be achieved because the rig is not built yet
- The tanks are rounded at their ground
- The street stays free for emergency exit and small transports

Disadvantages

- 2 Cranes for rig move operation necessary
- A lots of pieces have to be moved
- New rail cars are needed to be planned and built
- Cranes are moving 5 times between the drilling locations during move
- The monkey board still needs a person to work on (bad safety factor)
- Main rail is blocked by equipment

8.2 Company A 2

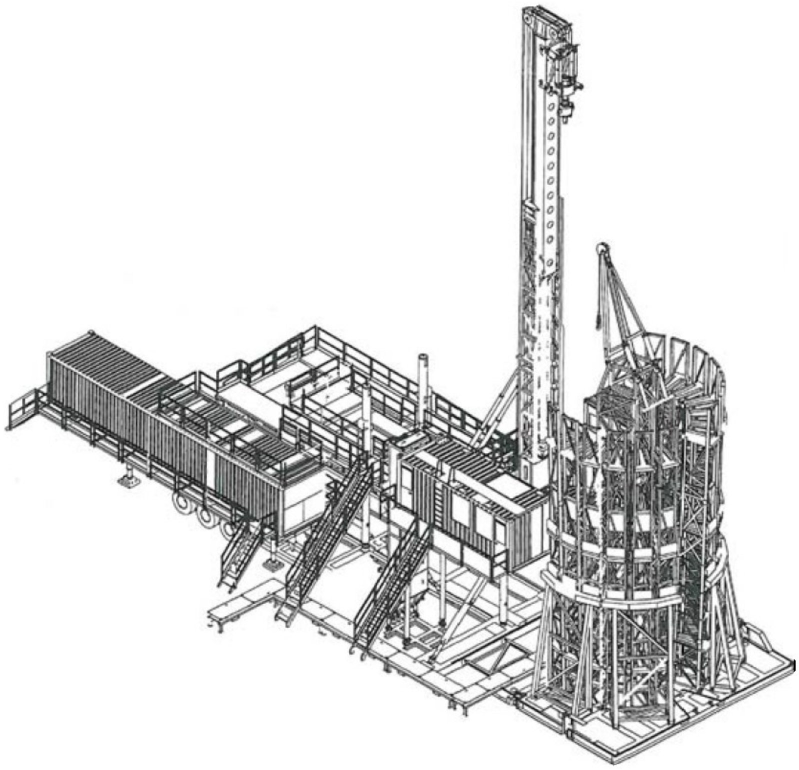

Figure 8.3: Rig A2

Technical Concept

The rig is a trailer based super-single rig with a full automatic pipe handling system. The rig concept includes a semitrailer mounted, high mobility, cantilever rotary drilling & workover rig which is diesel driven and hydraulically operated. The hoisting system is based on a telescopic mast, operating as a hydraulic hoist. The mast is a welded box type and composed of two independent sections: the bottom section is fixed to the drill floor on the trailer and the telescopic section is running up and down. Raising and lowering of the mast are performed with help of a hydraulic jack and with built-in safety devices.

The telescopic mast is running up and down by hydraulic jack. A safety belt is installed to avoid possible operator's fall. An auxiliary hydraulic winch is provided on the side of bottom mast section to handle materials on the rig floor and to lift materials from the ground to the rig floor. The crown block is fixed to the mast telescopic section. The substructure and the drill floor are directly connected to the rig trailer. Due to its specific design which allows to cantilever the drill floor, this type of rig can be easily set over large existing cellars and provide ample space under the drilling floor for BOP installation. The bottom of the drill floor, completed with the lower section of the substructure, is equipped with rails and rail chassis to facilitate the sliding of BOP to the well centerline. A hydraulic clamp is installed in the mouse hole and located underneath the drilling floor. It’s furnished with steel guide to help the pipes to center the hydraulic clamp. The pipe handler is a fully automatic working system with a vertical pipe racking system and operates with range 3 pipes. Drill pipes are stored in boxes in a radial arrangement. A hydraulic driven arm supplies the drill pipes from the pins to the mouse hole position and back. A crane on the top of the pipe handler including a slide inside the mast of this crane is responsible for heavier loads like the BHA or drill collars.

Rig Up Procedure

The trailer based rig which could be moved easily in the field because of the trailer design. The full automatic pipe handling system consists of many long pipe storage boxes and a middle mast including a crane arm and a winch. Four independent hydraulic outriggers stabilize the semitrailer and substructure rising. The outriggers are provided with a safety mechanical locking system and are controlled by a side control panel.

When the trailer stands at site the telescopic mast will be erected and also the trailer will elevated hydraulically. The drawwork is fixed at the trailer. The driller cabin will be placed at the drill floor and both will be mounted behind the mast. Tank system, the power unit, the pumps, service containers and other equipment will be moved with trailers on rail or tractors with the carrier. The power unit is installed in a container on wheels.

Rig move

The main problem of this system is that the trailer weights 63 tons. The maximum allowed weight on the rail is 60 tons. With exceeding the 60 tons no transport in the field is possible. The 3 tons overload have to be reduced if company A is further interested in this rig concept.

Advantages

- Full automatic pipe handling machine
- No person on a monkey board
- Trailer mounted rig provides a fast rig up procedure
- The street stays free for emergency exit and small transport
- Possible changes on the rig can be achieved because the rig is not built yet

Disadvantages

- 2 cranes are needed for rig move
- The pipe handler has a lot of additional parts which has to be moved

- The transportation weight of 63 tons exceed the load restrictions for the field Ruehlermoor
- Rig up of the pipe handler needs a lot of space and time
- Main rail is blocked by equipment

8.3 Company B

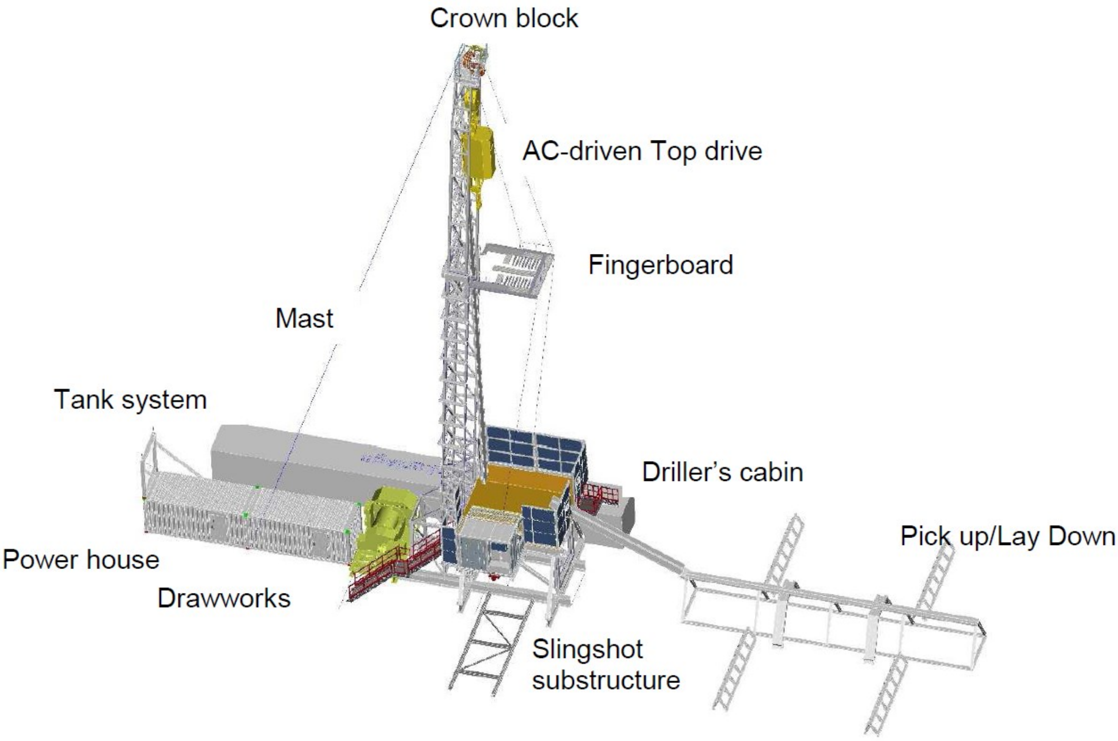

Figure 8.4: Rig B

<u>Technical concept</u>

The diesel-electric powered (AC) double-stands rig for 2 range II drill pipes is assembled out of many relatively light modules and a separate 40 ft. power house container. The internal lined mast is hydraulic erectable and can be telescoped once. Mast and associated load-carrying elements (crown block, traveling block with hook) are constructed to handle a hook load of minimum 170 t. The mast base will be used as a transport carrier for the BOP stack to provide a compact transport unit. The drawwork stays on the ground. The finger board with a maximum storage capacity for 800 – 1000 m 5“ or 3 ½“ drill pipe, heavy weight drill pipe and also drill collar is capable

of fulfilling the requirements in the field Ruehlermoor. Operations outside the field may require a higher capacity and a change of the finger board.
The rig is equipped with a traveling block and a hook, which can be operated with a top drive as well as with a swivel – kelly combination. This raises the flexibility of the rig during malfunctions of the top drive. The top drive is a Canrig, Model 6027 AC which is AC driven. With a maximum load of 249 t and the provided power of 450 kW the top drive is sufficient regarding speed and make-up / break out torque.
The drill floor is designed as a slingshot-substructure. It has a free height of 5.50 m and a load capacity of 100 t. The rotary table is equipped with a 20 ½" orifice, a split type master bushing and bowls 1-3. A hook load of 170 t can be handled. The substructure has also an integrated BOP-rail chassis-system to manage a safe handling of BOP-equipment.
The air-conditioned driller's cabin is located on the drill floor at B-side. All control devices and displays are integrated parts of controls. This ensures a safe operation of the rig. The position of controls guarantees a clear view at the drill floor. Barely visible spots are monitored by cameras and viewable on monitors installed in driller's cabin. The MH Wirth Single Gear GH 1000 EG-AC-1G draw work is equipped with an AC-drilling engine with 858 kW and a 4Q-control device. An additional disk brake is installed for emergency and parking situations. The power house (VFD) controls, adjusts and distributes the entire electricity provided by generators to all AC and DC consumers. The necessary energy supply is ensured by 3 generators. Each of them can provide 1000 kVA. Dependent on power demand and operating status one or two generators will operate. Backup power supply is ensured by a 150 kVA generator. This emergency generator can also be used during the rig move for power supply on the next well site. Pipe handling is done with a PULD. The systems allows the transport of 2 7/8" to 20" (outer diameter) pipes with maximum length of 14.6 m from pipe rack to the rig floor (and back) without manual intervention. The transport of all pipes shall be done on railway. The pipe racks are designed to enable a direct on- and offloading from train without additional equipment for loading.

Rig Up Procedure

For the Rig up procedure 2 cranes are used. First the sling shot substructure is placed on site to mount the wind walls and the driller´s cabin. After that the substructure will be hydraulically erected, the mast support structure with the BOP inside will be placed under the position of the mast and the BOP is placed under the drill floor with a hoisting system. For maintenance or pressure tests, the BOP can be driven out of the substructure on a minimum of 2 different sides with a BOP rail chassis system. Behind the drawwork the 40 ft. power house with the VFD will be placed. On top this 40 ft. container the mast will be placed with both cranes and connected to the drill floor. The mast has already the fingerboard and the top drive installed. With hydraulic cylinders the mast will be erected and telescoped afterwards. The internal guying lines will be fixed. Then the PULD system will be installed. Mud pumps, mud tanks, service and personal container will be placed and the rig up procedure is finished.

Rig move

Company B tries to achieve a rig move from spud to spud in 3 days with 12 hours per day working time. For the movement two 60 t crawler cranes provided by a contractor are responsible for the hoisting works. Company B pays attention that no component weights more than 30 tons. To remember: The maximum possible movable weight by S-30 rail is 60 tons and 15 tons per axle. In total 43 parts have to be moved in the plan of company B. Big parts like the VFD and the tanks stay on rail during the moving time. The other parts will be transported on rail carrier only for the distance between the two drilling locations. One crane will load on drilling location 1 and the other one will unload on the other location after both cranes hoist the mast together on a rail car at the leaving location. During the move the mast is around 20 m long and a special steel structure which contains the BOP and supports the mast is pinned to the mast additionally. Therefore, this combination of parts has to be hoisted with both cranes for load and safety reasons.

Advantages

- Possible changes on the rig can be achieved because the rig is not built yet
- The main rails stays free (except the cutting box) for different types of transports and other services like cementing
- The street stays free for emergency exit and small transport
- The pour on of additional area at the dyke to gain more space for the drilling area like on RLMR 801(compare Figure 4.3 points 15 – 19) is not necessary for this concept
- Mainly German parts provide a flexible and fast after sale service
- The rotary table and Kelly pipe are together with the swivel a complete drilling alternative
- The tanks are rounded at the ground with connections and pipes underneath. This provide close to 100% usage of the drilling mud at a smaller needed area

Disadvantages

- 2 Cranes are necessary during rig move
- New rail cars are needed to planned, built and purchased by GDF Suez
- Canrig top drive out of the USA without a backup on other rigs, when spare parts are needed fast
- The monkey board still needs a person to work on (bad safety factor)
- Many small pieces have to be moved

8.4 Company C

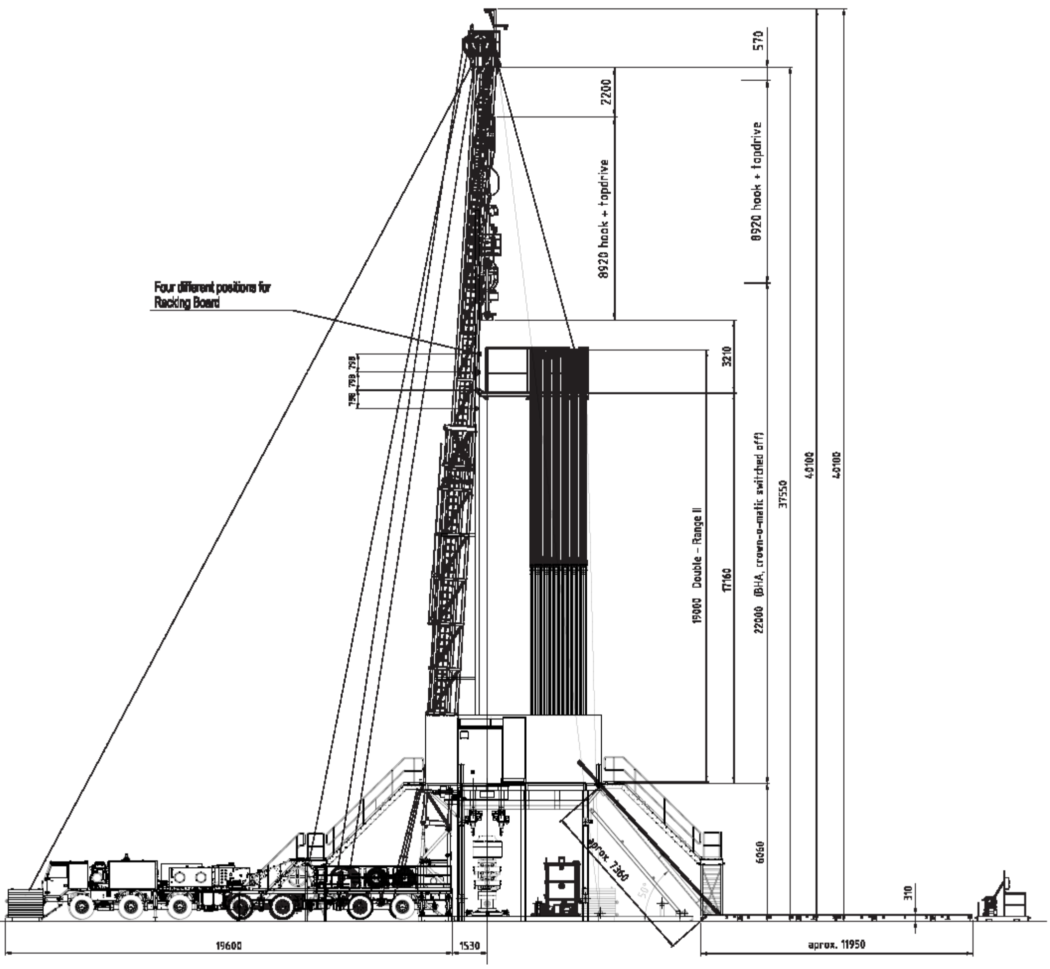

Figure 8.5: Rig C

Technical concept

The rig of company C is a drilling rig conceptualized by STREICHER Drilling Technology GmbH. It is a carrier based rig for 2 range II drill pipe with 7 axles and an internal guying. It is diesel-hydraulically driven with a mechanical drawwork. The substructure is not constructed, but will be placed directly behind the carrier.

Rig Up Procedure

Due to the fact that the rig is a carrier based the rigging up procedure is easier than with the other concepts. Mast, Engine, drawwork and other components are mounted at the carrier and move during one transport. The mast is erected and telescoped

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hydraulically and guyed internally showed in Figure 8.5. The drill floor is placed behind the rig probably with cranes. The final procedure is not planned yet.

Rig move

The rig move within the field is only possible with a massive preparation of the transportation way to the location. The driving way has to be prepared in advance with a solid sand bed and so called DURA-BASE® mats on top. [13] To ensure that no hillside slide arises the rig has to be driven at least in 4.5 m distance to the slope. Therefore, some fences and equipment of existing wells has to be removed. Afterwards everything has to be reconstructed. The rig drives on this prepared way on its own wheels at 7 axles. It has to be reached that all wheels are loaded simultaneously and equally to distribute the total load of the rig as much as possible. This is at the unconsolidated underground a big challenge. All other equipment, which is not installed at the carrier, will be transported via flatbed trucks which are driving on the DURA-BASE® mats loaded and on the streets unloaded circular.

Advantages

- Rotary table as drilling alternative to the top drive
- Robust equipment technique
- Easy rig up/rig down procedure
- The street stays free for emergency exit and small transport

Disadvantages

- With 73 t standard weight it is not possible to drive inside the field because of street load restrictions. Only with a report of a certificated company a movement in and within the field is possible on so called dura-base mats supported with additional sand between the rails
- For the transport needed sand, dura-base mats are linked with additional logistic and preparation work, which might make the company C rig uneconomic
- 2 x 60 t cranes and 2 flatbed trucks are necessary for the rig move
- Man on the monkey board is always a safety risk
- No automatic cat walk or pipe handler
- No automatic driller
- Link tilts: only 1.0 t in 1.5 m distance

8.5 Company D

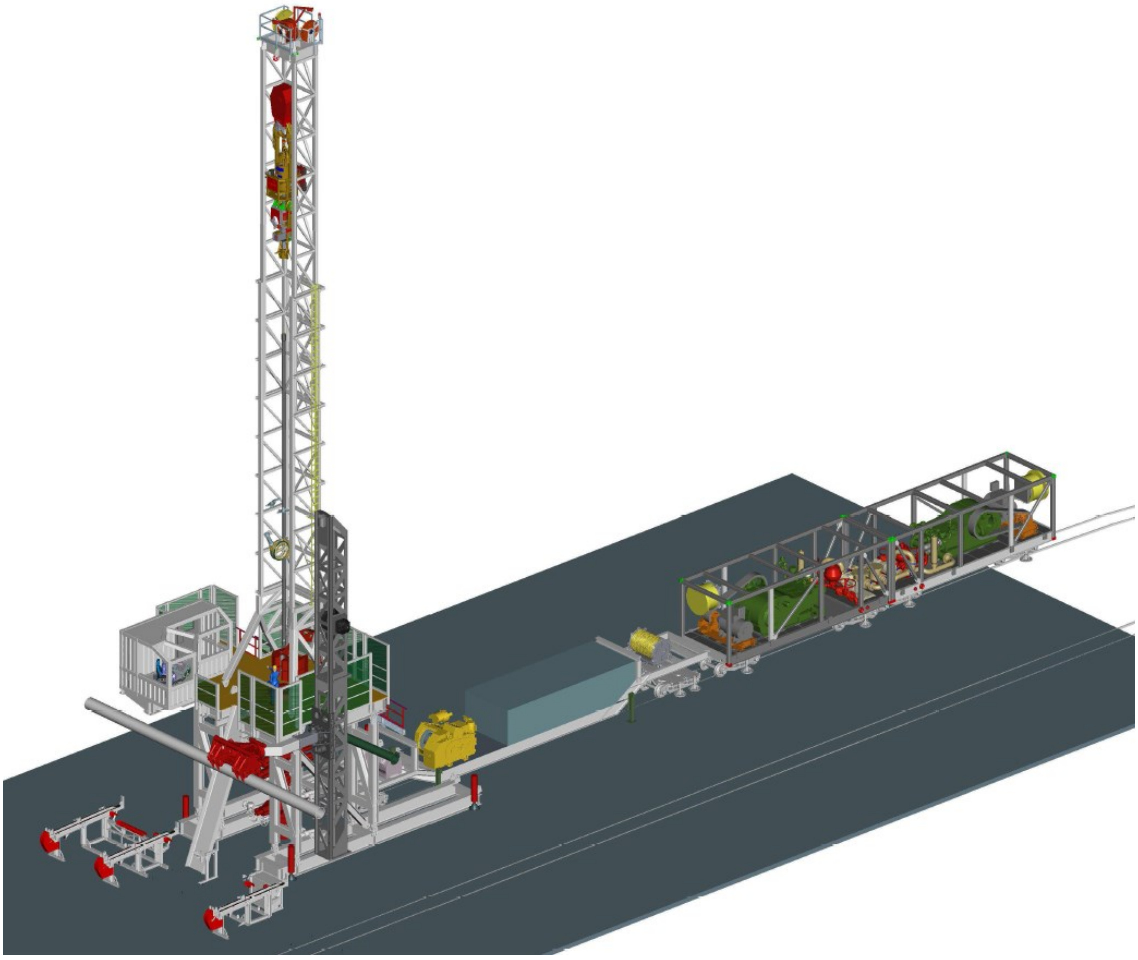

Figure 7.6: Rig D

Technical concept

The AC driven drilling rig stands for a highly automated super single drilling rig with the objective of achieving very short rig move times in the Ruehlermoor oil field. To achieve this target almost every component of the rig stays on rail during drilling operation and move. The drilling rig is characterized by a semi-automated pipe handling system enabling "hands-off" for standard operations, customization for rail transport and reduced crane requirements for rig up and rig down operations. The rig is also designed to operate outside the Ruehlermoor field. The drill floor is designed to enable the application of manual tongs as well as the automated wrench system and has an automated horizontal to vertical (HTV) pipe handler at the side. The telescopic mast is placed on a frame which provides the access to the rotary table as well as to the wrench system. The rig floor can be accessed by two independent stairs. The rig has an increased free working height under the top drive of 20 m to use casing running tools and circulation heads in combination with drilling tubular of Range III. Furthermore the increased free working height permits an increased length of BHA strings and reduces the amount of connections made on the drill floor. The rig is designed for levelling of the rig after rig up. The semi-automated pipe handling system consists of the pipe feeder, the pipe handler and the automated wrench system. The system is controlled by the driller in the cabin. In addition to the direct visibility of the handling system through the window of the driller´s cabin, cameras at the drawworks and the shakers and a third camera displayed in the driller's cabin provides visual information on the pipe handling area. A detachable pipe chute system in combination with drill floor winches and an external mobile winch can be used to transport tubular or other equipment up to the drill floor. The pipe handling gripper can also be equipped with a hook (optional) to transport e.g. a basket on the drill floor. The pipe handler can operate following pipes:

- Tubular/Casing Range 2 3/8" – 20"
- Max. Hoisting Capacity 3.500 kg
- Max. Length of Tubular 14,6 m

Also handling of wire wrapped filters and similar equipment is possible. The telescopic mast system has a top drive guide rail system that doesn't need to be adjusted after a rig move. This reduces the rig move time for the contractor. The BOP handling is possible without the need of a crane. The BOP will be brought to the drill site before the main rig arrives will be parked during rig up at the tubular handling area/pipe feeding location on a rail chassis. After the rig is built up the rail chassis including the BOP will be placed under the rig and connected to the lifting chains mounted under the drill floor. The rail chassis will be removed and the pipe feeder placed at its operating position by the fork lift. The substructure has a special sling shot design which can be rigged up without the need of cranes.

<u>Rig Up Procedure</u>

The plan is to reduce the crane works as much as possible. At first the substructure will be transported to the rig site. The two substructure elements are on rail chassis and will be placed on the end of the rail tracks. The substructure elements are separated from the rail track by the usage of cylinders. After placing the two substructure elements to the middle section of the drill floor it will be fixed in between of the substructure elements via fast connection system with the already placed substructure elements. The next step is to place the driller's cabin module and the driller's cabin on to the substructure with the forklift. The truck trailer including the mast system and drawworks is placed on the rig site and connected to the substructure. The telescopic mast will be lifted in the vertical position via the mast cylinders and the substructure will be elevated via hydraulic cylinder to the height of approx. 5.9 m. The telescopic mast system will be brought in operation position via a winch system and the pipe handling segments are connected with the support of the fork lift. Pipe handler including gripper will be positioned vertically via the drilling rig winch system. After positioning of the drilling rig three train transports can be brought to the rig site. These 3 train transports consists of mud pumps, the powerhouse, 3 generators and the 20 m³ diesel tank, the complete tank system and at last the re-filled mud tanks and water tanks. The substructure elements are separated from the rail track by the usage of cylinders. This rig concept needs only 1 crawler crane during the move and rig up/ rig down procedure for individual parts.

Rig move

The layout of the rig is based on four main transport packages (containing several units on rail chassis). The drilling rig consists of a truck trailer that comes with rail chassis during operation at the Ruehlermoor field. The rail chassis can be replaced by a chassis for road usage if drilling outside of the Ruehlermoor field is required. The truck trail has the drawworks, the two air winches, the HPU/Compressor and the reserve rope drum installed. The top drive and the travelling block are also included into the mast system during transport. The transport of the substructure will be done via rail chassis in the Ruehlermoor field. The main substructure transport unit consists of two modules (left-right) with approx. 1.5 meter width each and will be transported to the rig site first. The two substructure elements are on rail chassis and will be placed on the end of the rail tracks. The pipe handler mast and pipe handling gripper are transported to the rig site. The three main train transports have individual cabling which is not required to be disconnected during rig move. The electrical connection between power house and tank system needs to be connected after rig move as well as the mud piping to the external equipment e.g. mud pumps and tank system. The train transports, in case applicable, are internally connected (electrical, hydraulic, mud) and do not need to be disconnected during transport. After positioning of the train units the connection between the train units (electrical, hydraulic, mud) needs to be placed. The train parts stay on rail and are jacked up via hydraulic cylinder during operation. In addition all other equipment need to be transported via rail carrier to the drilling location and placed via the fork lift.

Advantages

- Only one crane needed
- The street stays free for transports or emergency escape
- Tank system can be placed on both sides of rig
- Good flexibility of the pipe handler (180° work radius, 3.5 t hoisting capacity)
- No guying
- Dismantling of the drill floor over a up to 1.5 high equipment possible
- Predictable relatively fast rig move
- Possible changes on the rig can be achieved because the rig is not built yet
- The tanks are rounded at the ground
- The pour on of additional area at the dyke to gain more space for the drilling area like on RLMR 801(compare Figure 4.3 points 15 – 19) is not necessary for this concept

Disadvantages

- The main rail is only reachable from one side
- The casing and the drill pipe has to be stored at the drilling area horizontally
- Only a small supporting rotary table is installed
- Before working with the BHA the well drill string has to be laid down
- Only few but heavy, slow and dangerous transports with train
- Purchasing of rail chassis needed
- Mast transport with 60 tons and roughly 20 m length could be difficult

8.6 Rig specifications of the contractors

After the first tender documents of the contractors were delivered and the presentation of their concepts were finished a table was developed where all specifications of the rig concepts could be compared. (Table 8.1) This table compares the specifications also asked in the tender documents of GDF Suez.

Table 8.1 Contractor comparison

		Company A1	Company A 2	Company B	Company C	Company D
General						
Needed space	(m)	25,6 x 81,0	25,6 x 81,0	26,9 x 85,2	30,0 x 90,0	22,0 x 140,0
Guying		no	intern	intern	intern	no
Excepted rig Move time	(days)	2-3	3	3 a 12 hrs.	3	2-3
Drive		diesel-electric	diesel-electric	diesel-electric	diesel hydraulic	diesel electric
Max. load of individual part	(t)	30	63,5 t	30	73	60
Drillers cabin / Doghouse		yes	yes	yes	yes	yes
A Mast, Drawwork, PULD etc.						
A 1 Mast						
Stands		2 pipes range 2	Range 3 super single	2 pipes range 2	2 pipes range 2	Range 3 super single
Type		hydraulically erectable	hydraulically erectable	hydraulically erectable	erectable	U-shape, hydraulically erectable
Year		new	new	2007	In construction	new
Free working height	(m)	No information	16	No information	34,0	20,00
Except load	(t)	150	136	170 (6 fold) 207 (10 fold)	150	150
Set back capacity monkey board						
- 3 1/2" DP	(m)	4000	4600	800 - 1000	No information	Super single
- 5" DP	(m)	2000	3600	800 - 1000	No information	Super single
- 6 1/4" DC (and)	(pcs.)	8 stands	8 stands	possible	No information	Super single
- 8 1/4" DC (or)	(pcs.)	4 stands	4 stands	No information	No information	Super single

Table 8.1 shows the first criteria of the contractor comparison table. The general specifications of the rig and of the mast can be compared. The complete table could be found in the appendix under point 13.4.3 “Contractor comparison”.

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9. Efficiency Analysis

This chapter describes the development process of the efficiency analysis. This includes the definition, description and the execution of the analyses. Basically the evaluation is divided in different criteria. (Figure 9.1)

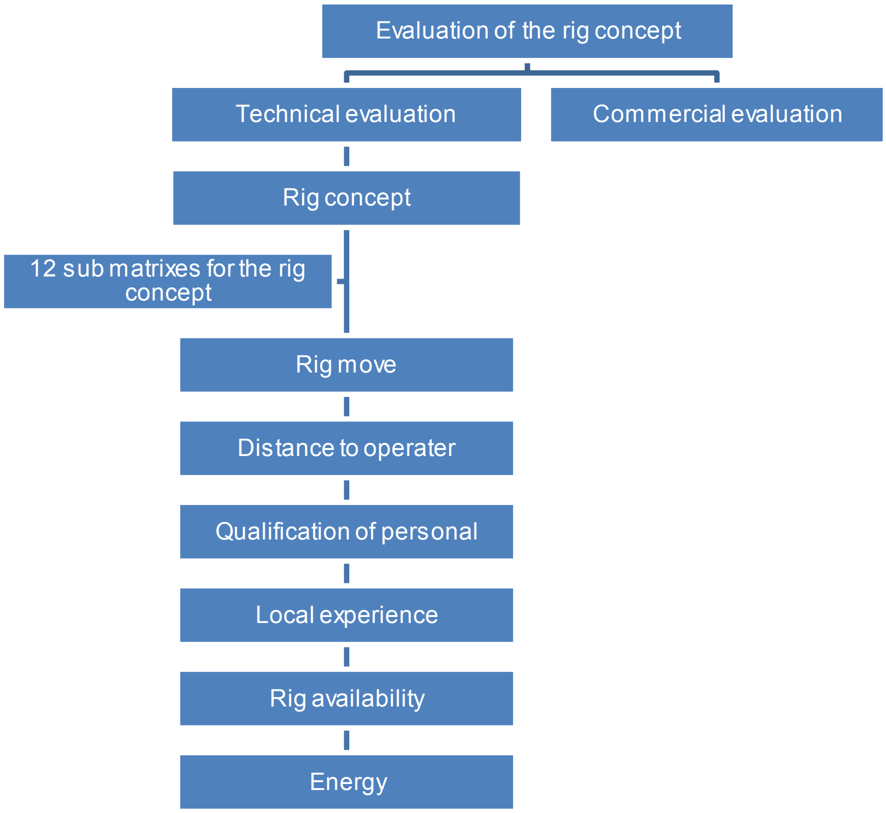

Figure 9.1: Evaluation structure

These separately considered criteria have a different influence on the end result of the evaluation. The weighting of the matrixes is separated in 7 sub-points on the technical side which include 70 % of the total evaluation and in 6 sub-points on the commercial side which include 30 % of the total evaluation. In summery all total values of the particular criteria (rig concept, rig move etc.) are involved in the final calculation with different weight. (Figure 9.2) In this thesis only the technical side will be considered.

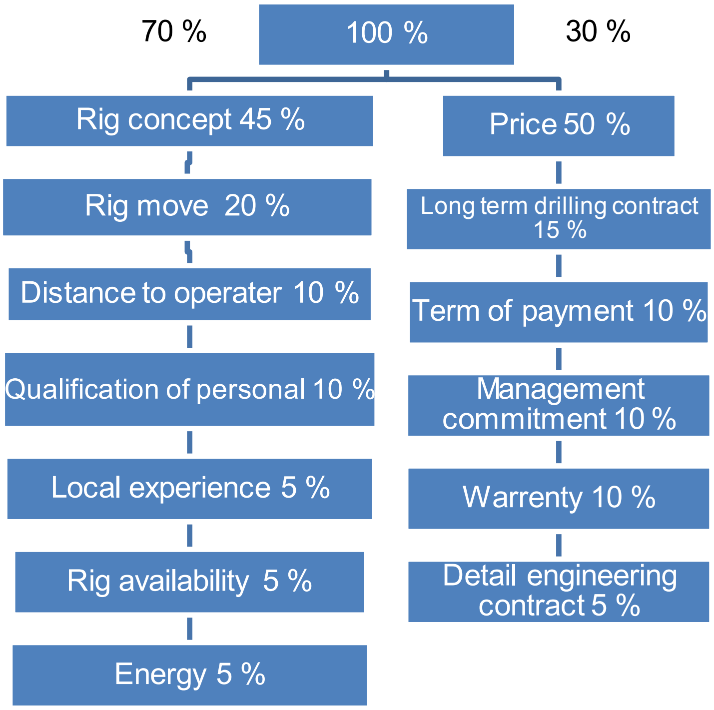

Figure 9.2: Evaluation structure with weighting

The rig concept

This point includes the technical rig concept with its different parts or equipment to achieve a good overview of the future drilling rig. The 12 sub-points of the criteria “Rig concept” are: Mast, substructure, drawwork, rotary table, top drive, pumps, tank, power supply, well safety equipment, installation equipment, data collection and storage and pipe handling. Each sub-point has different evaluation criteria (Appendix 13.3 “Evaluation matrixes”)

The rig move

In this criterion following points are considered:

- Weight and size of parts or equipment
- train and crane utilization
- expected time for the move

These criteria are used to get a first idea, how the contractors will perform an infield rig move and which requirements are necessary.

Distance to operator

In this point the most important factor is the distance from the contractors head office to the field Ruehlermoor. With a short distance the operator expects a high flexibility of the contractor and the opportunity of a fast acting process in terms of repair, maintenance, personal supply, experts supply (mechanics, electricians etc.) or other occurring situations.

Qualification of personal

This chapter was not evaluable because of insufficient information about the future personal working at and for the rig.

Local experience

This point covers the experience of the operator with the contractor past projects. Has this contractor ever worked with the operator? What was the result? Was the job done sufficiently, safe and fast and was everybody satisfied?

Energy consumption

With energy consumption all for the rig needed energy in form of diesel, gas and electricity is meant which is consumed to operate the rig properly. But no rig is built yet and the energy consumption changes with the downhole conditions, the used tools, the trajectory of the well etc. To get predictable energy consumption values the detailed engineering phase has to be used. Currently this criterion will be rated for each contractor the same.

Rig availability

The fact that no rig is built yet, and the companies insured that they can all build their rigs within 9 months, leads to the same ranking in this criterion. Only company C could provide the future drilling rig earlier, because their concept is already in production.

9.1 Definition and Reasons

Generally financial decisions like investments are based on facts. Is the investment economically, is the company able to enlarge the revenue and/or the profit, how long does the depreciation take or when will the investment amortize? These are crucial questions.

The redevelopment project is linked to several investments for the joint venture of GDF Suez and EMPG. Every investment has to be approved by the management. For GDF Suez the task is to find the best rig concept out of 5 concepts, which covers the requirements of the Ruehlermoor oil field most effectively. To reduce the uncertainties and risks as much as possible an efficiency analyses has been chosen. It can help with a complex problem by weighting and analyzing of different pre-defined criteria to find out the best concept in its entirety. The efficiency analysis does not give absolute or objective benefit about the criteria, however it can help to develop rational results to facilitate the choice. Per definition the efficiency analysis is an evaluation process, where different alternatives can be evaluated and compared with several different outcome measurements. It involves also qualitative factors. [8]

9.2 Description of the Concept

An efficiency analysis is done by several steps:

1. The targets, the criteria and eventual K.O. - criteria have to be defined
2. Weighting of the criteria,
3. Rating of the criteria and calculation
4. Result analysis, maybe finding alternatives by developing a ranking and linkage to the weighted criteria

In this chapter the targets and K.O. - criteria are defined. The criteria were generated with the support of drilling engineers and drilling supervisors and are compared pairwise and weighted afterwards. It is based on a comparison of merely 2 criteria with each other. Therefore, a matrix is developed (Table 9.1(fictional)). This table correlates the criteria directly to each other and gives a weighting and the fraction in percentage. With this measurement a fast and easy distribution of the different criteria is made possible.

Table 9.1: Criteria weighting procedure

1 A Criteria	Criterion 1	Criterion 2	Criterion 3	Total	%
Criterion 1		1	0	1	16.6
Criterion 2	1		1	2	33.3
Criterion 3	2	1		3	50.0
				6	100

Table 9.1 has to be filled out at the right side of the orange diagonal first with the three weighting grades 2, 1 and 0. The left side of the diagonal results from the values of the right side. Starting point is criterion 1. If this is more important than criterion 2 it gets a “2”. If it is less important it receives a “0” and if both criteria are equally important it gets a 1. With this procedure the table is filled out. The columns on left side of the diagonal get the opposite/same values of the right side depending on the value. 1 stays 1, 2

becomes 0 and 0 becomes 2. After that the values of each criterion is summed up and noticed in the column with the name “Total”. With the sum of all total values each particular percentage or weight can be calculated like in following example:

$$\frac{6}{1} * 100 = 16{,}6\% \qquad (1)$$

An example of a filled in table is given in table 9.2, which is also used for the later on evaluation of the concepts. In this table the criterion “Mast” is chosen.

Table 9.2: Mast criteria weighting

1 A Criterion Mast	Year	Free working height	guying	Max. except load	Max. usually load	Setback capacity monkey board	Derrick Man System	Elevation of the Mast	climbing device	Total	Factor
Year		0	0	0	0	0	0	0	1	1	0.014
Free working height	2		2	2	2	2	2	2	2	16	0.222
Guying	2	0		2	2	2	2	2	2	14	0.194
Max. except load	2	0	0		0	2	2	2	2	10	0.139
Max. usually load	2	0	0	2		2	2	2	2	12	0.167
Setback capacity monkey board	2	0	0	0	0		2	2	2	8	0.111
Derrick Man System	2	0	0	0	0	0		0	2	4	0.056
Elevation of the Mast	2	0	0	0	0	0	2		1	5	0.069
Climbing device	1	0	0	0	0	0	0	1		2	0.028
										72	1

In total 72 points are distributed into 9 sub-criteria such as year, free working height etc. These points are necessary to calculate the percentage (the weight) of each criterion. Example criterion “guying”:

$$\frac{14}{72} * 100 = 19{,}4\% \qquad (2)$$

To combine the weighted criteria with the concept of the contractor the factor and not the percentage is used, which is in this case 0.194.

To get a weighting of the criteria several drilling engineers and drilling supervisors were interviewed. This is important to get a reliable result, when a lot of experience is involved. The weighting is always a mean value of the interviewed persons and stays a subjective estimate. That weighting was generated especially for the requirements of Ruehlermoor. The result of this weighting procedure may look completely different for a drilling rig for another oilfield, because of different circumstances. In this case the sub-criterion “free working height” is declared as the most important sub-criterion in the criterion “Mast” with 22.2 %. To use this calculated value it has to be linked to the ranked future concepts. This is explained in the following chapter.

9.3 Analysis of the weighted criteria

The weighted criteria give only information about the importance of the criterion for the future rig concept. Only with this the concepts cannot be ranked. The linkage between the weighted criteria and the concepts of the contractors are made in analysis matrixes. Within these matrixes the weighted criteria get ranked by experts, drilling engineers and supervisors, who know how to get a proper ranking accordingly to the requirements of the field. The concepts are compared and ranked in every criterion (Table 9.3) and with the help of the preliminary equipment list (Appendix (13.1)). This leads to a personal view and a subjective ranking. It is not an absolute value and could change if the properties or circumstances of the project changes or another person get interviewed.

Table 9.3 is a fictional example for a ranking of the criterion “Mast”. For the real evaluation of the rig concepts the matrix has 4 different columns with rankings from 1 to 4. If all contractors are equally appraisable they all get a 1. If only two of them are equally good the ranking will be 1,2,2,4 or 1,1,3,4. Many different options are possible. One fictional example: 3 companies want to use a totally new mast and the other one will take a used one, then the first 3 get a 1 and the fourth a 4. Or if they want to use masts with different age the ranking could be 1,3,2,4 for company A, B, C and D.

Table 9.3: Contractor rating

Criteria \ Contractor	Contractor 1	Contractor 2
Year	1	2
free working height	2	1
guying	1	2
Max. except load	1	2
Max. usually load	2	1
Setback capacity monkey board	1	2
Derrick Man System	1	2
Elevation of the Mast	1	1
Climbing device	2	1
Total	**1.417**	**1.514**

The determined values of each contractor of the various criteria are multiplied with the factor (weight) of the respective criteria.

Based on this rating and in combination with the weighted criteria the following calculation is made to get a reference of the best contractor in the criteria mast. Therefore, table 9.2 and 9.3 are used:

Criterion “Year” with 0.014 (Table 9.2) is multiplied with the rank 1 (Table 9.3), criterion “free working height” with 0.222 is multiplied with the rank 2, and so on.

<u>Contractor 1:</u>

$$0.014 * 1 + 0.222 * 2 + 0.194 * 1 + 0.139 * 1 + 0.167 * 2 + 0.111 * 1 \\ +0.056 * 1 + 0.069 * 1 + 0.028 * 2 = \mathbf{1.417} \tag{3}$$

<u>Contractor 2:</u>

$$0.014 * 2 + 0.222 * 1 + 0.194 * 2 + 0.139 * 2 + 0.167 * 1 + 0.111 * 2 \\ +0.056 * 2 + 0.069 * 1 + 0.028 * 1 = \mathbf{1.514} \tag{4}$$

The result shows, that for the criterion “Mast” contractor 1 provides a better concept, because of a lower value. Now the value of the criterion “Mast” is calculated. This is done with all different sub-criteria. (Appendix 13.3: Evaluation matrixes). Every matrix evaluation ends up with a calculated value.

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Table 9.4 shows the calculated final values of the 12 sub-matrixes of the criterion “rig concept”. The sub-matrixes of the matrix “Rig concept” like “Mast”, “Substructure”, “Drawwork”, etc. are weighted with the same weight of 8.3 % each. Company B provides the best rig concept with the value 1.08.

Table 9.4: Results rig concept

Criteria \ Contractor	Company A	Company B	Company C	Company D
Mast	1.74	1.60	2.07	2.11
Substructure	0.67	1.19	2.11	1.15
Drawwork	0.93	0.93	2.64	0.93
Rotary Table	1.17	1.63	0.63	1.17
Top drive	2.32	0.70	2.31	0.70
Pumps	1.81	0.86	1.81	1.46
Tank System	1.44	1.00	1.74	1.15
Power supply	0.27	0.27	0.44	0.27
Well safety equipment	1.00	1.75	1.00	1.00
Installation equipment	1.00	1.75	1.00	1.00
Data Collection	0.04	0.04	0.04	0.04
Pipe Handler	1.19	1.19	2.14	2.33
Total	**1.13**	**1.08**	**1.49**	**1,11**

The calculated total value of each contractor (Table 9.4) will be multiplied with 45 % in the particular end value. (Figure 9.2 and Table 10.3)
Furthermore, this weighting and calculation procedure is done with the other matrixes “Rig move”, “Distance to operator”, “Local experience”, “Rig availability” and “Energy consumption” and summed up to a final evaluation matrix shown and explained in chapter 10.3 “Efficiency analyses result”

10. Evaluation of the efficiency analysis

This chapter combines the evaluation of the rig move scenario, which was part of the second phase of the tendering process, to get more information about the future concepts, the pre-disqualification of concepts in combination with the K.O. - criteria and the final technical evaluation of all matrixes.

10.1 The rig move scenario

The rig move has an immense influence for the sucess of the drilling campaign and was used to support the evaluation of the companies. Arround 2 - 3 days, which is 20 % of the process from spud to spud is the moving procedure. The time schedule which implies 20 wells per year is reachable with a sufficient drilling phase and a fast rig move. Therefore, a rig move scenario was established to give the contractors the possibility to plan their rig move as precice as possible.
The evaluation of the rig move scenario is an additional value for the future contractor election. Table 10.1 shows the significant differences in the implementation of the rig move scenario of the contractors.

Table 10.1: Rig move durations

Result \ Contractor	Company A	Company B	Company C	Company D
Loaded train [min]	63.0	67.0	-	37.5
Empty train [min]	23.2	18.0	-	10.8
Total [min]	**86.2**	**85.0**	**-**	**48.3**
Loc. moves empty	17	15	0	9
Loc. moves loaded	18	15	0	11
Total	**35**	**30**	**0**	**20**

The fact that Company C neglects the train totally is the reason that no values could be generated. Company C wants to execute the move on street and commissioned a third party to evaluate, if driving on the dyke is possible with their carrier based rig which weight 73 tons. The maximum allowed street load is 40 tons at a heavy load street and 60 tons on rail. The third party IMN (Ingenieurbuero Mueller und Neumann GmbH) is an engineering office which supports occasionally the oil and gas industry. IMN declared that the weight of the rig does not exceed the capable load of the dyke, if the driving way is prepared in advance with a solid sand bed and so called DURA-BASE® mats on top to distribute the occurring loads. These mats are made out of thermoplastic and can be connected which each other to a solid underground. [13] The distance to the slope of the dyke has to be minimum 4.5 m otherwise the underground structure gets damaged. To ensure this distance some of the pre-existing drilling areas with their surrounding fences, some pipelines and well equipment have to be removed. The equipment which is not mounted on the carrier based rig will be transported via flatbed trucks.

The other 3 contractors executed their rig moves scenario with the utilization of the rail way system. With 48.3 minutes traveling time of empty and loaded locomotive Company D needs the least time to move their rig from location A to location B in 300 m distance. Table 10.2 lists the estimated resources for the rig move of each contractor.

Table 10.2: Rig move requirements

Requirements \ Company	Company A	Company B	Company C	Company D
Locomotives	2	3	0	2
Cranes	2	2	2	1
Location change of Crane	5	2	0	1
Carrier	7	10	0	5-7
Flatbed truck	0	0	2	0
Rail chassis	16	7	0	28
Needed parking rail	4	2	0	4
Expected time [days]	2-3	3	3	2-3
Max. part weight [t]	Ca. 30	30	73	60
Max part length [m]	ca. 20	ca. 20	ca. 20	ca. 20
Location changes of empty & loaded trains	35	30	-	20

Noticeable is the big difference in needed rails chassis and location changes of the empty and loaded trains between the contractors. Depending on the concept more carriers or more rail chassis are used for transportation. Company A and company D are planning the move with a train organization, where big and heavy components like tanks, generators and the powerhouse stay on rail and will be moved with mounted rail chassis. Company B does the rig move with the utilization of carrier. The loads are hoisted on carrier at location A and reloaded at location B. Thereby the differences can be explained. There is another explanation for the different amount of moves of the train. Company D plans to transport more equipment within one move of a train including more pieces, which are separated on different parking rails. Company A and B plan to transport less equipment within one train. This is the reason why company D can transport the equipment with less moves in less time. The number of moved parts or the amount of moves is for the evaluation not important, because if a company can reach a shorter time for moving more parts than another company, the first one should be preferred.

10.2 Pre – disqualification

Before the efficiency analysis is done and a final decision can be made, the K.O. - criteria should be considered. These criteria have to be fulfilled completely of each concept. Otherwise the concept has to be disqualified. One example is the maximum individual transportation part width of 4 m. If a part is bigger, than it cannot be transported within the field and the concept will be disqualified.
Concept A2 and concept C cannot fulfil all K.O. - criteria. They exceed the maximum allowed load on roads or on rail. The third party IMN was not able to eliminate the possibility that the rail and street system on the dykes withstand the occurring loads without any damage. These facts and risks result in a too complex measurement and disqualified the tenderer company C.
Company A2 with their rig concept of a super single drilling rig also does not fulfil the requirements. The load restrictions in the field will be exceeded with over 60 tons transportation weight. Furthermore, the full automatic pipe handler with its vertical round pipe storage system contains a lot of big and especially long parts which are not easy to transport within the field. Additionally they cannot be handled on the small drilling sites. These facts are responsible for a pre-disqualification of the rig concept of concept A2.

10.3 Efficiency analyses result

With all generated information and data, delivered from the contractors and the employees of GDF SUEZ following results are developed with the evaluation matrixes and sub-matrixes of the efficiency analyses:

Table 10.3: Efficiency analyses result

Criteria \ Contractor	Company A	Company B	Company C	Company D	Best concept per criteria
Rig Concept (45 %)	0.509	0.484	0.672	0.499	B
Rig Move (20%)	0.354	0.410	0.585	0.333	D
Distance to operator (10%)	0.036	0.064	0.121	0.093	A
Qualification of personal (10%)	0.000	0.000	0.000	0.000	-
Local Experience (5%)	0.075	0.042	0.100	0.025	D
Energy (5%)	0.033	0.033	0.033	0.033	ABCD
Rig availability (5%)	0.100	0.100	0.050	0.100	C
Total value	**1.107**	**1.133**	**1.562**	**1.084**	**-**
Total ranking	**2**	**3**	**4**	**1**	**-**

Table 10.3 shows the total ranking of the different concepts based on the total points of all matrixes. Company D has the most appropriate technical concept with 1.084 points followed by company A with 1.107, company B with 1.133 and company C with 1.562 points. A main effect of the end result has the rig move. This part of the drilling process has a major effect on the success of the future drilling campaign.
The total values of table 10.3 are very close together and the ranking can change immediately, if only one criterion will get a different weighting or the subjective evaluation get changed. Out of the question company C is not capable to keep up with the 3 other concepts, because of the pre-disqualification and other points which are later on discussed in this chapter.

<u>The rig concept</u>
Company B provides the best rig concept, because of a narrow rig construction and the highest hoisting capacity. Additionally it provides a powerful top drive, a rotary table which can work as a drilling alternative and sufficient German pumps. With these pumps a lot of good experience was made in other projects and the manufacturer of the pumps provides a sufficient after sale service. Furthermore, the tanks are

constructed like bathtubs and allow an easy cleaning and therefore a fast possible mud change with a nearly 100 % usage. These points lead to the best ranking. Company A and D provide a similar good rig concept. Company A has a low ranking in the criterion “Mast” because of the low free working height. Additionally they want to use Chinese pumps which may can produce some problems with the after sale service and the quality of the pumps itself. Company C is at the last rank because of the old technical standard of the rig. It does not provide a PULD machine, the diesel-hydraulic drive is not preferred in a nature reserve, mechanical drawwork with no automatic lowering device and the widest guying of all concepts are the main points of the last rank of company C.

<u>The rig move</u>

Company D and A are planning their rig move similarly. Both plan to move as much as possible on rail and want to leave it there during operation as well. The fact, that company D moves faster and needs less crane operation leads to the first rank. Company A convinces with a low center of gravity of the moved heavy parts like generators, VFD etc. and less equipment during the move insofar as carrier and rail chassis. On the other hand they have to move their cranes much more than the competitors and moves parts/equipment the most. Company D loses points because of the highest amount of needed rail chassis and the fact that they have to move parts up to 60 tons. More weight means more risk on the unconsolidated underground. Company A and B have a maximum part weight of approximately 30 tons.

Company B needs the most rail carrier and the most hoisting works. This in combination with a relatively long locomotive moving time and that they want to use a third locomotive (Company A and D need 2) ends up in the third place in the rig move ranking. Company C has the least efficient rig move concept because of conditions explained in the chapter 10.2 “Pre-disqualification” and 10.1 “The rig move scenario”.

<u>Distance to operator</u>

Company A, B and D are located in Germany and C in the Czech Republic and has the longest distance to the oilfield Ruehlermoor. This may leads to a worse flexibility in case of unwanted events like illnesses of employees or the need of a technical support by experts. Because of that company C is listed at the last rank. Between the other competitors the distance to the head quarter or to the future supporting/operating facilities is taken for the ranking. Therefore, company A wins this ranking with the closest distance in front of B, D. The fact that the drilling company, which wins the tender, could organize a nearby supporting facility (workshop, office etc.) for the duration of the drilling campaign is not considered in this evaluation.

Qualification of personal

This chapter was not evaluable, because of too less information about the future personal working at and for the rig. Therefore, it has to be thought about, if the 10 % weighting may have to change to another criterion to evaluate the total 100 %.

Local experience

In this category the operators experience with company D and B was the best, because of a lot of past projects. Nowadays the work with company A is also increasing and should be considered in a few months again. With company C no project was executed so far.

Energy consumption

No rig is built yet. Therefore, the experience of the future energy consumption is only predictable. Moreover the energy consumption changes with the downhole conditions, the used tools, the trajectory of the well etc. To get detailed predictable energy consumption the detailed engineering phase has to be used. At this time this chapter will be rated for each contractor the same.

Rig availability

The fact that no rig is built yet, and the companies insured that they all can build their rigs within 9 months leads to the same ranking in this point. Only company C can provide earlier the future drilling rig, because their concept is in production and could start to drill immediately after finishing of construction in the beginning of 2017. The competitors will then start the construction of their rig concepts.

10.4 Efficiency and HSE considerations

Neither the drilling operation, nor the rig move operation or the drill site organization is the most important point. All processes are equally important. The results of the efficiency analyses do not include operational processes like delivering of pipes and casings to drill site or cementing the casings. A drilling rig which is able to drill the required 500 – 700 m deep wells in 8 days but needs 6 days for moving is less interesting for the project than a drilling rig which is able to drill the wells in 10 days and move in 3 days. Subsequently all procedures have to be regarded. Therefore, the contractors were asked in the second tendering phase next to the rig move scenario, how they will perform the transport of pipes and casings and execute the cementing job. Following differences are striking. Company B and D do not use the additional elevated pocket at the drilling site (Figure 4.3 green area), which saves time and money for the construction. Company A, C and D will store the casings on storage areas on the drilling side whereat company B store them in pipe carrier on a neighbour well site rail. Company D needs an additional storage area for drill pipes, because they are using a super single drilling rig, which is not able to store the drill pipes vertical in the monkey board on the drill floor after drilling like the other companies. All companies will place the cementing unit on rail and will leave it there during the cementing job. Company B provides the only concept were the main rail stays almost free. Only the cutting box stays on rail and can easily be removed. This increases the flexibility of rail transports to the drilling site. All concepts leave the street for thoroughfares free, which also can be used in case of an emergency for an ambulance.

In addition to that all management and safety qualifications have to be fulfilled from the contractors. GDF Suez will not contract a company which is not able to provide a safe working environment. Therefore, a HSE evaluation was made (Table 10.4)

Table 10.4: HSE considerations of the contractors

Company	Employees	work related injuries/illnesses			Working days lost			Fatalities or multiple hospital admissions
		2011	2012	2013	2011	2012	2013	
A	224	0**	2**	0**	0**	185**	0**	No
B	244	1	1	3	15	8	112	No
C	546	6	8	8	706	629	577	No
D	160*	2	1	0	29	16	0	No

*in 2013

**in 2012; 2013; 2014

Company	Total work related injuries	% of injured personal	total work days lost	days lost per employee	Rating	Ranking***
A	2	0.89	185	0.83	0.87	1
B	5	2.05	135	0.55	1.55	3
C	22	4.03	1912	3.50	3.85	4
D	3	1.88	45	0.28	1.34	2

*** To get a ranking the % of injured personal gets 2/3 of importance and the days lost per employee get 1/3 of importance

This table was developed on basis of the contractor qualification questionnaire, which was part of the tender documents of GDF Suez. In this questionnaire next to other points, the amount of employees, the work related injuries/illnesses and the related lost working days for the years 2011 - 2013 were investigated. These numbers were related to each other to develop a ranking.

The fact that a work-related injury / illness happened is rated 2/3 of the total value, compared to the associated lost workdays, which enter into the calculated final value with 1/3. Normally the work related injuries/illnesses and the lost working days were related to the amount on worked hours. But because of missing data the amount of employees was taken to give an overview or an evidence of how safe the contractor will work. The second part of table 10.4 shows the calculated results.
One example: Company C has 546 employees. From 2011 to 2013 they had 22 work related injuries/illnesses. That means that 4.03 % of the company´s own employees were injured/ill during this period. Furthermore, due to the injuries/illnesses they lost 1912 working days. That means every employee was 3.5 days in this 3 year period not at work. With the weighting following calculation is made:

$$4.03 * \frac{2}{3} + 3.50 * \frac{1}{3} = 3.85 \qquad (5)$$

With 3.85 points company C is ranked on the last place. Company A has the best value with 0.87 followed by D with 1.34 and B with 3.55.
This ranking was only done to support the evaluation of the efficiency analyses and was not a part of it.

11. Conclusions

The oilfield Ruehlermoor is unique worldwide and the biggest onshore oilfield in Germany. The load and size restrictions make it very difficult to enter the field with a 150 t onshore drilling rig. In addition to that the target to drill 20 wells a year is a challenge under the given circumstances. The wells drilled with the Franks Cabot 300 gave the technical team the experience that this rig will not be capable to drill the campaign within the given time and without major problems. The rig was built in 1982, and would have to be upgraded for roughly 2.7 million Euros and the personal and the maintenance system must be provided. Additionally, it was shown that an assignment of a contractor could be even cheaper. Therefore, the decision was made to instruct a contractor for the drilling campaign. A tendering process was initiated. 19 European companies were informed and 11 indicated interest. Four different contractors with in summery 5 concepts intended to fulfil the recommendations to win the tender.
With around 20 % of moving time (2-3 days) the rig move procedure is very important. Mostly for drilling operations the rig move and the drilling side play a sub role in a drilling campaign. In this case the circumstances are different. Load and size restrictions encourage the contractor to develop a new concept to move the rig with all its equipment on the existing rail system. Additionally the area during move and on the drilling side is limited, resulting in a need of a good organization and a well-structured rig move plan. The drilling and moving procedure should be possible within 14 days. A focus was placed on a rig move scenario. This scenario was developed to understand the future moving process and for estimation of the consumed time of each rig concept during move.
In an evaluation process the concepts were rated and analyzed. With an efficiency analysis rationally comprehensible results were produced, based on personal assessments. This analysis works with pairwise weighting of criteria and sub-criteria which are cumulated in matrixes. The matrixes were developed and filled out with the help of drilling engineers and drilling supervisors.
HSE statistics of the contractors were analyzed to get an overview of their working terms. Furthermore, efficiency measures were asked for to find out, how the contractor will implement tasks like running casing after drilling, cementations or change of BHA. Two concepts were disqualified because of pre-developed K.O. - criteria. In conclusion, all concepts are suitable to work in the oil field Ruehlermoor, but 2 of them have a major negative effect to the infrastructure, because of exceeding load restrictions. Therefore, they cannot be considered for the drilling campaign. 3 concepts were able to convince the technical team of GDF Suez and will be ranked commercially also. The pre-disqualified company C was part of the efficiency analyses and the evaluation process, because the final disqualification decision was made in cooperation of the

technical team with the legal and the commercial department after finishing the technical evaluation. On the technical view all concepts are suitable for the oil field Ruehlermoor and are capable to do the drilling campaign but two concepts should be accentuated. Due to the fact of the second place in the technical evaluation and the first place in the HSE statistics company A gets a more possible contractor for the redevelopment project and the drilling campaign. Company D with a good rig concept and a similar HSE statistic is the most preferable concept. These results are based at this point of time on finishing the efficiency analyses and the evaluation process with the given data. Company A prefers a double stand rig and company D a super single rig. A super single rig needs more space for drill pipes and casings on the drilling side which has to be considered. The double stand rig itself is bigger. After the commercial evaluation the final result may change the result but this could not be considered in the technical evaluation.
On the technical side these two companies should be emphasized. Company B loses the evaluation with their rig move concept. Many parts have to be hoisted on carriers or moved by tractors. On the future drilling location all these parts have to be hoisted and placed again. The move was done with the 300 nearly the same, but with less equipment and less time pressure. Company A and Company D invited an innovative concept which simplifies the rig move procedure. Company C and the second concept of company A were pre - disqualified which is explained in chapter 10.2 due to the fact that they exceed the load restrictions of the dykes. The expertise of a third party (IMN) showed that the infield move is possible with a load of over 70 tons, but the fact that a damage of streets, rails and dykes could not be excluded leads to a disqualification of the concept. Table 11.1 shows the final results after the efficiency analyses.

Table 11.1 Final efficiency analyses result

Criteria / Contractor	Company A	Company B	Company C	Company D
Total value	**1.107**	**1.133**	**1.562**	**1.084**
Total ranking	**2**	**3**	**4**	**1**

The final decision will be made after the commercial documents are opened and evaluated.

12. Outlook

This thesis does not provide a perfect decision for the most fitting rig concept for the redevelopment project. It provides a recommendation developed out of given and raised data because of the subjective interpretation of the criteria weighting and ranking. The technical team can use this thesis to get an overview of the concepts and to get the possibility to rate them prospectively based on the provided evaluation and interpretations under consideration that some points cannot be ranked in this stage of the tendering process. One example is that because of insufficient information the criterion “Qualification of personal”, which implies 10 % of the total value, could not be ranked. The 10 % should maybe put in the criterion “Rig move”, because of the tremendous impact of the execution of the rig move for the success of the project. This maybe could lead to a slightly different result, because of similar suitable rig concepts of company A, B and D. Subsequently the commercial ranking will have an impact on the final decision.

The efficiency analysis is a procedure and is never really finished. It is an evaluation process. During the future detail engineering phase many problems and ambiguities will be solved predictably. This redevelopment project encourages the organisation team to think “out of the box”, to find new ways to work in the field Ruehlermoor and solve problems which have never been there before.

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13. Appendix

13.1 Preliminary Equipment List

A GENERAL

A 1 Mast

Mast height to handle double stands with a static hook load of 150 tons.

The rig location shall be provided with illumination with strength of 300 lux in all working areas and 200 lux in all storage areas. The mast illumination should be heavy duty, vapor tight and fluorescent type.

All handrails have to be fitted with 2 rails and a kicking board. Handrails on the drill floor should be plated in where a risk of falling tools exists. All floor penetrations on the rig floor to be covered where a risk of falling tools exists.

CONTRACTOR shall ensure that the drilling mast is inspected by a recognized inspection CONTRACTOR in accordance with the API Specification 4F – Drilling and Well Servicing Structures and to meet the requirements of the certifying authorities (see Engineering and Manufacturing Status in the ITT)

Mast complete with:

a) Racking platform with locks on fingers able to accommodate:

- 1500 m 5" drill pipe.
- 1500 m 3 1/2" drill pipe.
- 250 m 2 3/8" drill pipe.
- 4 stands 8" drill collar.
- 8 stands 6 3/4" drill collar.
- 4 stands 8" drill collar.
- 4 stands 8" drill collar.
- 4 stands 4 3/4" drill collar.

b) Air winch system at racking platform level to aid the racking of drill collars (up to 8”).

c) Fast and deadline guide for drilling line.

d) Climbing safety device for derrick man.

e) Three counterbalances system: two for the rotary tongs and one for the pipe spinning tong.

f) Two drill floor-mounted air-winches, one min. SWL of 3000 kg and one min. SWL of 1500 kg. All winches to be equipped with automatic brakes, overload protection, automatic spooling device and marked with SWL.

g) Certified derrick man escape device, including safety harness, riding belt, mechanical slide and test weight.

h) Camera system at racking board position with colored monitor system in driller's cabin.

A 2 Substructure

One set of substructure with flooring having sufficient clear height to permit easy installation of CONTRACTOR furnished BOP stacks and COMPANY furnisher wellhead. Complete as follows:

a) Set back capacity of substructure ~100 to simultaneous with ~150 to rotary table load.

b) Handling gear for easy handling BOP stacks and wellheads. Rail chassis beams and chain hoist. Two chain hoist with min. 10 tons capacity each. All lifting equipment to be marked with SWL.

c) Non slip matting covering those areas of the floor where personnel are required to stand when handling pipe.

A 3 Drawworks

One electric drawworks of at least 500 kW rating.

Complete with:

a) Mechanical park break

b) Crown block safety device.

c) Grooving on main drum for drilling line.

d) Automatic driller

A 4 Crown Block

To be rated for static hook load capacity of min. 150 tons.

A 5 Travelling Block

One travelling block-hook combination, min. 150 tons capacity c/w

a) Spring assembly.

b) Hook locking device.

A 6 Top-Drive

Rated static capacity 150 tons, working pressure min 350 bar. Make up Torque wrench moment 50.000 Nm. Continuous drilling torque 30.000 Nm. Max. RPM at max. continuous torque 140. Max RPM 200.

Complete with:

a) Full range of jaws.

b) Upper IBOP valve 350 bar.

c) Saver sub lower connection NC50.

d) Lower IBOP valve 350 bar.

e) Casing circulating packer.

f) Elevator links (running casing) w/ rated capacity min 150 tons. Link tilt capacity of 3 tons at 1.5 m tilt distance.

g) Two spare saver subs.

A 7 Drilling Line

One drilling line min 1-3/8", 6x19 IPS with IWRC at least 2000 m length.

Drilling line must be spooled on a power driven steel drum.

Complete with:

a) Cover for drum and chain.

b) Support frame for drum with lifting eyes for crane handling.

A 8 Deadline Anchor

One dead line anchor for 1-3/8" wire line completed with load cell.

A 9 Rotary Table

One rotary table with an opening of min. 17-1/2", independently driven. AC driven preferred.

Complete with:

a) Split type master bushings.

b) Full range of insert bowls for running of 9 5/8”, 7”, 5” casings, 3 1/2” tubing and 12 1/4”, 8 1/2”, 6 1/8 and 4 1/8” bits.

c) Drip pan underneath rotary table.

d) Able to rotate clockwise and anti-clockwise.

e) Mechanical locking device.

A 10 Pipe Racks

One set of pipe racks with adequate capacity for 1.000 m of 9-5/8” 47.0# casing of max. 3 layers and suitable to accommodate drill pipe, drill collars and tubing complete with catwalk.

Air winch for end of catwalk c/w wood lined pipe catcher across with of catwalk. All lifting equipment to be marked with SWL.

Automatic cat walk system or an automatic pickup/laydown device (e.g. pipe handling) will be preferred.

A 11 Rig Service Air System

The rig air system should have sufficient compressor capacity to operate the rig.

A 12 Power Equipment

The specified power has to be the effective (real) out power. The CONTRACTOR has to provide an electrical single line diagram with the tender bid documents.

Complete power system consisting of diesel driven generator sets using an SCR or VFD system.

Sufficient power must be available to control and power simultaneously two mud pumps and the rotary table (top drive) all at full load and the drawworks at half load. CONTRACTOR to supply calculations demonstrating that power plant is suitable for maximum operating conditions and specifying limitations.

Sufficient power must be available to meet the power demand of all motors and lighting equipment simultaneously.

Emergency shutdown switches for the complete power system must be provided at the driller's position and the power plant.

Provision for power supply for a mud-logging and mud lab unit.

Provision for power supply for all rig site accommodation and offices.

Engines should be equipped with spark arresters on the exhausts. Air intake shut off valves should operate either from the driller's console or from the power plant.

Drilling unit should be capable of supplying sufficient power for third party solids control/ treatment equipment.

Emergency generator for the rig.

Electrical power and compressed air for COMPANY and third party use within the limit of availability and priorities on the rig.

Generator sets to be equipped with spill protection

B HIGH PRESSURE MUD SYSTEM

All components of the high-pressure mud system must have a working pressure of 350 bars and be designed and constructed in accordance to the given manufacturing standards. All connections should be welded and not threaded.

B 1Pumps

Triplex pumps, each equipped with an independently driven centrifugal charging pump. Pump power rating minimum an output of overall 2500 l/min and a minimum overall output of ~1200 l/min at 350 bars.

Integrated closed loop-cooling system for each pumps.

There has to be an efficient number of spare parts for the mud pump units at the rig site. This includes but not be limited to spare liners, piston, wear plates, fluid end, fluid end packing and bolts, piston rods, pony rods, piston clamps, etc.

Complete with:

a) Forged or cast steel fluid ends.

b) Quick-change system for liners and pistons.

c) Cooling/lube oil system for liners.

d) High-pressure pulsation dampener.

e) 3" reset relief valve (adjustable) with discharge to active tank.

f) Suction and discharge strainer.

g) Covers over piston pots.

h) Full range of liners and pistons to operate at the optimum volume/pressure as required by the drilling program.

B 2 Pump Discharge Lines

One 4"x 350 bar WP mud pump discharge line with 4" 350 bar gate valves. All flexible hoses to be equipped with whip lines or turnbuckles.

B 3 Standpipe

One 4" ID 350 bar WP standpipe with gooseneck connected to an H-type standpipe manifold. All 4” connections must be Fig 1002 Weco unions and all 2” connections must be Fig 1502 Weco unions.

Standpipe manifold complete with:

a) Pressure gauges and sensors for instrumentation and recorders.
b) Kill-line outlet.
c) Fill-up/bleed-off line outlet.
d) Spare outlet with Weco Fig. 1002 and 1502
e) Drawing of stand pipe manifold to be attached to the tender bid documents.

B 4 Rotary Hoses

Two 3 1/2” ID 350 bar WP rotary hoses complete with whip lines and 4” Weco Fig 1002 unions. One in use and one as spare. Both hoses c/w integral connections (no LP connections).

One 2" ID 350 bar WP casing wash down hose 15 m long each with 2” Weco 1502 unions. Both hoses c/w integral connections (no LP connections).

B 5 Fill-up System

A balanced fill-up system connected to the low pressure system, fed by a centrifugal pump and a valve at the rig floor.

C LOW PRESSURE MUD SYSTEM

A flow schema showing the piping configuration of the active mud system, the reserve mud system, the mixing system and the solids control system has to be provided with the tender bid documents.

C 1 Mud Tank System

Active mud tank system with a total capacity of 50 m³. Each tank equipped with sufficient number of mud agitators. Tanks to be sectionalized for in series treatment by solids removal equipment (shaker tank -settling tank, desander suction comp., desilter suction comp., degasser suction comp., intermediate tank, suction tank w/ pill tank, etc.)

One settling tank /shaker. Capacity of settling tank to be specified.

One pill tank of about 5 m³ with mud agitator.

One trip tank with two independent chambers. Each chamber with 1.5 m³ Trip tank complete with centrifugal pump, an alarm and chart recorder.

One mixing tank of about 10 m³ with an agitator.

Additional three mud reserve silos with each about 30 m³ equipped with digital level indicator. Including manifold and transfer pump.

Mud tanks to be capable of handling mud with MW of 2.0 kg/l.

All tanks (incl. reserve tanks) must have the possibility to be connected and disconnected with the active mud system by flow lines and valves. Transferring of mud between the tanks must be possible while circulating with the mud pumps through the well.

A round-tank system (or a similar system) is preferred due to the ability for quick and safe tank cleaning without the necessity to send a person into the tanks.

C 2 Mud Mixing System

Complete mixing system comprise one hopper and one centrifugal pump. System to be able to treat mud in the active system together with mixing a pill or reserve mud whilst not interfering with the mud pump and charging pump operation.

The hopper should be fitted with a big bag safety frame above it. The hopper should be easily accessible by a forklift.

The hopper should be to mix polymer mud.

One emergency shower must be installed at the mixing area. Eye wash stations have to be installed on the rig floor, closed to the mixing area and at the shale shakers.

C 3 Shale Shakers

Minimum two independently driven linear motion shale shakers, capable of handling 2500 l/min mud through API mesh 100 screens. A full range of screens must be available and supplied by the Rig CONTRACTOR.

Acceptable manufacturers/ type include:

a) Swaco Mongoose PRO

b) Derrick Flo-Line Cleaner

c) Brandt King Cobra

C 4 Desander/ Desilter or Mud Cleaner

One Desander/Desilter unit capable of handling 1000 l/min.

C 5 Vacuum Degasser

One independently drove vacuum type degassing unit. Design approved at the discretion of the COMPANY. The vent line has to be a separate line and not connected to the vent of the mud gas separator.

C 6 Mud-Gas Separator (Poor-Boy Degasser)

One atmospheric mud gas separator with vent line regarding vertical with 48”. The vent line must be securely anchored.

The mud gas separator has to be located between the choke manifold and the shale shakers and has a straight discharge to the vent line.

The mud gas separator inlet line size should be the same size or larger than the choke manifold discharge line.

C 7 Cellar Pump

One air operated sump pump for evacuating the cellar

C 8 Mud Saver Bucket

One mud saver bucket for 5" and 3 1/2” drill pipe, return of mud bucket to be routed to the trip tank.

C 9 Ditch Magnet

Two ditch magnets to fit on the flow line.

C 10 Mud Testing Equipment

One set of mud testing equipment according to API Spec 10, RP-13B.

D BOP EQUIPMENT

All equipment shall be in accordance with API RP 53 & 16C. Drawings giving detailed data on pressure rating and BOP stack configuration, indicating also choke and kill line hook up to be submitted with the bid documents. The complete BOP equipment including choke manifold and accumulator unit requires valid manufacturer equipment certification. The certification has to be made available to COMPANY at contract award.

D 1 11” BOP Stack

One 11” x 5000 psi WP annular blowout preventer

One double or two single 11” x 5,000 psi WP ram type preventer (pipe rams placed top and blind/shear rams placed bottom).

One set of blind rams, one set of 5” pipe rams, one set of 3 1/2” pipe rams, one set of 2 7/8”-5” variable rams, one set 7” casing rams

One spacer spool 11” 5000 psi to install BOP stack to surface level (height has to be specified).

One drilling spool with 3-1/16” outlets for 11” BOP stack to install choke and kill line.

One double studded adapter flange 11” 5000 psi to 7 1/16” 3000 psi

Flow risers for use with BOP's and for the stovepipe (bell nipple, mud pitcher).

All necessary clamps, bolts, nuts and gaskets for above BOP's and spools including gasket between wellhead and BOP's.

Spare parts for above.

D 2 7 1/16” BOP Stack (optional)

One 7 1/16” x 3,000 psi WP annular blowout preventer.

One double or two single 7 1/16” x 3,000 psi WP ram type preventer (pipe rams placed top and blind/shear rams placed bottom).

One set of blind rams, one set of 3 1/2” pipe rams, one set of 2 3/8”-4” variable rams, one set 5” casing rams

One spacer spool 7 1/16” 3000 psi to install BOP stack to surface level (height has to be specified).

One drilling spool with 3-1/16” outlets for 7 1/16” BOP stack to install choke and kill line.

Flow risers for use with BOP's and for the stovepipe (bell nipple, mud pitcher).
All necessary clamps, bolts, nuts and gaskets for above BOP's and spools including gasket between wellhead and BOP's.
Spare parts for above.
D 3 Blow-out Preventer Control System
One 5,000 psi WP automatic pump accumulator unit. Clearly specify make, model etc. of the complete unit and of the following individual components.
Number and capacity of air-driven pumps.
Capacity electrically driven triplex pump.
Capacity fluid reservoir.
Number and total capacity of cylindrical bottles.
Pressure reducing and regulating valves for manifold and for annular BOP.
Low level, low pressure alarm for the hydraulic fluid level.
The unit to be sized such that with the pumps out of service, 1,200 psi (200 psi above pre charge) remains after completing the following cycle.
Specify and calculate fluid requirements for each individual operation and the complete cycle. Total accumulator capacity should be two times the fluid requirement to complete the cycle (close-open-close and open HCR). CONTRACTOR to supply calculations demonstrating that total accumulator capacity is suitable for the requested operating conditions.
Two remote control panels. One control panel at driller´s position and one panel close to the toolpusher office.
The main closing unit should be located in a safe area away from the cellar and derrick floor.
D 4 Choke Manifold
One 5,000 psi WP choke manifold in accordance with API RP 53 & 16C.
Drawing giving detailed data on pressure ratings and dimensions of the choke manifold to be submitted with the bid documents.
One remote choke control panel according to API RP 6 & 16 including choke position as well as rig air, hydraulic, standpipe, casing and choke manifold pressures.
D 5 Choke Line
One 5,000 psi WP choke line in accordance with API RP 53 & 16C. Min. 3 1/8" ID 5000 psi WP coflex hose with flange connections on both ends.
One 3 1/8" 5000 psi WP H_2S resistant manually operated gate valve.
One 3-1/8" 5000 psi WP hydraulically operated HCR valve.
D 6 Kill Line
One 5,000 psi WP kill line in accordance with API RP 53 & 16C. 2 1/16" ID 5000 WP line with flanged connections on both ends.
Two 2-1/16" 5000 psi WP resistant manually operated gate valve.

One 2-1/16” 5000 psi WP check valve.

D 7 Hydraulic Test Pump

One hydraulic air operated 5,000 psi test-pump complete with chart recorder, gauges, HP and LP hoses.

D 8 Test Stump (optional)

One test stump/flange for 11” 5000 psi BOP stack complete with 5” tool joint box with side port on bottom.

D 9 Cup Type Tester

Cup type testers with cups for 9-5/8” 47.0 – 53.5 # and 7" 23.0 – 35.0 #

Standard combination tools to pull wear bushings from CHH for the above mentioned casing sizes.

E INSTRUMENTS

E 1 Drillers Position

One weight indicator.

Two standpipe pressure gauges, 0 - 350 bar.

One choke manifold pressure gauge, 0 - 350 bar.

One rotary tachometer.

One rotary torque indicator.

One cumulative pump stroke counter for each mud pump.

Two pump stroke indicators; one for each mud pump.

One tong torque indicator.

One pit volume totalizer with floats in all active mud tanks and on reserve tank complete with loss gain indicator and alarm (audio and visual). One mud flow indicator with high and low alarm.

E 2 Drillers Doghouse

Recorder for pump pressure, circulation rate (pump strokes), weight on bit/string weight, rotary RPM, rotary torque and rate of penetration.

One recorder for the mud volume totalizer and flow rate.

One recorder for trip tank.

E 3 Choke Manifold

One standpipe manifold pressure gauge, 0-350 bar.

One choke manifold pressure gauge, 0-350 bar.

One 1" NPT connection for pressure gauges of various ranges.

E 4 Standpipe Manifold

One pressure gauge 0-350 bar, visible from the drillers position.

E 5 Mud Pumps

Each pump equipped with a pressure gauge before the isolation valve.

F TRANSPORT & LIFTING EQUIPMENT

All necessary transport and lifting equipment to efficiently handle all CONTRACTOR's and COMPANY furnished materials, equipment, supplies and personnel at the drilling location.

F 1 Forklift

Capacity min 5 tons c/w certified forklift hook beam extension, pick up hook and with pipe clamp.

G MISCELLANEOUS EQUIPMENT

G 1 Fire Fighting

Necessary fire-fighting and safety equipment as required for the operations and as specified by local regulations.

G 2 Fuel Tank(s)

Fuel tank with a minimum capacity of 5 days of operation with individually measuring system. Fuel tanks to be double skinned (with leak detection) or fuel storage area to be surrounded by bund walls.

G 3 Water Tank(s)

Water tank(s) with a min. total capacity of 60 m^3 with electrically powered water transfer pump.

G 4 Welding Unit

2 electric welding sets 300 - 400 Amp.

Two oxygen and acetylene cutting torch sets.

G 5 High Pressure Cleaner

Two industrial high pressure jet washing and steam cleaning systems.

G 6 Rig Floor Hand Tools

Complete furnishing of standard rig floor hand tools according good oilfield practice, such as chain tongs, spanner, pipe wrench, torque wrench, hammer, grease guns, etc.

G 7 Communication System

A communication system between drill floor, tool pusher office, mud tanks, COMPANY offices, service office, mud logging unit and mud engineer office.

Sufficient amount ex-proof radios for communications on site (e.g. during cementing, crane lifts)

G 8 Gas Detection / Protections

2 psc. Explosimeter

2 pcs. H_2S and CO_2 Detectors (DREAGER Multiwarn)

A detection system for combustible gases will be provided by 3rd Party.

G 9 Skinny Pipe (Top Job Cementation)

50 m 1 1/2” pipe with 1 1/2” thread pin x box to be used for top cementing job. Including adapter T-piece with 2” Weco connection Fig. 1502.

G 10 Lighting

Sufficient portable Floodlights (height ~7 m) with capacity ~500 W. Each equipped with sufficient cable to be positioned anywhere on the drilling location

Sufficient amount of hand torches explosion proofed and completed with Batteries.

Sufficient amount of emergency lighting (battery powered) located at drill floor, doghouse, escape routes

G 11 Safety Signs

Sufficient safety signs on the drilling location s per German standards. Where possible these signs should be in pictograms.

G 12 Personnel Protective Equipment

CONTRACTOR to provide sufficient personnel protective equipment for all its personnel plus spare, such as safety helmets, safety boots, safety overalls, ear protection, safety glasses, rubber gloves, safety impact gloves, rubber aprons, full face visors, eye shields (for grinding machines etc.), dust masks, safety belts c/w lines, etc.

G 13 Wind Socks

CONTRACTOR to provide two wind socks, located at opposite sides of the drilling location

G 14 Callipers

Ring gauges for 12 1/4”, 8 1/2”, 6 1/8" and 4 1/8” bits.

13.2 Rig Franks 300 Specification

Tool/Equipment	Detail Information
Drilling Equipment	
Mast	U-Type with 29 m free working height
Load capacity (normal)	6 fold: 656 kN; 4 fold: 448 kN
Load capacity (exception)	6 fold: 956 kN; 4 fold: 784 kN
Drawwork	Type : 1068/ 210 Diesel driven with Lebus system and supporting break
Band Brake	Refurbished 2011
Dynamic Brake	Hydromatic system
Rotary Table	Manufacturer / Type / Capacity: Ideco / SR 175 / 102 t Hydraulically driven with soft torque system, orifice: 17 ½”, 22.000 Nm power at 350 bars, max. 190 min^{-1}
Swivel	Ideco TL 120, 120 t capacity, 350 bar
Kelly & Kelly Drive Bushing	4” 9 m length Kelly
Crown Block	Reeving: 4 & 6 possible (480 kN & 702 kN regular load capacity)
Travelling Block	Ideco UTB 110 Shorty (100 t capacity)
Deadline Anchor	Manufacturer / Type: National / F
Hook	Manufacturer / Capacity: Ideco / 100 t
Drill line	1”
Substructure	Enfab Industries Inc, Texes (year 2000)
Guying	6 steel wires: 4 anchored in the ground and 2 neck wires
Tuggers and Sheaves	Manufacturer / Type: Braden / PD 12
BOP Hoisting equipment	Yes (50 kN)
Fingerboard	For 5000 m 2 7/8” tubing or 3 ½” drill pipe
Drill Floor	4.5 x 4.6 m, covered with anti-slip material, Set back hole, 3 m height underneath usable
Mud System	
Mud Pumps	Manufacturer / Type: Halliburton / HT 400, mechanical drive, max. Pressure. 772 bar, max. Vol.-rate: 1650 l/min
Shale Shakers	Manufacturer / Type: Swaco / Mongoose, max. capacity: 1.5 m^3/min
Centrifugal pumps	2

Mud-mixing System	3 Brine Tanks a 34,5 m³ 3 Tanks (25, 25 & 50 m³) 2 Mixing Hoppers
Mud-Mixing Agitator	Manufacturer / Type: SEW_EURODRIVE /FAF77/ A/112/ Go
Trip Tank System	Single Tank: appr. 3 m³
Standpipe Manifold and Rotary Hoses	3" Chiksan Lines
Well control Equipment	
Ram-Type Preventer	Manufacturer / Type / Rating / Size: Shaffer / LWP / 3000 psi / 7 1/16", (9" Schaffer double ram)
Annular Type Preventer	Manufacturer / Rating / Size: Hydrill / 5,000 psi, 7 1/16", 9" Cameron Townsend
Choke Manifold	ID: 2 1/16"; Rating: 350 bar
Mud Degasser	yes
Remote Choke Control Panel	Manufacturer: Cameron
Surface Hydraulic BOP control unit	1 electric-motor-powered, belt driven triplex pump, 7 accumulator bottles (4 x 54 L. & 3 x 60 L.)
Power Plant	
General	Manufacturer / Type / Drive: Mercedes / 6 Cylinder Diesel / Allison automatic gearbox with torque converter, 450 kVA output
HPU Engine	Manufacturer / Type: Mercedes / 8 cylinder
Generator	2 x 450/350 kVA
Air Compressor	Make / Serial no.: Boge / 136.011.55
Air Receivers	1
Refrigerating and Air-Conditioning	Wall-mounted carrier units
Electrical Equipment	
Main Switchboard	Siemens Switchboard
AC Motors	-
Cables and Cable Trays	Less protection
Safety Equipment	
Fire Extinguisher	Several portable extinguisher
Closing unit	Valvcon, 290 l Volume, 210 bar, 1 electrical pump, remote control
Preventer testing unit	Pressure Rating: 1050 bar
Spare parts	
Stock Control	Limit stock on site

13.3 Evaluation Matrixes

13.3.1. Rig Concept 45 %

1 Mast, Substructure, Drawwork, Accessories

1 A Criteria Mast	Year	free working height	guying	Max. except load	Max. usually load	Setback capacity monkey board	Derrick Man System	Elevation of the Mast	climbing device	Total	Factor
Year		0	0	0	0	0	0	0	1	1	0,014
free working height	2		2	2	2	2	2	2	2	16	0,222
guying	2	0		2	2	2	2	2	2	14	0,194
Max. except load	2	0	0		0	2	2	2	2	10	0,139
Max. usually load	2	0	0	2		2	2	2	2	12	0,167
Setback capacity monkey board	2	0	0	0	0		2	2	2	8	0,111
Derrick Man System	2	0	0	0	0	0		0	2	4	0,056
Elevation of the Mast	2	0	0	0	0	0	2		1	5	0,069
Climbing device	1	0	0	0	0	0	0	1		2	0,028
										72	1

1 B Substructure	Year	Size of working Area	Free Height under drill floor	BOP Handling System	Set Back capacity	Elevation of Substructure	Drip Pan	Cat walk	Total	Factor
Year		0	0	0	0	0	1	0	1	0,019
Size of working Area	2		0	0	0	2	2	2	8	0,148
Free Height under drill floor	2	2		2	2	2	2	2	14	0,259
BOP Handling System	2	2	0		0	2	2	1	9	0,167
Set Back capacity	2	2	0	0		2	2	2	10	0,185
Elevation of Substructure	2	0	0	0	0		2	1	5	0,093
Drip Pan	1	0	0	0	0	0		0	1	0,019
Cat walk	2	0	0	1	0	1	2		6	0,111
									54	1

1 C Drawwork	Year	Drive	LEBUS System	Brake Type	Supporting brake	automatic lowering device	Rotation monitoring	Anti-collision System	Total	Factor
Year		1	0	0	0	0	0	0	1	0,018
Drive	1		1	2	2	2	2	0	10	0,179
LEBUS System	2	1		2	1	2	1	0	9	0,161
Brake Type	2	0	0		0	1	2	0	5	0,089
Supporting brake	2	0	1	2		2	2	1	10	0,179
automatic lowering device	2	0	0	1	0		1	0	4	0,071
Rotation monitoring	2	0	1	0	0	1		0	4	0,071
Anti-collision System	2	2	2	2	1	2	2		13	0,232
									56	1

2 Rotary Equipment

2 A Rotary Table	Year	orifice	Static load capacity	Drive	Max. rotational speed	Number of Bowls	Total	Factor
Year		0	0	1	0	0	1	0,033
Orifice	2		2	2	2	2	10	0,333
Static load capacity	2	0		2	2	2	8	0,267
Drive	1	0	0		1	2	4	0,133
Max. rotational speed	2	0	0	1		1	4	0,133
Number of Bowls	2	0	0	0	1		3	0,1
							30	1

2 B Top Drive	Year	Drive	Power	Static load capacity	Dynamic load capacity	Max. possible torque	Continuous torque	Soft torque system	Handling of pipes/Flexibility	Total	Factor
Year		1	0	0	0	0	0	0	0	1	0,014
Drive	1		0	0	0	0	0	0	0	1	0,014
Power	2	2		1	1	1	0	0	0	7	0,095
Static load capacity	2	2	1		2	0	0	2	0	9	0,122
Dynamic load capacity	2	2	1	0		0	0	2	0	7	0,095
Max. possible torque	2	2	1	2	2		0	2	0	11	0,149
Continuous torque	2	2	2	2	2	2		2	2	16	0,216
Soft torque system	2	2	2	0	0	0	0		1	7	0,095
Handling of pipes/Flexibility	2	2	2	2	2	2	1	2		15	0,203
										74	1

3 Pumps

3 A Pumps	Number	Power	Drive	Max. Pressure	Max. Volume rate	Noise protection	Feeding pump	Pulsation dampener	soft pump system	Total	Factor
Number		0	0	0	0	0	0	0	0	0	0,000
Power	2		2	0	0	2	2	2	2	12	0,174
Drive	2	0		0	0	1	0	1	2	6	0,087
Max. Pressure	2	2	2		1	2	2	2	2	15	0,217
Max. Volume rate	2	2	2	1		2	2	2	2	15	0,217
Noise protection	2	0	1	0	0		1	0	1	5	0,072
Feeding pump	2	0	2	0	0	1		1	2	8	0,116
Pulsation dampener	2	0	1	0	0	2	1		2	8	0,116
soft pump system	2	0	0	0	0	1	0	0		3	0,043
										69	1

4 Tank System

4 A Tank System	Number	Single Volume	Total Volume	Sand trap	Agitator	Tank Construction	Space	Shaker System	Desilter	Total	Factor
Number of tanks		0	0	0	0	0	0	0	2	2	0,029
Single Volume	2		0	0	0	0	0	0	2	4	0,059
Active Volume	2	2		2	2	0	2	2	2	14	0,206
Sand trap	2	2	0		2	2	0	0	2	8	0,118
Agitator	2	2	0	0		0	1	1	2	8	0,118
Tank Construction	2	2	2	0	2		0	2	0	10	0,147
Space	2	2	0	2	1	2		1	2	10	0,147
Shaker System	2	2	0	2	1	0	1		2	10	0,147
Desilter	0	0	0	0	0	2	0	0		2	0,029
										68	1

5 Power Supply

5 A Power supply	Number of engines	Drive	Power rating	Energy consumption	Efficiency	Space	Emergency energy supply	Compressor	Total	Factor
Number of engines		1	0	0	0	0	0	0	1	0,018
Drive	1		0	1	0	0	0	0	2	0,036
Power rating	2	2		2	2	1	1	2	12	0,218
Energy consumption	2	1	0		2	0	0	0	5	0,091
Efficiency	2	2	0	0		0	0	1	5	0,091
Space	2	2	1	2	2		1	2	12	0,218
Emergency energy supply	2	2	1	2	2	1		2	12	0,218
Compressor	2	2	0	2	0	0	0		6	0,109
									55	1

6 Well Safety Equipment

6 A Well Safety Equipment	Drilling-/Spacer Spools	BOP Stack	Closing unit	Tripping Equipment	Choke Manifold	Choke-/ Kill Line	Flare	Test Equipment	Total	Factor
Drilling-/Spacer Spools		0	0	0	0	0	2	1	3	0,054
BOP Stack	2		2	2	2	2	2	2	14	0,250
Closing unit	2	0		2	2	2	2	2	12	0,214
Tripping Equipment	2	0	0		0	0	2	1	5	0,089
Choke Manifold	2	0	0	2		1	2	2	9	0,161
Choke-/ Kill Line	2	0	0	2	1		2	2	9	0,161
Flare	0	0	0	0	0	0		0	0	0,000
Test Equipment	1	0	0	1	0	0	2		4	0,071
									56	1

7 Installation equipment

7 A Installation Equipment	Elevator	Slips	Ezy Torque	Spill winch	Torque Wrench	Spinning Wrench	Floor Hand / Iron Roughneck	safety clamps	Rotary Tong	Total	Factor
Elevator		1	0	0	1	1	0	0	0	3	0,042
Automatic Slips	1		0	0	0	1	0	0	0	2	0,028
Ezy Torque	2	2		1	0	0	2	2	2	11	0,153
Spill winch	2	2	1		1	2	2	2	2	14	0,194
Torque Wrench	1	2	2	1		2	2	2	2	14	0,194
Spinning Wrench	1	1	2	0	0		2	2	0	8	0,111
Floor hand/ Iron roughneck	2	2	0	0	0	0		0	0	4	0,056
safety clamps	2	2	0	0	0	0	2		2	8	0,111
Rotary Tong	2	2	0	0	0	2	2	0		8	0,111
										72	1

8 Data collection and storage

8 A Data Collection	Hook Load	Trip Tank Volume	Multi-Channel Data collector	Tilt Measurement	line Indicator	Lithology Measurement	Gas measurement	Geo Data Interface	Total	Factor
Hook Load		1	0	1	0	0	1	0	3	0,056
Trip Tank Volume	1		2	1	2	2	1	2	11	0,204
Multi-Channel Data collector	2	0		0	0	0	0	0	2	0,037
Tilt Measurement	1	1	2		2	2	1	2	11	0,204
Mud Measurement, Flow line Indicator	2	0	2	0		2	0	2	8	0,148
Lithology Measurement	2	0	2	0	0		0	2	6	0,111
Gas measurement	1	1	2	1	2	2		2	11	0,204
Geo Data Interface	2	0	0	0	0	0	0		2	0,037
									54	1

9 Pipe Handling

9 A Pipe Handling	Year	Degree of automation	Range of handable pipes	Energy consumption	Working speed	Loading of pipe rack	Drive	Total	Factor
Year		0	0	0	0	0	0	0	0,000
Degree of automation	2		0	2	0	0	2	6	0,143
Range of handable pipes	2	2		2	2	2	2	12	0,286
Energy consumption	2	0	0		0	0	0	2	0,048
Working speed	2	2	0	2		1	2	9	0,214
Loading of pipe rack	2	2	0	2	1		2	9	0,214
Drive	2	0	0	2	0	0		4	0,095
								42	1

13.3.2. Rig Move 20 %

Criteria	Size of parts	weight of parts	Transportability	Crane Utilization	Train Utilization	Number of moved parts	Expected Time	Total	Factor
Size of parts		1	0	2	2	2	2	9	0,231
Weight of parts	1		1	2	2	2	0	7	0,179
Transportability	2	1		2	2	2	2	9	0,231
Crane Utilization	0	0	0		1	2	0	3	0,077
Train Utilization	0	0	0	1		2	0	3	0,077
Number of moved parts	0	0	0	0	0		0	0	0,000
Expected Time	0	2	0	2	2	2		8	0,205
								39	1,0

13.3.3. Distance to operator 10 %

Criteria	speed of action	Need of Housing	Time depending Costs	Flexibility	Total	Factor
Speed of action		2	2	0	4	0,286
Need of Housing/Hotel	0		1	0	1	0,071
Time depending Costs	1	2		0	3	0,214
Flexibility	2	2	2		6	0,429
					14	1

MONTAN UNIVERSITÄT

13.3.4. Qualification of personal 10 %

Criteria	Education	Experience	Certificates	Age	Total	Factor
Education		0	0	1	1	0,083
Experience	2		1	2	5	0,417
Certificates	2	1		2	5	0,417
Age	1	0	0		1	0,083
					12	1

13.3.5. Local experience 5 %

Criteria	Years in the field	GDF/Contractor experience	Number of experienced personal	Total	Factor
Years in the field		2	0	2	0,333
GDF/Contractor experience	0		1	1	0,167
Number of experienced personal	2	1		3	0,500
				6	1,0

13.3.6. Energy 5 %

Criteria	Type of Energy	Amount of used energy	Costs of the energy	Total Points	Factor
Type of Energy		2	2	4	0,667
Amount of used energy	0		2	2	0,333
Costs of the energy	0	0		0	0,000
				6	1

13.3.7. Rig availability 5 %

Criteria	Training period	Delivery time	Total Points	Factor
Training period		0	0	0,000
Delivery time	2		2	1,000
			2	1,000

13.4 Time Analysis of well RLMR 801 and H 25

13.4.1. RLMR H 25

		Drilling													Run & Cement Casing									
	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
	Rig up/Rig down	Lay down / Pick Up pipe	Circulate and condition mud	Drilling	POOH / Trip Out	RIH / Trip in	Ream and/or Wash	Survey Other/ Hande tools	Cleaning Rig floor	Safety Meeting	Formation Pressure Test	Well Control	Logging safety meeting	Logging	Casing Running Eqp. GTS	Run in Casing	Run out Casing	Circulate Casing	Handle tools	Safety Meeting	Other	Cement Casing	WOC	Work with BOP / WH
02.06.2014	0	3,25	0,75	12,5	2	3,5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03.06.2014	0	0,5	1,25	17,25	3,5	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04.06.2014	0	0	0,75	0	3,5	0,75	3,5	0	1	0	0	0	0,25	2,5	0,5	3	0	4,5	1,5	0,25	0	1,75	0,25	0
05.06.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12
06.06.2014	0	2,25	1	14,75	0	3,75	1	1	0	0	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0
07.06.2014	0	0	0,5	21,25	1,25	0	0	0,75	0	0	0	0,25	0	0	0	0	0	0	0	0	0	0	0	0
08.06.2014	0	0,5	2,25	0	4,5	1	1	0	2,25	0,25	0	0,25	0	0	0	0	0	0	0	0	0	0	0	12
09.06.2014	0	1	2,75	0	2,5	1,5	12,75	0	0	0	0	0,5	0	0	0	0	0	0	0	0	0	0	0	3
10.06.2014	0	0	1	0	3,25	0	4,5	0	0	0	0	0,25	0,25	7,75	1,5	5	0	0	0	0,5	0	0	0	0
11.06.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0,5	0,25	1	3,25	9	6
12.06.2014	0	2,5	1,5	6,75	0	3	0	2	0	0	0,5	0,25	0	0	0	0	0	0	0	0	0	0	0	7,5
13.06.2014	0	1	0,75	9	7,25	3,25	1,5	0	0,5	0	0	0,25	0	0,5	0	0	0	0	0	0	0	0	0	0
14.06.2014	0	0,5	0	0	0	0	0	0	0	0	0	0	0	11,5	1,5	4,5	0	5,5	0	0,5	0	0	0	0
15.06.2014	0	0,5	0	1,25	3,25	0	0	0	0	0	0	0	0	0	0	5,5	8	4	0	0,25	0	1,25	0	0
16.06.2014	0	0	1,25	15,5	5,75	1,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.06.2014	8	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
SUMME	8	12	13,75	98,25	38,75	19,75	25,25	4,75	3,75	0,25	0,75	1,75	0,5	22,25	3,5	19	8	17	2	1,75	1	6,25	21,25	54,5

13.4.2. RLMR 801

		Drilling												Coring										Run & Cement Casing											
	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
	Rig up/Rig down	Lay down / Pick Up pipe	Circulate and condition mud	Drilling	POOH / Trip Out	RIH / Trip in	Ream and/or Wash	Survey Other	Cleaning Rig floor	Rig Service	Safety Meeting	Formation Pressure Test	Well Control	Safety Meeting	Lay down / Pick Up pipe	Circulate and condition mud	Trip In	Trip Out	Ream and/or Wash	Coring	Well Control / Other	Fishing	Logging	Casing Running Eqp. GTS	Trip in Casing	Trip out Casing	Circulate and condition mud	Circulate Casing	Handle tools	Safety Meeting	Other	Test Phase	Cement Casing	WOC	Work with BOP / WH
07.05.2014	8	2,5	2,5	6	2,5	2,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08.05.2014	0	4,25	0	15	0	1,5	2,5	0,75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09.05.2014	0	0	0	20	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.05.2014	0	0	1	5,25	6,5	2,5	6,25	1,5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11.05.2014	0	6,25	1,75	0	0	0	8,75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,5	1,5	0	0	0	0	0	0,25	0	0	0	0	0
12.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,75	5,75	0	0	5	0	1	4	0,25	2,75	4,5	0
13.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	15
14.05.2014	0	3,5	0,5	5,5	0	8,25	0	0	0	5	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
15.05.2014	0	0,5	0,75	10,25	4,25	2,75	3,25	0	0,75	0	0	0,75	0,75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16.05.2014	0	0	6,25	0	4	0	3,5	0	0	0	0	0	0	0,5	1,5		2,25	1,5	0	4	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3,5	1,5	4	9,75	0,25	3,75	0,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,5	2,5	5,5	10	0	3,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0,25	1,75	1,5	2,5	12,25	0	5	0,75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0,5	3	2,5	5,5	10,5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21.05.2014	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2,5	0,5	3,25	12	0	3,25	0,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.05.2014	0	0	2	5,5	1,75	4,5	10,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.05.2014	0	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3,5	15,5	0	0	0	0	0	0	0	0	0	0	0	0
24.05.2014	0	1	1	0	4	5	1,75	0,75	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4,5	1	0	0	0	0	0	0	0	0	0	0	0
25.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,75	4,25	0,5	0	4,5	0	2,75	2,75	2,5	0	0
26.05.2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,5	0	0	0	1	0	3		3,5	0	13
27.05.2014	0	2	1,25	10,5	0	4,25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
28.05.2014	0	3	0	0	0	0	0	5,5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,5
SUMME	8	24	17	78	27	31,25	36,25	14,5	1,75	5	0,25	0,75	0,75	2,25	14,75	8,5	23	56	0,25	21,5	2	8,5	25,5	3,25	16	4,25	0,5	5	5,5	1,25	9,75	3	8,75	13,5	38,5

13.5 Contractor comparison

		Company A1	Company A 2	Company B	Company C	Company D
General						
Needed space	(m)	25,6 x 81,0	25,6 x 81,0	26,9 x 85,2	30,0 x 90,0	22,0 x 140,0
Guying		no	intern	intern	intern	no
Excepted rig move time	(days)	2-3	3	3 a 12 hrs	3	2-3
Drive		diesel-electric	diesel-electric	diesel-electric	diesel hydraulic	diesel electric
Max. load of individual part	(t)	30	63,5 t	30	73	60
Drillers cabin / Doghouse		yes	yes	yes	yes	yes
A Mast, Drawwork, PULD etc.						
A 1 Mast						
Stands		2 pipes range 2	Range 3 super single	2 pipes range 2	2 pipes range 2	Range 3 super single
Type		hydraulically erectable	No information	hydraulically erectable	erectable	U-shape, hydraulically erectable
Year		new	new	2007	In construction	new
Free working height	(m)	No information	16	No information	34,0	20,00
Except load	(t)	150	136	170 (6 fold) 207 (10 fold)	150	150
Set back capacity monkey board						
- 3 1/2" DP	(m)	4000	4600	800 - 1000	No information	Super single
- 5" DP	(m)	2000	3600	800 - 1000	No information	Super single
- 6 1/4" DC (and)	(pcs.)	8 stands	8 stands	possible	No information	Super single
- 8 1/4" DC (or)	(pcs.)	4 stands	4 stands	No information	No information	Super single
A 2 Substructure						
Type		slingshot	No information	slingshot	No information	slingshot
Height until drill floor	(m)	6,2	5,64	5,5	4,8	5,60
DP set back capacity	(t)	No information	No information	100	115	No information
Max. rotary table load	(t)	~153	No information	160	No information	No information
Max. set back capacity with rotary table load	(t)	~254	No information	No information	~265	No information
BOP installation equipment		hydraulic chain hoist system	hydraulic jack up	BOP Trolley System	rail and dolly system	JDN Pneumatic Monorail Hoist
- hoisting capacity	(t)	2 x ~10	No information	No information	No information	10
Drip Pan		yes		yes	no	yes
Substructure elevation process		hydraulically	hydraulically	hydraulically	No information	No information
A 3 Drawwork						
Manufacturer		No information	No information	MH Wirth	No information	Prep
Type		TSM 1000 HP	DrillMec	Single Gear GH 1000 EG-AC-		DL-2-0800A-3B

					1G		
	Drive		AC	AC	AC (4Q)	mechanically	AV (VFD)
	Available power	(kW)	745	671	858	560	600
	Main brake		4Q	No information	Drive Motors (VFD controlled)	No information	No information
	Supporting brake		Disc	yes	Disc	Disc	No information
	Automatic driller	ja/nein	yes	yes	ADS	nein	yes
	Anti-collision System	ja/nein	yes	No information	zone positioning system	No information	yes
A 4	**PULD / Pipe Handler**						
	Type		Hercules	DrillMec	PULD for transferring pipes, casings a.s.o. from trailer to rig floor	no	Streicher HTV Pipe Handler incl. Pipe Feeder
	Range of Pipes		2 3/8" - 13 3/8"; max lift 9 1/2" DC	2 3/8" - 13 3/8"	2 7/8" - 20" until 14,6 m length	No information	2 3/8" - 20" until 14,6 m
	Hoisting capacity	(t)	No information	No information	4	No information	3,5
	Pipe rack		No information	Pipe rack	Directly load/unload from rail to rack	180 m 8 3/4"	No information
A 5	**Drilling line**						
A 5.1	**Drilling line**						
	Diameter	(inch)	1 1/8"	hydraulic system	1 1/4", 8X19 S/IWRC	1 1/8"	1 1/8" 2000 m
A 6	**Supporting winch**						
	Number	(pcs.)	2	1	2	2	2
	Drive		hydraulically	hydraulically	No information	hydraulically	air driven
	Max. pulling force	(t)	1x 4,0; 1x 1,5	2,5	3	je 3 to	3
B	**Rotary equipment**						
B 1	**Rotary table**						
	Manufacturer		National	No information	National Type	No information	Streicher
	Type		C275	No information	C 205	No information	No information
	Orifice	(inch)	27 1/2	27 1/2	20 1/2"	27 1/2	27 1/2"
	Load capacity	(t)	No information	No information	160	No information	150
	max. Torque	(Nm)	No information	No information	No information	4.400	45.000
	drive		hydraulically	No information	hydraulically	hydraulically	No information
B 2	**Top drive**						
	Manufacturer		Tesco	DrillMec	Canrig	Streicher	Canrig
	Type		EMI 400HP	HTD250C	6027 AC	TD180	6027 AC
	Drive		AC	No information	AC	hydraulically	AC
	Power	(kW)	298		450	380	450
	Max. load capacity	(t)	227	226	249	1.765	275

	Max. rpm	(rpm)	0 - 200	180	225	240	No information
	Max. torque	(Nm)	20.300 @140rpm	36.000	81.300	44500	90.800 @ 7 rpm
	Continuous torque	(daNm)	2.847	No information	4.070	No information	4.070 @ 105 rpm
	Soft Torque Rotary System		No information	No information	ja	No information	No information
C	**Mud pumps**						
C 1	**Pumps**						
	Number		2	2	2	2	2
	Manufacturer		Bomco	Bomco	MH Wirth	IDECO	Streicher
	Type		light F-800	light F-800	TPK 1000 AC-RC / 5000 psi	IRI T1000	Honghua HHF-800
	Drive		electrical	electrical	AC	hydraulically	AC
	Available power per pump	(kW)	597	597	858	No information	600
	Max. pressure	(bar)	345	345	146 at 7 1/4" Liner 345 at 4 1/2" Liner	No information	345
	Max. volume rate	(l/min)	2350 l/min @137 bar 350 bar @815 l/min	2350 l/min @137 bar 350 bar @815 l/min	2761 at 7 1/4" Liner 1064 at 4 1/2" Liner	Per pump 2650	2.500
	SPS (Soft Pump System)		No information	No information	ja	350 bar @1.100 l/min	No information
	Feeding pump		No information	No information	Vision Magnum	No information	No information
D	**Mud system**						
D 1	**Circulation tank**						
	Total volume	(m³)	55	55	47,3	No information	50
D 1.1	**Shaker tank**						
	Volume	(m³)	15	8 m³ Sand trap 15 m³ shaker	2 pcs (3 optional) 8 m³ Sand trap 18 m³ desander/desilter	No information	20
D 1.2	**Trip tank**						
	Number		2	2	2	2	2
	Volume	(m³)	je 2,0	je 2,0	1,5	je 2,0	1,5
D 1.3	**Suction tank**						
	Volume	(m³)	2 x ~15	2 x ~15	22	No information	30
D 2	**Mixing system**						
D 2.1	**Mixing tank**						
	Volume	(m³)	10	10	22 (= suction tank)	No information	10
	Pill tank	(m³)	5	5	5	No information	5
D 2.2	**Hopper**						
	Number		1	1	1	No information	1

D 3 Mud regeneration system					
D 3.1 Shale shaker					
Number	2x Mongoos Pro (1x as mud cleaner)	2x Mongoos Pro (1x as mud cleaner)	Swaco Mongoose pro shaker 2 (3 optional)	3x Mongoos	3 (2 single, 1 double)
Power (kW)	No information	No information	1,8	No information	No information
D 3.2 Desander / Desilter					
Number	10" Desander 1300l/min per Cone (3 Cones)	10" Desander 1300l/min per Cone (3 Cones)	3	No information	1 Desander 1Desilter
Number of cyclones	4" Desilter 180 l/min per cone (20 cones)	4" Desilter 180 l/min per cone (20 cones)	3 x 12" 10 x 4"	No information	2 X 10" 20 x 4"
D 3.3 Mud degasser					
Number	1	1	No information	No information	1
Manufacturer	No information	No information	No information	No information	Derrick Vacu Flow
Type	DG-10/12 vacuum type	DG-10/12 vacuum type	No information	Swaco	Vacuum
Mud flow rate (l/min)	No information	No information	No information	No information	3000
D 3.4 Mud gas separator					
Number	1	1	1	1	1
Manufacturer	Company A	Company A	No information	No information	No information
Type	No information	No information	Vacuum or Poor-Boy	No information	3700
Flow rate (l/min)	No information	No information	No information	No information	No information
D 4 Additional tanks					
D 4.1 Reserve tanks / Water tanks					
Number	No information	No information	No information	No information	2
Volume (m³)	No information	No information	No information	No information	30
D 4.3 Cutting Tank					
Number	No information	No information	No information	No information	1
Volume (m³)	No information	No information	No information	No information	No information
E Energy supply					
E 1 Drive	Diesel-electrical	Diesel-electrical	Diesel-electrical	No information	No information
E 2 Energy consumption					
Rated power (kW)	No information	No information	No information	No information	1950
E 3 Diesel engines					
Number	3	No information	3	2	No information
Manufacturer	Cummins	No information	Caterpillar	No information	No information
Type	No information	No information	C 32	No information	No information

	power	(kW)	each 695	No information	No information	each 720	No information
E 4	**Generators**						
	Number		3	No information	3	No information	3
	Manufacturer		Stamford	No information		No information	MTU or Caterpillar
	Type		HCI634G2	No information	SR4B, 3 Phase synchro	No information	No information
	Power	(kVA)	750	No information	1000 kVA / 690 V	No information	1000 kVA / 690 V
	Backup power	(kVA)	yes	No information	150 kVA / 400 V	No information	no
E 5	**Fuel tanks**						
	(double wall)						
	Number		1	No information	1	2	1
	Volume	(m³)	20	No information	20	je 20	20
E 6	**Compressor**						
	Number		No information	No information	2	No information	No information
	Manufacturer		No information	No information	Renner screw compressor RS 22	No information	No information
	Suction volume	(m³/min)	No information	No information	3,46	No information	No information
	Max. working pressure.	(bar)	No information	No information	7,5	No information	No information
	Storage capacity	(l)	No information	No information	1.500	No information	No information
F	**BOHRLOCHSICHERUNGS-AUSRÜSTUNG**						
F 1	**Annulus preventer**						
	Number		1	1	1	1	1
	Manufacturer		Shaffer	Shaffer	Axon	No information	No information
	Type		No information	No information	Type 52	No information	No information
	Size	(inch)	11"	11"	13 5/8 or 7 1/16	11"	11"
	Pressure rating	(psi)	5000	5000	5000	5000	5000
F 2	**Shear / Pipe preventer**						
	Number		1	1	1		1
	Manufacturer		Shaffer	Shaffer	Axon		
	Type				Type 50		
	Size	(inch)	11"	11"	13 5/8 or 7 1/16"	11"	11"
	Pressure rating	(psi)	5000	5000	5000 psi	5000	5000
F 3	**Closing unit**						
	Manufacturer		Koomey	Koomey	NCS	CAD Control Systems. Broussard	No information
	Type		No information	No information	No information	CAD -Ex-88055007	No information
	Total storage volume	(l)	1500	1500	900	923	No information
	Storage pressure	(bar)	No information	No information	210	No information	No information
	Annulus preventer pressure control valve		yes	yes	No information	No information	No information

G VERSCHRAUBEINRICHTUNGEN					
G 1 Catheads					
Type	No information	No information	No information	No information	Streicher
Number	No information	No information	No information	1	1
Max. Line pull force (kN)	No information	No information	No information	No information	140
	No information	No information	No information	No information	No information
G 2 Ezy Torque					
Number					
Type					
G 3 Spinning Wrench					
Manufacturer	part of iron roughneck	part of iron roughneck	ja	No information	via iron roughneck
Type	No information	No information	hydraulically	No information	No information
G 5 Tubing jar					
Number	No information	No information	No information	No information	no
G 6 Rotary Tongs					
Type	HT100, HT55, HT35, HAT 25	HT100, HT55, HT35, HAT 25	BV 65 3 1/2" - 21 1/2" 88140 Nm	No information	ja
Type	No information	No information	BV 100 4" - 21" 135.600 Nm	No information	No information
G 7 Iron Roughneck					
Type	Bauer PT100/800	DrillMec System	Floor hand FH-80 (Wrench & Spinner combination Tool)	McCoy WeTorq 105H	Automated Wrench System modified by Streicher
Manufacturer	No information	No information	B+V	No information	NOV ST 80
Pipe Range		2 3/8" DP - 8" DC	3 1/2" DP - 8 1/2" DC		2 7/8" - 8 1/2"
Make up torque (Nm)	No information	80.000	88300	No information	81500
Break out Torque (Nm)	No information	No information	108500	No information	108500