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Fall 2016 PETE Senior Design Team 1: Final Report

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University of Wyoming Project Plan

Final Report

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PETE 4736-01: Petroleum Engineering Design

Prof. Brian Toelle
12/09/2016
This document is the Final Report submitted by Drillit Safe company on the project 30/31 field development plan. This report contains a project plan with work breakdown structure, workflow chart, schedule, Gantt chart, project results, well location, and drilling plan.

<table>
<thead>
<tr>
<th>Deraldo de Carvalho Jacobina Andrade</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Meshari Aldhafeeri</td>
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<tr>
<td>Mohammad Aldhafeeri</td>
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</tr>
</tbody>
</table>
# Table of Contents

1. Executive Summary .................................................................................................................. 5
2. Introduction ............................................................................................................................... 6
3. Project Plan ................................................................................................................................ 7
    3.1 Work Breakdown Structure ................................................................................................. 8
    3.2 Workflow Chart .................................................................................................................. 9
    3.3 Gantt Chart with Schedule ............................................................................................... 10
    3.4 Risk Analysis ...................................................................................................................... 11
4. Data Review ................................................................................................................................ 12
5. Static Model ................................................................................................................................ 13
    5.1 Petrophysical and Lithological Analysis .............................................................................. 13
    5.2 Stratigraphic Map ................................................................................................................ 14
    5.3 Reservoir modeling ............................................................................................................. 15
        5.3.1 Structural Modeling .................................................................................................... 15
        5.3.2 Horizon Interpretation ............................................................................................... 16
        5.3.3 Pillar Gridding ........................................................................................................... 17
        5.3.4 Making Horizons and Zones .................................................................................... 18
        5.3.5 Layering ..................................................................................................................... 19
        5.3.6 Properties Modeling .................................................................................................. 19
    5.4 Properties Evaluation ........................................................................................................... 20
        5.4.1 Oil Saturation Evaluation .......................................................................................... 20
        5.4.2 Porosity Evaluation ................................................................................................... 21
        5.4.3 Permeability Evaluation ............................................................................................ 22
    5.5 Location of the New Well ....................................................................................................... 22
6. Drilling Plan ................................................................................................................................. 23
    6.1 Field Topology Analysis ...................................................................................................... 23
    6.2 Casing Location .................................................................................................................... 24
    6.3 Properties Evaluation ........................................................................................................... 25
    6.4 Drilling Costs ........................................................................................................................ 26
Conclusion ......................................................................................................................................... 27
References ......................................................................................................................................... 28
List of Figures

Figure 1: Location of Charlton 30/31 Field .................................................................................. 6
Figure 2: Work Breakdown Structure ......................................................................................... 8
Figure 3: Flowchart ..................................................................................................................... 9
Figure 4: Risk Analysis ............................................................................................................... 11
Figure 5: Gamma Ray Analysis .................................................................................................. 12
Figure 6: Stratigraphic Map on 3d window .................................................................................. 14
Figure 7: Stratigraphic map with counter lines on 3D window ................................................... 14
Figure 8: Model for the properties .............................................................................................. 15
Figure 9: Seismic horizon of each surface ................................................................................... 16
Figure 10: Skeleton grid .............................................................................................................. 17
Figure 11: Horizons picked to produce the surfaces ..................................................................... 18
Figure 12: Stratigraphic Layering ............................................................................................... 19
Figure 13: Water saturation model. ............................................................................................. 20
Figure 14: Effective porosity model ............................................................................................ 21
Figure 15: Permeability model ................................................................................................... 22
Figure 16: Field topology ............................................................................................................ 23
Figure 17: Charlton 5-30 casing sketch. .................................................................................... 24

List of Tables

Table 1: Gantt Chart with Schedule ............................................................................................ 10
Table 2: Drilling design ............................................................................................................... 25
Table 2: Drilling Costs .................................................................................................................. 26
Table 2: Completion Costs .......................................................................................................... 26
1. Executive Summary

The field development plan of the Charlton 30/31 field was chosen by Drillit Safe Company. This field is located in the northern Silurian reef trend in the Michigan Basin. The company was provided with some literature, boreholes, logs, and seismic data. In order to analyze this data, the program chosen was Petrel 2016. The objective of the company is to develop a Static Model of the Charlton 30/31 field and produce a field development plan using the given literature and data.

The project plan consists of four phases, as will be shown later in the flowchart. In order to organize and maximize the project plan, a Work Breakdown Structure (WBS), a Flowchart, and a schedule with a Gantt chart were all generated.

The first phase, which the objective was to study the literature available, the Petrel manual and share with the group, was successfully accomplished on time. The second phase, which the objective was to produce a well log, seismic, and topology interpretation. The third phase has the final objective of producing the static model. The fourth phase is the final phase, and it is the phase the group is currently working on. Its objective is to deliver the optimal field development plan.

After the production of the static model, with the porosity, permeability, and water saturation of the model, it was possible to analyze and primarily choose an optimal location for the new well based on these properties.

With the primary location of the well, it was possible to create a drilling plan, with casing design, location, and cost evaluation based on the available topology information, and the previously drilled well (Charlton 4-30 on 2006).
2. Introduction

For this project, Drillit Company is going to work on the Charlton 30/31 field. This field is located in the northern reef trend of the Michigan Basin, and it was developed within the stratigraphic unit historically referred to as the Niagara Brown, the Figure 1 shows the exact location of the field. This formation is now known as the Guelph formation.

The Charlton 30/31 oil field was discovered in 1974 by Shell and produced 2.6 million bbl. of oil during its primary production phase. It has a structural closure of approximately 300 feet and the field sits on 300 acres. The depth of the wells is approximately 5500 feet, and during the 1970s a total of six wells were drilled in the field to extract oil. The reservoir has a low porosity and low permeability limestone matrix with irregular dolomitized intervals of higher porosity and permeability (Toelle et al, 2008). Our company was provided with a 3-D seismic survey as well as the well log data, which we chose Petrel as the software to analyze it, and some literature. The objective of this project is to develop a static model and produce the optimal field development plan for drilling an additional borehole for production. In order to achieve this goal, this project plan was developed containing Work Breakdown Structure, Flowchart, and Gantt chart, so our project can be organized and efficient to develop a successful field development plan.

Figure 1: Location of Charlton 30/31 Field.
3. Project Plan

In order to achieve the objective of this project, which is to develop a Static Model of the Charlton 30/31 field and produce a field development plan, the project plan was created and it is illustrated by using a Work Breakdown Structure (WBS), a Flowchart (which used the standard symbols), and a Schedule with a Gantt chart. It is also important to analyze the risks associated with this project and for this reason a risk analysis was created as illustrated on Figure 4.

The project plan consists of four phases. The phase one has the objective of sharing the information of the literature and Petrel with the group, which can be done by searching and studying the available literature and the Petrel manual. The second phase has the objective to produce the well log, seismic, and topology interpretation, so the static model can be produced. This can be done by gathering and loading the data into the Petrel, and then analyzing the data. The third phase consists of producing the Static Model, and to do so it is necessary to produce the lithological, petrophysical, structural and stratigraphic modeling. The fourth phase has the objective to deliver the optimal field development plan and presentation to the clients. In order to do so, it is necessary to analyze the results obtained with the static model and then evaluate it with the manager.

The project is now concluded. A static model was created, and by analyzing the porosity, water saturation, and permeability distribution, an optimal location for the new well was created. The group developed the drilling plan, with casing location, design, and economics. The project then was presented on the senior design symposium on 12/06/2016 concluding the last part of the project.
3.1 Work Breakdown Structure

The work breakdown structure, shown on figure 2, was an important feature that helped the group plan the work more efficiently. It was important to visualize what the main deliverables were, and the tasks that were needed to perform in order to produce them. Based on the WBS it was possible to produce the workflow chart in a proper manner, plan more consistently, and effectively the project.

Figure 2: Work Breakdown Structure.
3.2 Workflow Chart

Based on the Work Breakdown Structure, the group created a Workflow Chart, which is shown on figure 3. This chart gives a more detailed information about the four main phases of the project plan. As the WBS, it contains the deliverables, but it explains in better detail what is the evolution of the project and also the sequence of tasks that are necessary to perform to achieve the goal in the main phases. This chart also contains the decision points, and the loops, that are needed in order to achieve optimal results. The workflow chart was an important feature to organize, visualize, and optimize the project plan.

Figure 3: Workflow chart.
3.3 Gantt Chart and Schedule

After the creation of the workflow chart, the group created a schedule and then developed a Gantt chart, shown on figure based on table 1. The schedule is a major feature to first, estimate the duration of each task and phase, and second, to assign the tasks for the group members. Major changes were done on the schedule since its creation, since, when the group were going through the project, some difficulties were encountered on some phases. On phase two the group spent two more weeks than expected, which made the group work extra time on phase three and four in order to deliver the project on time. The Gantt chart was important to visualize the time spent on each task, and to see the progress of the group.

<table>
<thead>
<tr>
<th>Task</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
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<tbody>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Find the data &amp; literature available for</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charon 3031</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study and get familiar with Petrel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study and get familiar with Charon 3031</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share information and experience with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>group</td>
<td></td>
<td></td>
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<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Gather data and Load on Petrel</td>
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<tr>
<td>Analyze data</td>
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<tr>
<td>Interpret the data</td>
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<td>Seismic Interpretations</td>
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<td>Well Log Interpretations</td>
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</tr>
<tr>
<td>Phase 3</td>
<td></td>
<td></td>
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<tr>
<td>Create static model</td>
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<td>Lithological Modeling</td>
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<tr>
<td>Analyze Static Model</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Phase 4</td>
<td></td>
<td></td>
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<tr>
<td>Optimal Field Development Plan</td>
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</table>

Table 1: Gantt chart with schedule.
3.2 Risk Analysis

After the creation of the risk schedule, the group developed the risk analysis, shown on figure 4. This chart was created by the group in order to predict some of the difficulties that could be encountered. This chart contains the impact of these difficulties and the likelihood that they would happen. It was important to develop the risk analysis because the group could try to avoid some of these problems since they were already predicted.

Figure 4: Risk analysis.
4. Data Review

In order to create the development plan of the Charlton 30/31, a set of data was provided as well as the topography and locations of previously drilled wells. This data is important to analyze the surface that could potentially influence the new well location. No problem was encountered with this data. The other set was the well logs, with GR, NP, DPHI, and RHOB. This data is important to analyze the lithology and to analyze the porosity, permeability, and water saturation which is crucial to the selection of the well location. No problem was encountered with this data. Another set of data was the seismic, which is essential to create the static model when it is tied to the well logs. The team encountered a problem with this data, since the CRS used on the seismic data was different from the one used on the well logs. The team put a lot of effort into bringing them to the same CRS, but with our knowledge at that point it was not possible. However, after talking to the group manager, he provided us with the seismic data brought to the same CRS as the well logs, and by doing that it was possible to continue the project.
5. Static Model

On this section it will be discussed the interpretation of the static model created by the group. The group created the static model by loading all the data provided on Petrel, and by using its features it was possible to develop the static model. By analyzing this model, it was possible to choose an optimal location for a new well.

5.1 Petrophysical and Lithological Analysis

In order to analyze the petrophysics and the lithology of Niagaran Brown reservoir, three well logs are needed, the Gama Ray (GR), the Density Porosity (DPHI), and the Neutron Porosity (NPHI). These logs from three different boreholes are shown on figure 5. The analyzed interval is from the blue line (Niagaran Brown) to the green line (Perf_base), which is the reservoir. First it is important to analyze the Gamma Ray. A low and constant line of GR mean that the reservoir has a low on no content of clay, which makes it a good reservoir. Second, it necessary to compare the DPHI and NPHI readings. When the DPHI and NPHI have different, contrasting readings means that that interval is a dolomite, and when they are equal it means that interval is a limestone. By doing this interpretation it was concluded that the reservoir has a limestone matrix with dolomitized intervals, which confirms the literature information.

Figure 5: Gamma ray analysis.
5.2 Stratigraphic Map

The field in study is located in the northern Silurian reef trend in the Michigan Basin. This basin was formed during the Paleozoic period when a large blanket of limestone was deposited over a vast surface of the great lakes region. This area is geologically known as the Michigan basin. In the following figures, we didn’t have the correct projection counter map, so we had to do it manually by scanning the lines of the counter map as shown in Figure 7 by using polygon editing. Then we produced the counter map depicted in Figure 6. On most topographic maps, the contour index lines represent elevation, from what the group known about counter lines, closely pack lines represent steep slope. On the other hand, spaced lines represent a gently slope. From what it is shown on the picture, there is a steep slope or a shape of an anticline, which is a good location for hydrocarbon accumulation.
5.3. Reservoir modeling

5.3.1 Structural Modeling

Structural equation modeling (SEM) is a statistical technique for building and testing statistical models, which are often causal models. In this phase, it is expected to model the horizons. As the manual interpretations for the horizon were chosen from the seismic volume, a surface and grid skeleton were made. This interpretation contains required geological information that will be used to evaluate the model. The properties modeled are shown on figure 8, there the first on is the permeability model, the second is the water saturation, and the third on the bottom is the effective porosity. This model is going to be analyzed on the following sections.

Figure 8: Model for the properties.
5.3.2 Horizon Interpretation

By using the seismic volume given, we had to select the horizons manually by using the auto tracker tool to connect the horizons. As shown in the figure below, we can identify the formation (Salina B Salt, A2 Carb, A2 Evab, Niagaran Brown and Niagaran Gray). On the figure below, these are the 5 horizons that were picked and correlated with the well tops. After picking the horizons, the surfaces were created and then, using a simple model in Petrel the static model was built.

Figure 9: Seismic horizon of each surface.
5.3.3 Pillar Gridding

Pillar Gridding is a procedure that involves the formation of the structural model. The Pillar Gridding procedure results in the arrangement of pillars alongside the Faults as well as in the middle of the Faults. However, no faults were encountered on the seismic data.

This phase was done by creating a border around the wells and by including the seismic volume. We then further converted these cells into surfaces from the gridding cells. The grid skeleton consists of a top, middle, and base skeleton grid. This skeleton was formed using the Niagaran Brown formation, top surface, and the Niagaran Gray surface, bottom surface.

![Figure 10: Skeleton grid](image-url)
5.3.4 Making Horizons and Zones

These surface horizons were entered from those interpreted surfaces that were earlier completed. This model incorporates four similar and one base reservoir tops, shown on figure 13. In order to produce the zones, it was applied isochoric process, which is a standard gridding algorithm (Convergent in Petrel and LS/BH in Z-MAP Plus) is used with the modified data to build the thickness grid.

Figure 11: Horizons picked to produce the surfaces.
5.3.5 Layering

Layering is the final step in building the structural framework. This step is to make the fine-scale layering, necessary for property modeling. These layers define the top and base of the cells of the 3D Grid. This procedure shows us a better resolution for each zone. In this figure, we can see a constant thickness parallel to the top, middle, and base zones.

Figure 12: Stratigraphic Layering.

5.3.6 Properties Modeling

In this phase, to add propriety to the model, properties from the well logs were entered into the model in order to understand the distribution and the heterogeneity of each surface of the reservoir. The well logs were up scaled, and then the next step was to make the faces of the model, which concluded the up scaled data from the well logs to the 3D model.
5.4 Properties Evaluation

On this section, the evaluation of the three properties that were simulated on the static model will be discussed. By analyzing the static model, it was possible to localize an optimal new well location where the conjunct of oil saturation, porosity, and permeability were the most favorable to produce oil inside the reef.

5.4.1 Oil Saturation Evaluation

The oil saturation evaluation was based on the water saturation model created, shown on figure 16. The oil saturation (which is one minus the water saturation) varies from 0, dark blue color, to 1, red color, so it was decided to choose a location inside the reef and on the dark brown area, where the oil saturation would be around 80%. The location of the new well is the red dot on the figure below.

Figure 13: Water saturation model.
5.4.2 Porosity Evaluation

For the porosity evaluation two models were created, one with the total porosity, and other with effective porosity. The group decided to rely on the effective porosity, shown on figure 16, since this is the one important for production. The effective porosity on the model varies from 0%, light purple, to 13%, red. The group decided to choose the location inside the reef and in the blue area, where the effective porosity would be around 4%. The location of the new well is the brown dot on the figure bellow.

Figure 14: Effective porosity model.
5.4.3 Permeability Evaluation

The permeability evaluation was done after the creation of the permeability model, shown on figure 17. The permeability varies from 1 md, purple color, to 10000 md, red color. The group decided to choose the location of the new well again inside the reef, where the permeability would be around 9 md. The location of the new well is the red yellow dot on the figure below.

Figure 15: Permeability model.

5.5 Location of the New Well

After the evaluation of the effective porosity, permeability, and oil saturation properties the group came up with an optimal location for the new well, which the group called Charlton 5-30. The estimated properties of this new well would be around 80% oil saturation, 4% porosity, and 9 md. The new well location was also chosen to be inside the reef since this is the producing zone of the Charlton 30/31 field. The coordinates of Charlton 5-30 well are x = 1959676.52 ftUS and y = 630859.66 ftUS based on MI83-NF SIS,501347 Coordinate Reference System. The depth of the well was chosen to be 5500 Drill Depth.
6. Drilling Plan

6.1. Field Topology Analysis

After creating the Static Model, and analyzing the porosity, permeability, and water saturation, the location of the well was chosen. The next step is to create the drilling plan, which will contain the casing depths, design, and the cost of the project.

In order to create a casing design, it was necessary to analyze the lithology of all the formations from the top to the pay zone. It was decided to gather the information of the lithology from previously drilled well on the same field. The group found a report online from a well that was drilled on Charlton 30/31 Field, Otsego County, Michigan in order to do a carbon sequestration. On the report it was found a picture, shown on picture 20, with all the lithology encountered on the field when they drilled the well. It was also shown on this picture important zones that the group paid major attention. There were drinking water, gas producing, and carbon sequestration zone.

Figure 16: Field topology, picture found on the online paper: “Prospective CO2 Saline Resource Estimation Methodology: Refinement of Existing US-DOE-NETL Methods Based on Data Availability”
6.2 Casing Location

After analyzing the lithology and the main zones on the field, the group located the casing depths, shown on figure 20. The conductor is placed 80ft below the surface, a standard location. Then it was necessary to isolate the drinking water zone, which ended at 700ft, and then put a safety factor of 100ft resulting in a location of the surface casing at 800ft. By doing that we avoid environmental problems, such as contamination of the water.

The next casing locations was chosen in order to isolate the other two main zones, the gas producing and the carbon sequestration zone. By doing that we avoid to having any leakage and also contamination of upper formation and zones. The location of the intermediate casing was chosen to be 3500ft. Finally, it was decided to position the liner at the pay zone depth 5500ft. The sketch of the well locations is shown on figure 20.

Figure 17: Charlton 5-30 casing sketch.
6.3 Casing Design

After locating the casing position, it was necessary to choose, bit diameter, casing OD, WT/FT and grade of the casing, the sacks of cement needed, location of cement top, and the mud weight. All of this information was acquired from a well drilled in 2006, the Charlton 4-30, where it was found an online report with all of these information. It was decided that we use the same specifications as this well since it was successfully drilled with no apparent problems, and it is located on the same field. The specifications are listed on table 2.

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Bit Dia. (in)</th>
<th>Casing OD (in)</th>
<th>WT/FT</th>
<th>Grade</th>
<th>Sacks CMT</th>
<th>Cement Top</th>
<th>Mud WT (lbm/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Driven</td>
<td>16</td>
<td>65</td>
<td>H-40</td>
<td>Driven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>14 3/4</td>
<td>11 3/4</td>
<td>42</td>
<td>H-40</td>
<td>375</td>
<td>Surface</td>
<td>FW</td>
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<tr>
<td>3500</td>
<td>10 5/8</td>
<td>8 5/8</td>
<td>32</td>
<td>J-55</td>
<td>400</td>
<td>1200</td>
<td>9.8</td>
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<tr>
<td>4250</td>
<td>7 7/8</td>
<td>5 1/2</td>
<td>15.5</td>
<td>K-55</td>
<td>200</td>
<td>4000</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Table 2: Casing design
6.4 Drilling Costs

By having the casing design information on hands, and based on the online report with the drilling phase for Charlton 4-30, the group developed an estimate cost of the drilling and completion phase of the suggested new well Charlton 5-30. The costs were found by analyzing a previous cost consulting made by Malone Petroleum Consulting, which is a well-known consulting company. Some corrections were made since this cost consulting was made on 2014, where the price of oil was close to 100 dollars per barrel. The group decided the reduce the costs by 10% since the actual price of the oil is 51.39 dollars per barrel. Table 3 shows the Drilling cost, and table 4 shows the Completion costs.

<table>
<thead>
<tr>
<th>Drilling</th>
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<tr>
<td>Set up</td>
<td>110,000</td>
</tr>
<tr>
<td>Rig days</td>
<td>546,000</td>
</tr>
<tr>
<td>Chemicals, Fluids, Transportation</td>
<td>203,350</td>
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<tr>
<td>Rental Equipment &amp; Services</td>
<td>295,850</td>
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<tr>
<td>Labor &amp; Engineering</td>
<td>63,800</td>
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<tr>
<td>Open hole logging &amp; testing</td>
<td>54,000</td>
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<tr>
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<td>118,936</td>
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<td>Drilling tangibles</td>
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<td><strong>Total</strong></td>
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Table 3: Drilling Costs.

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<th>Completion</th>
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<td>Rig &amp; Day work</td>
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<td>Chemicals, Fluids, Transportation</td>
<td>72,000</td>
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<td>Rental Equipment &amp; Services</td>
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<tr>
<td><strong>Total</strong></td>
<td>1,009,904</td>
</tr>
</tbody>
</table>

Table 4: Completion Costs.
Conclusion

The group has completed the four phases of the project. These phases include literature review, loading and analyzing the data, the creation of the static model and optimal field development plan. By analyzing the properties generated on the static model, porosity, permeability, and water saturation, the group has chosen an optimal location for the new well Charlton 5-30. The group then developed the drilling plan, with casing locations, design, and estimated costs for this operation. With this report Drillit Safe company delivers the field development plan for the Charlton 30/31 field.
References