Effect of gamma ray normalization on net pay calculation, a case study of “PE” field, central Sumatra basin

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Abstract. Reservoir’s quality is very important in exploration of oil and gas. This quality can be used to determine the productive field including the reserve itself. To analyse the reservoir quality, net pay thickness needs to be determined. However, different quality of logging tools will affect the log reading and thickness interval. Therefore, it needs to be normalized in order to equalize the reading of minimum and maximum log values in interest zone. This study is intended to interpret the impact of gamma ray normalization on net calculation. The net pay calculation is carried out with and without normalization. To do normalization, cumulative percentile used are 3% and 93%. For instance, before normalization, the highest net pay in PE_35 is 12ft. After P93 and P3 normalization, the highest net pay value become 13.5ft and 51.5ft respectively. If the net pay value of PE_35 using P3 normalization is compared to the net pay value before normalized, then the normalized value is optimized more than 5%, which is a good amount of optimization. Thus, to obtain an optimistic net pay value, normalization must be done. To conclude this study, 3% cumulative percentile normalization method has shown the most optimistic net pay value increase.

1. Introduction
Net pay as the parameter of reservoir evaluation can be used to identify the geology quality and the availability of oil and gas of a reservoir. Both quality and availability indicate the economic and productivity of a field. Net pay thickness is determined using the core and log data. Based on Nooh and Moustafa (2017), they have carried out a quantitative analysis of calculating clay volume and net to gross using gamma ray logs and FMI. From this, the results obtained are V shale or porosity cutoff which can determine very thin sandstone laminations, FMI logs of element identification and geological features. The thickness interval for each well is different, this can affect the log reading analysis and affect the characteristics of the mapped reservoir. Thus, log normalization is applied to obtain a same log reading. Fekete et al., (2015) also conducted research on net pay estimates for conventional and unconventional reservoirs with geological integration. The results showed that the method used is very useful to get good cutoff on determining the net pay conventional and
unconventional reservoirs. The rock integration gives good quality reservoir data to estimate the hydraulic characteristics of oil and gas reservoirs.

In this study, normalization is applied on gamma ray. According to Shier (2004), well log normalization is a process in eliminating systematic error from the well log curve. In certain cases, radioactive activity change of a time will cause a different result in gamma ray data recording at any time. Nazeer et al., (2016) predict lithological variations through the measurement of radioactive gamma ray log emissions. This shows that there is a sharp contrast from the gamma log indicating a settling limit because the logs are directly connected. Shier (2004) explained that the response of the tools to the thin layer will depend on the detector used. On a gamma ray curve, the correct response is the one that has a consistent response to the surrounding wells curve and provides an interpretation of shale volume that is appropriate for its type of rock variations. In other words, gamma ray scale is relative to other wells, and is not absolute. Also, in a study by Quartero et al. (2014), it was found that gamma ray data combined with normalization techniques would show a better interpretation of some formations and show the depositional model and surrounding soil data. One of normalization method according to Shier (2004) is statistical. Cumulative percentile in statistical method which can be used is using 10% and 90% which correlate with the gamma ray interval. Statistical normalization is based on assumption that the same rock shows the same percentage in a studied area. This study is intended to obtain an interpretation of the effect of gamma ray normalization on net pay calculation in determining the prospect of a hydrocarbon reservoir. The study area is located in PE Field, Central Sumatra Basin.

2. Research Method
In this research, the primary data needed are; wireline log data and well head data. Wireline log data is well recording data, the log used is neutron log, resistivity log, sonic log, gamma ray log, density log, and caliper log. The well head data explain the location of the well, the depth of the drilling and the measurement position of the logging tool (in this case the measurement starts from the kelly bushing) in each well. Meanwhile, the secondary data used were field research stratigraphy and special core analysis (SCAL). The study was conducted on wells as shown in figure 1. The processing stage starts from the correlation of the wells to get the formation boundary. The focused study area of this research is on Bekasap and Menggala Formation of Central Sumatra Basin.
The research begins with a literature study on regional geology in the research area. According to Heidrick and Aulia (1993) the Sumatran basin is included in the Cenozoic rock stratigraphic unit which consists of five formations, which are the Pematang formation, Sihapas formation, Telisa formation, Petani formation, and Minas formation. In the Central Sumatra Basin there is a bund formation above the bedrock and is the two dominant continental facies. The lithology of this formation is claystone with various colors, fine-grained sandstone interspersed with lacustrine shale, conglomerate sequence, coarse-grained sandstone, and clay rock. The Sihapas Formation occurred in the transgression phase which covered the Telisa formation with its deposits. The Telisa Formation at the lowest level is indicated by the smaller conglomerate grain size, the order of sandstone grain size from coarse to fine. Next is the Telisa Formation which is dominated by a succession of shale with alternating limestone and fine grained glauconite sandstone. Whereas in the Petani Formation, it is deposited monotonically from shale mudstone which contains a small amount of sandstone and siltstone intercalation. And the Minas Formation contains alluvial sandstone.

Then, as shown in figure 2, gamma ray normalization was carried out and continued by calculating VCL, PHIE, Sw. VCL calculation is carried out to determine the amount of shale content in the rock layer based on Gamma Ray clay, Gamma Ray clean, and Gamma Ray values in the well. While the effective porosity (PHIE) calculation phase was carried out by using several logs such as VCL, LLD logs, density logs, and temperature using IP 3.5 Software. The porosity calculation is carried out simultaneously with the calculation of water saturation (Sw). The calculation of water saturation (Sw) used is the Indonesian equation as described in Harsono (1997) as proposed by Poupon and Levaux (1971) because Indonesia has a large volume of shale and contains fresh water as formation water, so it is appropriate to model this formation. Next, a cutoff and net pay summary is performed. The types of cutoffs used are VCL cutoff, porosity cutoff, and Sw cutoff. Simply, based on Worthington and Cosentino (2005), VCL cutoff is obtained to identify the net sand. Then, to determine the net reservoir, porosity cutoff is implemented. While, Sw cutoff is applied to obtain the net pay. The cutoff value is obtained by finding a match for the hyperbolic line through the data. After the data processing using normalization is
carried out, it is continued by processing the data as before but without normalizing gamma rays. Thus, a comparison between normalized and not-normalized calculation can be compared.

3. Results
Recorded GR log data of PE_08, PE_05 and PE_35 well is shown as a curve in figure 3. The curves in figure 3 are focused in reservoir zone of PE Field, which are Bekasap and Menggala formation (indicated as formation 3 and formation 4 respectively. All GR log data curves is arranged to scale of 0-200 API. In GR log, higher GR log value indicates more shaly formation, while lower GR log value indicates more sandy formation.

Figure 3. Recorded gamma ray log data shown in curves (a) PE_35 well (b) PE_05 well (c) PE_08 well. The curve is displayed in different scale and focused in Bekasap and Menggalan formation.
Regionally, the reservoir zone of Central Sumatra basin is in Bekasap and Menggala formation. Histogram analysis is done to determine which well is going to be normalized and which well will become the reference well. There are three histogram analysis used in this study, as shown in figure 4. Based on histogram analysis, we may know which well has different gamma ray trend to others. Normalized well and reference well have been identified qualitatively based on its trend of each histogram analysis.

![Histogram analysis](image)

**Figure 4.** Gamma ray log histogram analysis based on (a) depth interval (b) well top marker of Bekasap Formation (c) well top marker of Menggala Formation.

Due to prior process (histogram analysis based on well depth interval and well top marker), three normalized wells were identified, namely PE 05, PE 08, and PE 35. While the reference well is PE 19. Different cutoffs used in each well is based on the cutoff sensitivity analysis. The net pay value before and after normalized for each percentile cumulative together with cutoff used, can be displayed in a table as a comparison. Below are the result of cutoff used and the net pay summary for each well. Each table consist of reservoir summary, net pay summary (used final result), and cutoff used.
Table 1. Net pay summary of PE_05 well before normalized.

| Reservoir Summary |
|-------------------|
| Zone Name | Top | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
| Formasi 3 | 1658.54 | 1964 | 305.46 | 1.5 | 0.005 | 0.5 | 0.2 | 0 |
| Formasi 4 | 1964 | 2075.6 | 111.6 | 23 | 0.206 | 0.3 | 0.3 | 0.1 |
| All Zones | 1658.54 | 2075.6 | 417.06 | 24.5 | 0.059 | 0.3 | 0.3 | 0.1 |

| Pay Summary |
|-------------|
| Zone Name | Top | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
| Formasi 3 | 1658.54 | 1964 | 305.46 | 1.5 | 0.005 | 0.5 | 0.2 | 0 |
| Formasi 4 | 1964 | 2075.6 | 111.6 | 22.5 | 0.202 | 0.3 | 0.3 | 0.1 |
| All Zones | 1658.54 | 2075.6 | 417.06 | 24 | 0.058 | 0.3 | 0.3 | 0.1 |

| Cutoffs Used |
|--------------|
| Phi | Sw | Vcl |
| PhiSw:PHIE | PhiSw:SwInd | VCL: VCLn93 |
| >= 0.2 | <= 0.4 | VCLn93:VCLn93 |

Table 2. Net pay summary of PE_05 well using P93 normalization.

| Reservoir 93 Summary |
|----------------------|
| Zone Name | Top | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
| Formasi 3 | 1658.54 | 1964 | 305.46 | 2 | 0.007 | 0.4 | 0.2 | 0.1 |
| Formasi 4 | 1964 | 2075.6 | 111.6 | 4 | 0.036 | 0.4 | 0.2 | 0.1 |
| All Zones | 1658.54 | 2075.6 | 417.06 | 6 | 0.014 | 0.4 | 0.2 | 0.1 |

| Pay 93 Summary |
|----------------|
| Zone Name | Top | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
| Formasi 3 | 1658.54 | 1964 | 305.46 | 2 | 0.007 | 0.4 | 0.2 | 0.1 |
| Formasi 4 | 1964 | 2075.6 | 111.6 | 4 | 0.036 | 0.4 | 0.2 | 0.1 |
| All Zones | 1658.54 | 2075.6 | 417.06 | 6 | 0.014 | 0.4 | 0.2 | 0.1 |

| Cutoffs Used |
|--------------|
| Phi | Sw | Vcl |
| PhiSw:PHIE | PhiSw:SwInd | VCLn93:VCLn93 |
| >= 0.3 | <0.4 | VCLn93:VCLn93 |

Table 3. Net pay summary of PE_05 well using P3 normalization.

| Reservoir 3 Summary |
|---------------------|
| Zone Name | Top | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
| Formasi 3 | 1658.54 | 1964 | 305.46 | 7.5 | 0.025 | 0.2 | 0.2 | 0.3 |
| Formasi 4 | 1964 | 2075.6 | 111.6 | 2 | 0.018 | 0.4 | 0.3 | 0.1 |
| All Zones | 1658.54 | 2075.6 | 417.06 | 9.5 | 0.023 | 0.3 | 0.3 | 0.2 |
| Zone Name | Top  | Bottom | Gross | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|-----------|------|--------|-------|------|------|--------|-------|--------|
| Formasi 3 | 1658,54 | 1964 | 305,46 | 7,5 | 0,025 | 0,2 | 0,2 | 0,3 |
| Formasi 4 | 1964 | 2075,6 | 111,6 | 2 | 0,018 | 0,4 | 0,3 | 0,1 |
| All Zones | 1658,54 | 2075,6 | 417,06 | 9,5 | 0,023 | 0,3 | 0,3 | 0,2 |

**Cutoffs Used**

| Phi | Sw  | Vcl |
|----|-----|-----|
| PhiSwn3:PHIE | PhiSwn3:Sw | VCLn3:VCLn3 |
| >= 0,114 | <=0,3 | <=0,5 |

**Table 4.** Net pay summary of PE_08 well before normalized.

| Zone Name | Top  | Bottom | Gross | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|-----------|------|--------|-------|------|------|--------|-------|--------|
| Formasi 3 | 1801,2 | 2071,25 | 270,03 | 18 | 0,067 | 0,2 | 0,3 | 0,3 |
| Formasi 4 | 2071,3 | 2229,08 | 157,83 | 7,5 | 0,428 | 0,2 | 0,3 | 0,3 |
| All Zones | 1801,2 | 2229,08 | 427,86 | 85,5 | 0,2 | 0,3 | 0,3 |

**Cutoffs Used**

| Phi | Sw  | Vcl |
|----|-----|-----|
| PhiSw:PHIE | PhiSw:SwInd | VCL:VCL |
| >= 0,2 | <=0,3 | <=0,6 |

**Table 5.** Net pay summary of PE_08 well using P93 normalization.
| Zone Name | Top   | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
|-----------|-------|--------|-------|-----|-----|--------|-------|--------|
| Formasi 3 | 1801,2| 2071,25| 270,03| 18,5| 0,069| 0,2    | 0,2   | 0,3    |
| Formasi 4 | 2071,3| 2229,08| 157,83| 66,5| 0,421| 0,2    | 0,2   | 0,3    |
| All Zones | 1801,2| 2229,08| 427,86| 85  | 0,199| 0,2    | 0,2   | 0,3    |

**Reservoir 3 Summary**

| Zone Name | Top   | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
|-----------|-------|--------|-------|-----|-----|--------|-------|--------|
| Formasi 3 | 1527,77| 1889,25| 361,48| 4,5 | 0,012| 0,3    | 0,3   | 0,2    |
| Formasi 4 | 1889,25| 2067,21| 177,96| 7,5 | 0,042| 0,3    | 0,1   | 0,1    |
| All Zones | 1527,77| 2067,21| 539,44| 12  | 0,022| 0,3    | 0,2   | 0,1    |

**Table 6.** Net pay summary of PE_05 well using P3 normalization.

### Pay Summary

| Zone Name | Top   | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
|-----------|-------|--------|-------|-----|-----|--------|-------|--------|
| Formasi 3 | 1527,77| 1889,25| 361,48| 4,5 | 0,012| 0,3    | 0,3   | 0,2    |
| Formasi 4 | 1889,25| 2067,21| 177,96| 7,5 | 0,042| 0,3    | 0,1   | 0,1    |
| All Zones | 1527,77| 2067,21| 539,44| 12  | 0,022| 0,3    | 0,2   | 0,1    |

**Cutoffs Used**

| Phi | Sw | Vcl |
|-----|----|-----|
| PhiSw93:PHIE | PhiSw93:SwInd | VCLn93:VCL |
| >= 0,2 | <= 0,3 | <= 0,6 |

**Table 7.** Net pay summary of PE_35 well before normalized.

### Pay Summary

| Zone Name | Top   | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl |
|-----------|-------|--------|-------|-----|-----|--------|-------|--------|
| Formasi 3 | 1527,77| 1889,25| 361,48| 4,5 | 0,012| 0,3    | 0,3   | 0,2    |
| Formasi 4 | 1889,25| 2067,21| 177,96| 7,5 | 0,042| 0,3    | 0,1   | 0,1    |
| All Zones | 1527,77| 2067,21| 539,44| 12  | 0,022| 0,3    | 0,2   | 0,1    |

**Cutoffs Used**

| Phi | Sw | Vcl |
|-----|----|-----|
| PhiSw:PHIE | PhiSw:SwInd | VCL:VCL |
| >= 0,28 | <= 0,47 | <= 0,35 |
Table 8. Net pay summary of PE_35 well using P93 normalization.

| Zone Name      | Top    | Bottom      | Gross  | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|----------------|--------|-------------|--------|------|------|--------|-------|--------|
| Formasi 3      | 1527,77| 1889,25     | 361.48 | 4.5  | 0.012| 0.3    | 0.3   | 0.2    |
| Formasi 4      | 1889,25| 2067,21     | 177.96 | 9    | 0.051| 0.3    | 0.1   | 0.1    |
| All Zones      | 1527,77| 2067,21     | 539.44 | 13.5 | 0.025| 0.3    | 0.2   | 0.1    |

Pay 93 Summary

| Zone Name      | Top    | Bottom      | Gross  | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|----------------|--------|-------------|--------|------|------|--------|-------|--------|
| Formasi 3      | 1527,77| 1889,25     | 361.48 | 4.5  | 0.012| 0.3    | 0.3   | 0.2    |
| Formasi 4      | 1889,25| 2067,21     | 177.96 | 9    | 0.051| 0.3    | 0.1   | 0.1    |
| All Zones      | 1527,77| 2067,21     | 539.44 | 13.5 | 0.025| 0.3    | 0.2   | 0.1    |

Cutoffs Used

| Phi           | Sw     | Vcl      |
|---------------|--------|----------|
| PhiSwn93:PHIE | <= 0.28| PhiSwn3:SwInd <= 0.47 |
| VCLn93:VCL    | <= 0.35|

Table 9. Net pay summary of PE_35 using P3 normalization.

| Zone Name      | Top    | Bottom      | Gross  | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|----------------|--------|-------------|--------|------|------|--------|-------|--------|
| Formasi 3      | 1527,77| 1889,25     | 361.48 | 23   | 0.064| 0.3    | 0.3   | 0.2    |
| Formasi 4      | 1889,25| 2067,21     | 177.96 | 28.5 | 0.16 | 0.3    | 0.2   | 0.1    |
| All Zones      | 1527,77| 2067,21     | 539.44 | 51.5 | 0.095| 0.3    | 0.2   | 0.2    |

Pay 3 Summary

| Zone Name      | Top    | Bottom      | Gross  | Net  | N/G  | Av Phi | Av Sw | Av Vcl |
|----------------|--------|-------------|--------|------|------|--------|-------|--------|
| Formasi 3      | 1527,77| 1889,25     | 361.48 | 23   | 0.064| 0.3    | 0.3   | 0.2    |
| Formasi 4      | 1889,25| 2067,21     | 177.96 | 28.5 | 0.16 | 0.3    | 0.2   | 0.1    |
| All Zones      | 1527,77| 2067,21     | 539.44 | 51.5 | 0.095| 0.3    | 0.2   | 0.2    |

Cutoffs Used

| Phi           | Sw     | Vcl      |
|---------------|--------|----------|
| PhiSwn3:PHIE  | >= 0,25| PhiSwn3:SwInd <= 0.4 |
| VCLn3:VCL     | <=0,35 |
Table 10. Net pay summary of PE_05 well before normalized.

| Zone Name | Top       | Bottom  | Gross | Net | N/G | $\overline{Av}_{\Phi}$ | $\overline{Av}_{Sw}$ | $\overline{Av}_{Vcl}$ |
|-----------|-----------|---------|-------|-----|-----|--------------------------|-----------------------|------------------------|
| Formasi 3 | 1558,72   | 1781,86 | 223,14| 5   | 0,022| 0,3                      | 0,2                   | 0,1                    |
| Formasi 4 | 1781,86   | 1968,02 | 186,16| 33,5| 0,18 | 0,3                      | 0,2                   | 0,1                    |
| All Zones | 1558,72   | 1968,02 | 409,3 | 38,5| 0,094| 0,3                      | 0,2                   | 0,1                    |

Pay Summary

| Zone Name | Top       | Bottom  | Gross | Net | N/G | $\overline{Av}_{\Phi}$ | $\overline{Av}_{Sw}$ | $\overline{Av}_{Vcl}$ |
|-----------|-----------|---------|-------|-----|-----|--------------------------|-----------------------|------------------------|
| Formasi 3 | 1558,72   | 1781,86 | 223,14| 5   | 0,022| 0,3                      | 0,2                   | 0,1                    |
| Formasi 4 | 1781,86   | 1968,02 | 186,16| 33,5| 0,18 | 0,3                      | 0,2                   | 0,1                    |
| All Zones | 1558,72   | 1968,02 | 409,3 | 38,5| 0,094| 0,3                      | 0,2                   | 0,1                    |

4. Discussion

Normalization affects the difference of gamma ray index, so that the given cut-off values are also different. Based on a prior study of Cahyaningati (2020), physical parameters plotting is also used to determine the cut-off value in this study. This affects the thickness of net pay which is the clean reservoir area used in volumetric calculation. The well that considered as a reference well is PE_19 because its gamma ray curve trends are relatively the same as other wells and normalized wells of gamma ray is PE_05, PE_08, PE_35 because the curve trend is significantly different. PE_19 well as a reference well has VCL of 56%, effective porosity of 13%, and water saturation of 46.99%. With neutron log and density analysis, crossover occur in Menggala Formation of 33.5 ft and has a large net pay value. So that the PE_19 well has considerable potential to become an oil and gas reservoir zone. In normalized wells, PE_05 reservoir zone at a depth of 1658.5 ft - 2075.6 ft shows an effective porosity of 30%, 30% water saturation, and 10% VCL obtained from a wireline log analysis, while gamma ray log data analysis under normal conditions is used in the calculation of physical parameters using cut-off_{PHIE} more than 20%, cut-off_{Sw} up to 40%, and cut-off_{VCL} no more than 20%. Based on wireline log analysis and physical calculation under normal condition, net pay value of PE_05 well is 24.5 ft. After normalization, the cumulative percentage 93% gives net pay value of 6ft, while the cumulative percentage 3% gives net pay value of 9.5 ft. Based on gamma ray normalization using cumulative percentage 93%, wireline log analysis shows VCL 10%, effective porosity 40%, and water saturation 20%. Whereas cut-off_{VCL} is no more than 40%, cut-off_{PHIE} more than 30%, and cut-off_{SW} less than 40%. Whereas at a cumulative percentage 3%, wireline log analysis show VCL 20%, effective porosity 30%, and water saturation 30%. Cumulative percentage of 3% using cut-off_{VCL} no more than 50%, cut-off_{PHIE} more than 11.4%, and cut-off_{SW} no more than 30%. Optimization level of this study shows that normalization should be done as 5%.

At PE_08 well, reservoir zone is at depth of 1801.22 – 2229.08 ft. Under normal condition, net pay value indicates a value of 85.5 ft. After normalization, cumulative percentage of 93% gives 85 ft net pay value. Whereas at cumulative percentage of 3%, obtained net pay value is 6ft. Based on the net pay value, this well has small optimization at cumulative percentage 93%, so that normalization only needs to be done at cumulative percentage 3% since the difference of net pay value is no more than 5% than net pay value under normal condition affected by cut-off value limit. In the reservoir zone of
PE_35 well with a depth of 1527.77 - 2067.21 ft / Under normal conditions the net pay value is 12 ft, whereas after normalization, a cumulative percentage of 93% gives a net pay value of 13.5 ft. whereas at a cumulative 3% percentage a net pay of 51.5 ft is obtained. According to the net pay value, PE_35 well has more than 5% optimization under normal condition.

Among three normalized wells, PE_08 has the biggest net pay value with cumulative percentage of 93%. But, at cumulative percentage of 3%, it does not indicate the level of net pay optimization. If normalization done on both cumulative percentages, PE_35 well has better optimization level, on the neutron log data and its density there is crossover between interval 2000.5 – 2012.5 ft. The impact of normalization is gamma ray index gives significant changes on net pay calculation using statistic normalization method with 5% optimization. The high net pay value indicates optimistic net pay quality and vice versa. The result of this study gives better interpretation of the studied formation (Menggala and Bekasap). Nearly to this study, Quartero (2014) also have shown a better interpretation in gamma ray data after normalized, with one of used method is statistical value reading and cumulative percentile, as well as in this research. Thickness of net pay affects the amount of hydrocarbon reserves obtained with the support of other parameters. So that hydrocarbon reserves to become larger, net pay must be thicker.

5. Conclusion
Based on this study, it can be concluded that PE_35 well have shown a significant change on net pay value after gamma ray normalization is applied. Moreover, this change exceeds 5% of optimization, so that it gives more optimistic net pay value, particularly on P3. Consequently, normalization must be done to obtain an optimistic net pay value. Still, for cutoff sensitivity determination needs to be done using more accurate methods.

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