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Application of a statistical zonation technique to Granny Creek field in West Virginia

Venkata Kristamsetty
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**APPLICATION OF A STATISTICAL ZONATION TECHNIQUE TO
GRANNY CREEK FIELD IN WEST VIRGINIA**

VENKATA KRISTAMSETTY

**Thesis Submitted to the
College of Engineering and Mineral Resources
at West Virginia University
in partial fulfillment of the requirements
for the degree of**

**Master of Science
in
Petroleum and Natural Gas Engineering**

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Statistical Zonation Technique, Granny Creek Field.**

ABSTRACT

APPLICATION OF A STATISTICAL ZONATION TECHNIQUE TO GRANNY CREEK FIELD IN WEST VIRGINIA

VENKATA KRISTAMSETTY

The significance of dividing the sedimentary intervals into flow units reflects groups of rocks that has similar geologic, physical properties and depositional environment that affect fluid flow. Variations in rock properties result from depositional, diagenetic and post-depositional changes. A flow unit is a volume of a reservoir rock that is continuous laterally and vertically and has similar averages of those rock properties that affect fluid flow.

In this study, a statistical zonation technique developed by Testerman to identify and describe naturally occurring zones in a reservoir is applied to Granny Creek field in West Virginia. This technique is particularly useful in describing a reservoir where crossflow between adjacent strata is important in determining reservoir behavior. We established a linear relationship between the core permeability and density from the log in the cored wells to predict the permeability of the uncored wells, allowing for extension of flow units to these wells. Then the flow units from well to well were correlated by statistical calculation. Although it has been used for permeability zonation, the technique is general and can be used to correlate any reservoir property.

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Dedication

Dedicated to my parents, who have provided me with support emotionally and financially throughout this long journey thousands of miles away from home.

Acknowledgement

A journey is easier when you travel together. Interdependence is certainly more valuable than independence. This thesis is the result of two years of work whereby I have been accompanied and supported by many people. It is a pleasant aspect that I have now the opportunity to express my gratitude for all of them.

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NOMENCLATURE:

B	Variance between zones
Erf	Error function
F^*	Measured cumulative distribution function
$F(z)$	Distribution density function
$F(z)$	Cumulative distribution, $0 < F < 1$
F_s	Shape factor
FU	Flow Unit
FZI	Flow zone indicator
HU	Hydraulic Unit
i	summation index for number of zones
j	summation index for number of data within the zone
k	Permeability, mD
k_i	Mean of the permeability data in the i^{th} zone, mD
$k_{\cdot}$	Overall mean of the data in the well, mD
k_{ij}	Permeability data, mD
k_h	Arithmetic average of permeability data of the h^{th} zone in one well
L	Number of zones
$\bar{x}_i$	Mean of i^{th} observation
m_i	Number of data in the i^{th} zone
N	Total number of data
n_g	Number of cluster groups
n_h	Number of data in the h^{th} zone

n_i	Number of data in the i^{th} zone
N_U	Number of hydraulic units
	Objective function of minimization
z	Pore volume to grain volume ratio
RQI	Reservoir quality index
R	Zonation index
S	Standard deviation of all the permeability data of the reservoir
S_{gv}	Effective surface area per unit grain volume
	Tortuosity
i	Weight of the HU distribution
i	Standard deviation of the i^{th} distribution
W	Variance within zone
z	$\log(\text{FZI})$

CHAPTER -1

INTRODUCTION

Accurate well correlations are paramount for a reliable reservoir characterization. All geologic modelling have their foundation in correlation work. Therefore, it is worth knowing that any geologic correlation that is not consistent with the reservoir physical properties will give a misrepresentation of different flow units. In constructing an appropriate model, it is important that both the “form” and “function” of the reservoir is honoured as much as possible. The form represents the geologic environment, rock type, and the reservoir architecture. The function represents the petrophysical properties that result in the flow performance. While the former is associated with the geologic zones, the latter on the other hand is associated with the quantitative statistical zonation.

One of the first problems encountered by the reservoir engineer in predicting or interpreting fluid displacement behavior during secondary processes is that of organizing and using the large amount of data available from core analysis. Permeabilities pose particular problems because they usually vary by more than an order of magnitude between different strata. Due to the sheer volume, it is almost always necessary to group data and to use an average value to represent a number of measurements. Perhaps the most common method now used to group permeability data is the capacity-friction technique, which ranks permeabilities in order of magnitude, regardless of the physical location of the permeabilities within the reservoir.

Reservoir engineering techniques being developed will handle cross flow that occurs between adjacent communicating reservoir strata because of imbibitions and gravity segregation. Since crossflow occurs between physically adjacent layers within the reservoir, a flow unit technique recognizing the actual location of strata within the reservoir is necessary. Similarly, the recognition of natural flow unit is important for predictions of oil recovery by processes involving diffusion. One such process is miscible displacement, where predictions of lateral diffusion within the reservoir must recognize the actual location of the invaded zones in relation to the rest of the formation. Natural zones must also be adequately recognized to account for heat transfer within the reservoir during the thermal exploitation.

Because of the complexity of the problem, statistics appear to offer the only practical hope of dividing a reservoir into physically - meaningful natural flow units. This thesis presents a statistical zonation technique developed by Testerman¹ to identify and describe porous and permeable zones in a reservoir, and for determining which ones are likely to be continuous between adjacent wells. The flow units defined have minimum variation of permeability internally and a maximum variation between zones. The technique is general and can thus be applied to reservoir properties other than permeability. However, a statistical correlation based on core permeabilities and density from the log in two different wells is no guarantee that the flow units so defined are, in fact continuous. Rather, the assumption of continuity must be consistent with geological data concerning the depositional environment, as well as justified on the basis of engineering

judgment in combination with statistics, just as judgment is required with conventional zonation methods.

Although core data is not available for all wells since core analysis is expensive, a linear correlation has been made between core data and log data to predict permeability for uncored wells. The statistical method was utilized to identify the flow unit using the permeability data. The flow units from the predicted permeability and measured core permeability were correlated with each other throughout the reservoir. The technique is particularly useful in describing the reservoir where cross flow between adjacent strata is important in determining reservoir behavior.

CHAPTER-2

LITERATURE REVIEW

2.1 Concept of Flow Units²

In recent years, the concept of hydraulic unit or flow unit has been introduced as a method of subdividing a sedimentary interval for reservoir description. A flow unit is defined as a volume of reservoir rock that is continuous laterally and vertically and has similar averages of the rock properties that affect fluid flow. Flow units represent an assemblage of facies having similar characteristics and are related to geological facies distributions but do not necessarily coincide with the facies boundaries. The parameters that influence fluid flow are mainly pore-throat geometrical attributes. The pore geometry is in turn controlled by mineralogy (type, abundance, location) and texture (grain size, grain shape, sorting, packing). Various combinations of these geological properties can lead to distinct rock flow units that have similar fluid transport properties. The significance of dividing the sedimentary intervals into flow units is that each flow unit usually reflects a specific depositional environment and the characteristics of fluid flow.

2.2 Flow Unit Identification Techniques^{3, 4}

2.2.1 Flow Unit classification using core data:

Flow units can be identified based on Flow Zone Indicator (FZI) values. Although there should exist one single FZI value for each flow unit, a distribution for each FZI values around its true mean results due to random measurement errors in core analysis. When multiple flow unit groups exist, the overall FZI distribution function is a superposition of

the individual distribution function around their mean FZI. Identification of each mean FZI, or the corresponding Hydraulic Unit (HU), would require decomposition of the overall FZI distribution into its constituting elements. This is a desuperposition problem and cluster analysis techniques allow for such a decomposition process.

Three approaches, histogram analysis, probability plot, and the Ward's analytical algorithm, are discussed for cluster analysis, although there are other declustering procedures, such as dendrogram or rose diagram.⁵ The declustering of FZI is performed on the basis of logarithm of FZI because FZI values calculated from actual field data usually exhibit log-normal distribution. This can be attributed to the strong dependency of FZI on permeability, which in turn often is a log-normal Gaussian distribution.

2.2.1.1 Histogram Approach²:

Because FZI distribution is a superposition of multiple log-normal distributions, a histogram of FZI (with the log scale in the x-axis) should show “n” number of normal distributions for “n” number of HUs. The convolved frequency distribution for a mixture of multiple Gaussian probability density functions is described by Equations 1 & 2.

$$f(z) = \sum_{i=1}^{N_U} \frac{1}{\sqrt{2\pi}\sigma_i} \exp\left(-\frac{(z - \mu_i)^2}{2\sigma_i^2}\right) \quad (1)$$

and

$$\sum_{i=1}^{N_U} \frac{1}{\sigma_i} = 1 \quad (2)$$

When clusters are distinctly separate, the histogram clearly delineates each HU and provides their corresponding FZI values. This is the easiest and simplest approach. However, it is often difficult to separate the overlapped individual distributions from a histogram plot. Therefore, this method is not suitable for most field applications because the transition zones between HUs often clouds the judgment on their identity.

2.2.1.2 Probability Plot Approach²:

It is also called as cumulative distribution function plot. It is the integral of histogram (probability density function), and as such, it is a smoother plot than histogram plot. In this plot the scatter in data is reduced and the identification of clusters is easier. The cumulative distribution function is given by Equation 3.

$$F(z) = \frac{1}{2} \left[1 + \sum_{i=1}^{N_U} \text{erf} \left(\frac{z - \mu_i}{\sigma_i} \right) \right] \quad (3)$$

where erf is the “error function” encountered in the integration of normal distribution.

The number of straight lines and the limiting boundary values of FZI or each HU can be obtained from the probability plot of Log (FZI). Because mean FZI values are not calculated from the probability plots, the representative FZI value for each HU is obtained by averaging all the FZI values within the corresponding HU limits. This exactly corresponds to a linear least-squares regression of data where the slope of the regression line is equal to unity. This method is more useful than histogram method

because it is easier to identify straight lines visually, although the superposition effects may shift or distort the straight lines to some degree.

2.2.1.3 Nonlinear Regression²:

Because FZI distribution function is a complex convolution of multi-Gaussian distributions, nonlinear regression analysis offers a robust means for decomposing such a multimodal distribution. In this approach, an objective function is minimized and the unknown parameters of mean and standard deviation of the comprising distribution functions are obtained. The objective function is defined by Equation 4.

$$\sum_{j=1}^{N_{all}} (F_j^* - F_j(\mu_j, \sigma_j, N_U))^2 \quad (4)$$

Equivalently, the regression can also be done on the histogram data. Any standard nonlinear regression algorithm⁶ can be used to optimize μ_j, σ_j . The mean of individual distribution functions corresponds to the FZI values of each HU. It is also possible to regress on the number of HUs as an unknown parameter.

2.2.1.4 Ward's Algorithm⁷:

The Ward's algorithm is an analytical technique in hierarchical cluster analysis. In this method, the distance between data points (FZI values) are calculated, initially treating each sample data as a cluster. Next, the two clusters that are closest in distance are merged and the distance of new clusters from other clusters is computed. The process of distance calculation and emerging of clusters is continued until all available data points are emerged or until the required number of clusters is attained. The number of clusters is

an input into the Ward's algorithm. Graphical methods, especially the probability plot, provide a good means to determine an appropriate number of HUs for a data set. One of the advantages of the Ward's algorithm over the others is its special treatment of the cluster variances. Clusters are formed so as to minimize the increase in the within-cluster sums of squares of deviations from their mean. The distance between two clusters causes an increase in the sum of squares if the two clusters were emerged. Therefore, each cluster tends to attain a minimum spread around its mean value while having maximum separation from the other clusters. This is exactly what is expected from a HU. The within-group sum of squared deviations is calculated using Equation 5.

$$W = \frac{n_g - n_i}{i-1, j-1} \frac{Z_{ij}^2}{z_i} \quad (5)$$

2.2.1.5 Hydraulic Unit Prediction Using Log Data:

The major task is to predict HUs in wells where only well log measurements are available. This is an inverse process that requires a probabilistic approach. Three steps are needed for the inference of HU distribution at logged wells. First, those logs that are sensitive to dynamic flow parameters of pore-throat attributes are identified. This is done by either assessing the degree of correlatability of various logs with permeability or FZI through rank correlation, or by performing principal component analysis. The second step involves constructing a training data base that captures information on the inter-relationship between logs and HUs. The third step uses the database information and well log measurements to infer distribution of HUs statistically along the logged wells. The above three steps are discussed below in more detail.

Amaefule³ presented a theoretical methodology to identify the flow units. He defined a concept called Flow Zone indicator, FZI, which classifies the flow units in a reservoir. FZI is defined by the following Equation 6.

$$FZI = \frac{1}{(\sqrt{F_s}) S_{gv}} \frac{RQI}{z} \quad (6)$$

where F_s is the pore throat shape factor, τ is the tortuosity, and S_{gv} is the effective surface area per unit grain volume. RQI is the reservoir quality index defined by Equation 7.

$$RQI = 0.0314 \sqrt{\frac{K}{z}} \quad (7)$$

where z is the pore volume to grain volume ratio is calculated using Equation 8.

$$z = \frac{V_p}{V_g} \quad (8)$$

The above parameters are derived from a modified form of the Kozeny-Carmen equation.

2.3 Statistical Zonation Technique:

A Statistical Zonation Technique has been successfully used to detect significant differences between samples. The object in the problem of zonation is to detect the existence of distinct vertical sections or flow units within the permeability profile of each well in the reservoir.

The reservoir zonation technique is a two-step operation.

1. Permeability data from the top to bottom of the strata of a single well are divided into two zones. These zones are selected such that the variation of permeability within the

zones is minimized and maximized between zones. The statistical equations⁷ used to zone the permeability data are:

$$B = \frac{1}{L-1} \sum_{i=1}^L m_i (\bar{k}_i - \bar{k}_{..})^2$$

$$\frac{1}{L-1} \sum_{i=1}^L \frac{\sum_{j=1}^{m_i} k_{ij}^2}{m_i} - \frac{\sum_{i=1}^L \sum_{j=1}^{m_i} k_{ij}^2}{N} \quad (9)$$

The variance within any zone, W, is computed from:

$$W = \frac{1}{N-L} \sum_{i=1}^L m_i \sum_{j=1}^{m_i} (\bar{k}_i - \bar{k}_{..})^2$$

$$\frac{1}{N-L} \sum_{i=1}^L \sum_{j=1}^{m_i} k_{ij}^2 - \frac{\sum_{i=1}^L \sum_{j=1}^{m_i} k_{ij}^2}{m_i} \quad (10)$$

Zonation index, R, is

$$R = \frac{B-W}{B} \quad (11)$$

The zonation of individual wells is a multi-step procedure:

- (a) First, the permeability data, in their original order of depth, are divided into all possible combinations of two zones. Then, Equation 9, Equation 10 and Equation 11, are used to calculate for each of these possible two zone combinations. The zonation index calculated from equation 11 is the criterion used to indicate the best division. R , which ranges between 0 and 1, indicates how closely the division corresponds to homogeneous zones. The closer R is to 1, the more homogeneous are the zones. The larger R value denotes the best division into two zones, is retained for comparison with other indices. Any negative values of R are replaced by zero in order to conform to the definition of R .
- (b) The permeability data of the best two-zone combination are divided into all possible three-zone combinations. The zonation index R is again calculated for determining the best three-zone division.
- (c) The permeability data of the three-zone combinations are divided into all possible four-zone combinations. Then the zonation index criterion is applied.

The division into additional zones continues until the difference between two successive indices, R , is negligible. In this study the difference is negligible if $R < 0.005$.

2. After all the wells in the reservoir have been zoned, the zones between adjacent wells are correlated for determining which strata are likely to be continuous, i.e., connected. The correlation is based on a statistical comparison of the difference of means of two zones in adjoining wells with the difference that could be expected from variation of measurements within zones. Zones are considered to correlate or connected if the

difference in mean permeability of two zones in adjoining wells is less than or equal to that expected from variations of measurements within zones.

2.4 Related Studies:

Estimation of permeability in uncored but logged wells is a generic problem common to all reservoirs. Any field-scale reservoir characterization study inevitably requires knowledge of petrophysical properties at drilled wells for its starting point. Therefore, scientifically sound and geologically compatible procedures must be sought to allow for reliable calculation of permeability distributions in wells. In this section we discuss some of the previous work done in estimating the permeability and reservoir zonation techniques.

Molnar⁸ developed a methodology by integrating actual well log responses (Gamma Ray, Deep Induction and Bulk Density) and geological interpretations to subdivide the formation into several zones which led to development of a reliable correlation between bulk density and permeability. Granny Creek field in West Virginia has been selected as the study area. In their study core data was available from 21 wells in the Granny Creek field and seven of these wells were selected for analysis. Well log data was collected from these wells, and the core data was adjusted to log depth by correlation of log and core porosity. Zones were then identified and delineated based on current stratigraphic, depositional environment and lithofacies interpretations. This approach enabled the development of a statistically viable permeability correlation which was verifiable by concurring analyses and permeability measurements of additional wells.

Lacentre et al⁹ developed a methodology to estimate permeabilities in uncored wells based on available well logs and core data. The analysis includes a first step consisting of the interpretation of the petrophysics and a characterization in lithofacies, electrofacies and hydraulic flow units. The method takes advantage of modern mathematical tools that have proved to be effective in other fields of science and engineering, including neural networks, cluster analysis, principal component analysis. The method assumes that the Carman-Kozeny equation holds for the reservoir rocks, which is a fairly reasonable assumption, and that the well logs available contain intrinsic information on tortuosity, sand size distribution, cementing characteristics, etc., which ultimately determine the flow performance of the rock. In this method the permeability is related to the porosity and the flow zone indicator (FZI). The method was tested using available core and log data in a sandstone formation in Chihuido de la Salina, Neuquen Basin, Argentina.

Lawal and Onyekonwu¹⁰ developed a novel approach to delineate flow units. The approach is general, robust and relies on commonly available data. The method is predicted on the following three principles:

1. Parameterization
2. Cluster analysis
3. Discriminant analysis

In this method a unique parameter, the Flow Unit Delineator (FUD) has been developed for identifying flow units. This method is applied on a field in the Niger Delta Basin, Nigeria and the results show that it is more superior than other existing methods.

Mustafa¹¹ developed a model to estimate permeability. In this study a linear relationship is developed between density from the log and core permeability data from six wells. Statistical Zonation technique is used to identify flow units in wells with core permeability data and the accuracy of the methodology was verified by comparing the original flow units with the predicted flow units in the wells with core data. Jacksonburg-Stringtown field was selected and data from six core wells is used for this study.

Gunter et al¹² and others developed graphical tools that would determine the number of flow units within the reservoir. This method requires continuous core porosity, permeability and saturation data for the entire horizon. The researchers considered the flow unit to be a stratigraphically continuous layer of similar reservoir characteristics that maintains the geologic frame work of rock types. The rock type is considered to be reservoir units having distinct porosity-permeability relationships and unique water saturations for the position in the reservoir above the free water level. A given rock type would be deposited under similar processes and experienced similar diagenetic processes resulting a unique permeability-porosity relationship.

Thomas¹³ developed a methodology for reservoir characterization via flow unit identification which is applicable to any field having limited data. This methodology utilizes limited core permeability data from a few wells as a key to predicting flow units within a field when only log based data is available. Various techniques for flow unit identification including graphic approaches using the permeability-porosity relationship within a given flow unit and ANN (Kohonen) analysis are utilized as a part of the

methodology developed. The core data and flow units are utilized in neural network models designed to predict flow units and permeability field-wide using only electric well logs. Jacksonburg-Stringtown field was selected for this study.

Alla¹⁴ used simulation of waterflood performance to verify the characterization of flow-units in a heterogeneous reservoir. BOAST98 software was used for simulation of waterflood performance. Two adjacent five spot patterns in the Stringtown field in West Virginia were selected to be evaluated in this study. The predicted permeability along with the porosity from Artificial Neural Network (A.N.N) was used for primary characterization purpose and identification of flow-units in the two five spots patterns. Two alternate simulation models were developed. The simulation model was developed using the available data and those predicted using A.N.N. to verify that the flow-units model was an accurate description of the field. One model had two layers representing two flow units whereas the second model had three layers representing three flow units. The output from the simulation runs was compared with 10 years of actual production history of both the wells. A close history matching was obtained with about 15-25% of total volume water injection rates into the individual patterns from each of the 6 wells. Though both models were effective in predicting the output, the results with the second model which was developed for three flow units yielded better results.

CHAPTER-3

OBJECTIVE & METHODOLOGY

Although there are many techniques to characterize a reservoir, statistical technique is very important to identify and describe naturally occurring flow units in a reservoir and to correlate these flow units from well to well. The technique is particularly useful in describing a reservoir where cross flow between adjacent strata is important in determining reservoir behavior. Permeabilities play an important role to determine flow units in a reservoir. Due to the sheer volume, it is always necessary to group data and to use an average value to represent a number of measurements. Flow unit computation is derived from the permeability data. But permeability at all depth level, at all wells is not available and not practical to measure. Hence, this study aims to economically predict permeability from available density and limited core data. The predicted permeability is used to correlate flow units from well to well. Core permeability data plays an important role in characterizing a reservoir. But core data is usually not available for all the wells in the reservoir.

The main objectives of this study are to

- Perform statistical calculation to identify flow units from original core permeability data.
- Develop a model to predict permeability from density from the log and limited core permeability data.
- Identify flow units from the predicted permeability.
- Validate the model by comparing predicted flow units against original flow units.

- Develop a model to predict the permeability for limited uncored wells from density from the Log and limited core permeability data and identify flow units from predicted permeability.
- Perform statistical correlation between the flow units throughout the reservoir for both cored and uncored wells.

3.1 Description of the field¹⁵:

Granny Creek field is located in Clay and Roane counties, West Virginia, (Figure 3.1), and produces from the Lower Mississippian Big Injun sandstone, a prolific oil producer (nearly 60 fields) in West Virginia. Shallow oil reservoirs, like Granny Creek field, typically have been developed as if they were homogeneous. The field is located approximately 25 miles northeast of Charleston, West Virginia. The field was developed over a period of nearly 30 years beginning in 1924. Production has continued throughout most of the field until the present day. The field is roughly five miles long, has a maximum width of a little over two miles, and has a total productive area of about 3,000 acres. The well spacing commonly is 400 feet. The crude oil in Granny Creek field is a paraffin base, Pennsylvania Grade oil. It has a viscosity of 3.14 cp and a liquid gravity of 45.4°API. Total oil production is estimated to be between 6,500,000 and 6,750,000 barrels. During the 1970 s and early 1980 s, the water flooding operations in Granny Creek Field were initiated. The water flooding has been moderately successful. However, the areal and vertical sweep efficiencies have been poor due to the heterogeneous nature of the formation. An enhanced recovery CO₂ pilot project was conducted beginning

in 1976. Because of the heterogeneous nature of the reservoir, less than 4 percent of the injected CO₂ entered the pattern. Even this small amount was responsible for the production of over 4000 barrels of oil from within the pattern. This recovery was considered very good under the circumstances. A minitest CO₂ project was conducted in a part of the same pattern several years later with a small amount of oil recovery.

Figure 3.1 Location of Granny Creek Field in West Virginia

The data pertaining to the structure, stratigraphy, and petrography of the Granny Creek Big Injun sandstone reservoir is presented. The field is located structurally on the northwest flank of a syncline and is surrounded to the west, south, and southeast by fields producing from the same interval. The western extent of the field might be limited by a gas cap, and the northeast extent is limited by erosional thinning of the reservoir.

The Big Injun has been divided into an upper-coarse grained fluvial channel facies and a lower fine-grained distributary mouth bar facies. The diagenetic features in the upper and

lower parts of the fluvial channel facies are sufficiently different to warrant the further subdivision into A and B members. Generally the porosity in the upper A member is preserved because of chlorite grain coating, while quartz cementation in the lower B member has resulted in reduced porosity and permeability. Erosion has removed the A and B members eastward across the field.

The lower fine-grained distributary mouth bar facies, or C member, laterally consists of prograding tongues, numbered from oldest to youngest, as C1, C2, C3. The C member and its tongues represent a facies deposited in a deltaic river-mouth bar environment, and the subfacies are the proximal and distal portions of the bar which are further differentiated by domination of fluvial or marine processes. The completion records indicate zone C2 within the Big Injun formation as the major producer.

3.2 Data Collection¹⁶:

The data for this field has been provided by “West Virginia Geological Survey” used in prior projects & presented in other publications. Data is analyzed from cores and logs.

3.2.1 Core Data:

A limited number of wells had cores from Big Injun formation. The results of core analysis were available from 20 wells. The core analysis included porosity, oil and water saturations, horizontal and vertical permeabilities, and horizontal permeability at 90°. Although core analysis is available for 20 wells we choose only 10 wells (Figure 3.2) for

this study because of incompleteness in their data and their irrelevancies due to very low permeabilities.

Figure 3.2: Location of Ten Cored Wells in the Granny Creek Field

3.2.2 Log Data:

Logs run in the field include Gamma Ray (GR), Density (RHOB), Neutron Porosity and Induction Logs. However, only Density Log was used in this study because of their availability in the studied wells and the readings were recorded for every quarter feet. In this study, average density log data for every single foot depth has been taken to identify

the flow units by statistical method. From the available data we have chosen 15 wells (Figure 3.3) for this study from different locations of the field to predict the permeability, allowing for extension of flow units to these wells using statistical methods.

Figure 3.3: Location of Fifteen Wells without cores in the Granny Creek Field

3.3 Development of Permeability prediction model:

Obtaining permeability data through core analysis is expensive and time consuming. Although permeability plays an important role to characterize a reservoir, it is not available for all wells in a reservoir. In this study a model is developed to predict permeability at definite depths of wells from the known permeability of other wells. The objective of this research is to develop a model which is computationally simple, easy and less expensive.

In lieu of a definite mathematical relationship of permeability with any measured parameter of the wells, this research aimed at developing a statistical model. Preliminary observation suggested that a linear regression model might be a simple but accurate enough solution. A regression model is a formal means of expressing the two essential ingredients of a statistical relation:

1. A tendency of the dependent variable Y to vary with the independent variable or variables in a systematic fashion.
2. A scattering of observations around the curve of statistical relationship. These two characteristics are embodied in a regression model by postulating that:
 1. In the population of observations associated with the sampled process, there is a probability distribution of Y for each level of X.
 2. The means of these probability distributions vary in some systematic fashion with X.

3.3.1 Selection of Independent Variable:

Since data must be reduced to manageable proportions whenever we contrast models, only a limited number of independent or predictor variables can - or should - be included in a regression model for any situation of interest. A central problem therefore is that of choosing, for a regression model, a set of independent variables which is “good” in some sense for the purposes of analysis. A major consideration in making this choice is the extent to which a chosen variable contributes to reducing the remaining variation in Y after allowance is made for the contributions of other independent variables that have tentatively been included in the regression model. Other considerations include the importance of the variable as a casual agent in the process under analysis; the degree to which observations on variable can be obtained more accurately, or quickly, or economically than on competing variables; and the degree to which the variable can be preset by management. Predictor variable must be readily available and have sufficient causal effect on the predicted variable. In the literature review it has been observed that bulk density has an impact on reservoir permeability. Density log, gamma ray and some other data are also readily available. Hence, density log data is used as an independent variable in this model.

3.3.2 Functional Form of Model¹⁷:

Density is the most influential factor in determining permeability, but exact form of the relationship is unknown. To get the relationship between density and permeability we tried the following approach

- 1) Permeability versus density linear plot.

2) Direct approach: changes the model according to the nature of the relationship. For example, a quadratic or polynomial relationship may be tried.

3) Transformation approach: uses transformation to linearize.

Among the above three approaches a better linear relationship or correlation is found between density (D) and logarithmic transformation of permeability (K). The transformation used is $Y = \text{Log } K$. The plot of transformed values for measured data from well 15-1184 is presented in Figure 3.4. The plots of transformed values for the remaining core wells are shown in Appendix B.

The general form of the proposed prediction model is:

$$\text{Log } K = \alpha_0 + \alpha_1 D$$

Figure 3.4: Plot of Density versus Log K data taken from well 15-1184.

3.3.3 Assumptions:

- 1) In model development, it is assumed that the average of the measured permeability over a small distance is a reliable representation of the permeability at the mid-point of that measured distance.
- 2) The model is only valid for the reservoir from which development data set is obtained.
- 3) The model assumes that reasonable number of permeability data is available for adjacent wells at various depths.

3.3.4 Validation of Model:

The density from the log and core permeability data from ten wells were available. The density from the log for each of those ten wells was measured for every $\frac{1}{4}$ feet interval. Table 3.1 below shows the number of permeability data available for ten wells used in this study.

Number of Well data set	Well name	Depth interval, ft	Original No. of permeability data
1	15-733	2085-2097	9
2	15-1059	2028-2031.5	4
3	15-1107	2140-2157.1	7
4	15-1108	2064.5-2093	19
5	15-1109	1915.1-1927.5	6
6	15-1128	2027.2-2038.6	9
7	15-1130	1885.3-1903.9	15
8	15-1132	1993.5-2012.1	14
9	15-1184	1872.5-1897.5	25
10	15-1309	1961-1982	16

Table 3.1: Number of available core permeability data for ten cored wells

For this data set ten different tests were performed to validate the proposed linear transformation model. In each test, the above data set is divided into two different sets. Set1 consists of measured data from 9 wells, which is used to develop the regression model parameters. The regression equation is then used to predict and compare the permeability of the remaining well, which is in set 2. Table 3.2 below shows the description of ten different tests:

Test Number	Development Data Set	Validation Data Set
Test-1	2,3,4,5,6,7,8,9,10	1
Test-2	1,3,4,5,6,7,8,9,10	2
Test-3	1,2,4,5,6,7,8,9,10	3
Test-4	1,2,3,5,6,7,8,9,10	4
Test-5	1,2,3,4,6,7,8,9,10	5
Test-6	1,2,3,4,5,7,8,9,10	6
Test-7	1,2,3,4,5,6,8,9,10	7
Test-8	1,2,3,4,5,6,7,9,10	8
Test-9	1,2,3,4,5,6,7,8,10	9
Test-10	1,2,3,4,5,6,7,8,9	10

Table 3.2: Lists of ten different tests performed.

The predicted permeability values are compared against the measured permeability values and the results are shown in Appendix B.

3.3.5 Development of Permeability prediction model for uncored wells:

The density from the log and core permeability data available from ten core wells are used to develop a linear relationship or correlation between density (D) and logarithmic transformation of permeability (K). The transformation used is $Y = \text{Log } K$. The plot of

transformed values for measured data is presented in Figure 3.5 and the proposed prediction model for uncored wells is:

$$\text{Log K} = 15.649 - 6.3461 * D$$

Figure 3.5: Plot of Density versus Log K data taken from ten core wells.

3.4 Determination of Flow Units for individual wells:

The different mathematical and statistical techniques discussed in Chapter 2 can be used in the determination of flow units. In this study, the statistical zonation technique is used to determine the flow units from measured core permeability and predicted permeability.

In the computational procedure, core permeability data measured at different depths from Set 1 (well 15-733) has been selected randomly. Table C-1 in Appendix C illustrates the calculation for well 15-733. Initially the cumulative sum of the permeability is calculated

followed by the difference of the grand sum minus cumulative sum of K. Later Equations 9, 10 and 11 are used to calculate B, W, R and the results are tabulated. In this calculation, the negative R values are replaced by zero according to the definition of R. For example, the first B, W, R values in Table C-1 are calculated as follows.

Variance between zones:

$$B = \frac{1}{L-1} \sum_{i=1}^L m_i (\bar{k}_i - \bar{k}_{..})^2$$

$$= 16.965$$

Variance within zones:

$$W = \frac{1}{N-L} \sum_{i=1}^L m_i \sum_{j=1}^{m_i} (\bar{k}_{ij} - \bar{k}_{..})^2$$

$$= 0.928$$

The zonation index:

$$R = \frac{B-W}{B}$$

$$= 0.9453$$

Similarly the other values in the Table C-1 are calculated. The best division into two zones occurs after the permeability of 2.7mD at 2087.5 ft since this depth yields the maximum zonation index R. The asterisk marks are the point of division into two zones in Table C-1.

In order to determine if more zones exist, the calculations of B, W, R are repeated and the results are tabulated in Table C-2. The second point of division (the first was after the permeability value of 2.7 mD in Table C-1) occurs after the permeability value of 4.9 mD at 2085.5 ft in Group 1 data series and divides our total data into three zones. It has been observed that the maximum zonation index R (0.8603), in Group 2 data is less than the initial zonation index R (0.9463) used for dividing into two zones. Hence Group 2 data cannot be divided further into any more zones. Therefore, we can conclude that there are three different flow units in the well 15-733.

Similarly all the other wells were divided into flow units using measured core permeability and predicted permeability data and the final results are tabulated in Appendix C and D respectively. Same approach is used for the predicted permeability values from selected wells without cores to identify the flow units and the results are tabulated in Appendix E.

3.5 Correlation of flow units between wells:

After all zones are determined for each well used in this study, the second portion of the calculation is undertaken. This part correlates the zones throughout the reservoir to aid the engineer in determining the continuity of the strata. The correlation is based on a statistical comparison of the difference of means of two zones in adjoining wells with the difference that could be expected from variation of measurements within zones. If the difference of means is less than or equal to that expected from individual data variation,

the zones represented by the means are considered to correlate and, by inference, be continuous.

The mathematical statement is given by Equation 12:

$$(\bar{k}_h - \bar{k}_i) \sqrt{\frac{1}{2} \left(\frac{1}{n_h} + \frac{1}{n_i} \right)} SZ_{(v,p)} \quad (12)$$

Harter¹⁸ provides a table of Z- values.

If the left side of Equation 12 is larger than the right side, the zones represented by the two means are considered, on the basis of statistics, to be different. However, if the left side of Equation 12 is smaller than the right side, the zones correlate and considered to be continuous.

From the Tables in Appendix C, D and E, Equation 12 has been applied to the zone data for flow unit correlation between wells. The calculations for flow unit correlation between wells are presented in Appendix F for original flow units from ten cored wells and for predicted flow units from fifteen wells without cores. The following steps are suggested as a conventional and efficient manner to apply Equation 12:

- (1) Rank well-zone means in the order of decreasing magnitude of permeability, as shown in Table F.1.
- (2) Calculate variance with Equation 10 using all permeability data in the entire reservoir.
- (3) Calculate the standard deviation from Step 2.
- (4) Select the z-values for a 99% probability level ($Z_{v,p}$)

(5). Multiply the z-values in Step 4 by the standard deviation in Step 3,

$$\text{e.g., } F_p = S z_{v,p}$$

(6). Test the significant differences among well - flow unit means. First the largest mean is compared with each of the smaller means.

Finally the means can be divided into separate groups, which are not significantly different.

CHAPTER 4

RESULTS AND DISCUSSIONS

In this study a predictive model is developed for flow unit correlation based on well log and core data. The model is validated with the data available from Granny Creek Field, WV. The density from the log and core permeability data was available for ten core wells. The model is validated several times by dividing the available data into two sets: Set I: development data set containing data from nine wells and Set II: the validation data set which consist the data from the remaining well. The resulting ten tests are described in Table 3.2. Apart from the model discussed above a second model is developed utilizing the density from the log and core permeability data of all ten core wells to predict the permeability for wells without cores, allowing for extension of flow units to these wells. In this chapter, the predicted flow strata for wells without cores and flow strata from measured data are presented and analyzed.

4.1 Discussion of results from Test 1:

In the first test case, data set is divided into the following two sets:

Set I: Development data set: Includes wells 15-1059, 15-1107, 15-1108, 15-1109, 15-1128, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set: Consists of well 15-733.

Based on the measured data for the wells in Set I, the linear model for permeability prediction is developed. The linear relationship of logarithm of permeability and density from the log is developed as discussed in Section 3.3.2. The model is given by:

$$\text{Log } K = 14.332 - 5.7905X,$$

Where X is the density from the log of the well.

Based on this model, the permeability for the well 15-733 in Set II is predicted. Figure 4.1.1 compares the predicted permeability and measured core permeability at different depths of the well. Using this predicted permeability and the method described in Section 3.4, flow units for the well 15-733 are computed. The predicted flow units are compared with the flow units obtained by using measured permeability based on data Set II. Figure 4.1.1 shows that the predicted permeability and measured permeability values at different depths of the well are pretty much in agreement.

Figure 4.1.2 shows that the well has three statistically significant flow zones based on measured permeabilities whereas two statistically significant flow zones were identified with the predicted permeability values. The incompleteness in the actual data and their irrelevancies due to very low permeability values tend to reduce the correlation between core permeability and density from the log. The flow unit computations based on the few predicted data have forced the well into two statistically significant flow zones. Figure 4.1.2 shows that the predicted mean permeability values are different from the actual mean values, but it is clear that the high permeability zone intervals are identical. In general, the model closely predicts the high permeability and low permeability zones for the well 15-733.

Figure 4.1.1 Comparison of Measured and Predicted permeability values for well 15-733.

Figure 4.1.2 Comparison of flow units for well 15-733 based on mean permeability from measured and predicted values.

4.2 Discussion of results from Test 2:

In the second test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1107, 15-1108, 15-1109, 15-1128, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1059.

The permeability prediction model is given by:

$$\text{Log } K = 16.378 - 6.6515X,$$

Where X is the density from the log of the well.

Figure 4.2.1 shows the comparison of the predicted permeability and measured core permeability values at different depths for well 15-1059. Using this predicted permeability and the technique described in Section 3.4 flow units for the well 15-1059 are computed. The predicted flow units are compared with the flow units obtained by using measured permeability (data Set II) in Figure 4.2.2.

Figure 4.2.1 shows that the predicted permeability and measured permeability at different depths of the well are in good agreement. Figure 4.2.2 shows that the original flow unit and the predicted flow unit has divided the well into single flow zone. The flow unit computations based on the few predicted data have forced the well into single statistically significant flow zones.

Figure 4.2.1 Comparison of Measured and Predicted permeability values for well 15-1059.

Figure 4.2.2 Comparison of flow units for well 15-1059 based on mean permeability from measured and predicted values.

4.3 Discussion of results from Test 3:

The third set consisted of the data divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1108, 15-1109, 15-1128, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from the well 15-1107.

The permeability prediction model is given by:

$$\text{Log } K = 15.382 - 6.2278X,$$

Where X is the density from the log of the well.

Figure 4.3.1 compares the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability in data Set II as shown in Figure 4.3.2.

Figure 4.3.1 shows that the predicted permeability and measured permeability values at different depths of the well are pretty much in agreement. However, the predicted values don't show the variation of permeability as observed in core measurements. Figure 4.3.2 shows that the predicted model divides the well into four flow zones whereas the original data shows that the well has three zones. The incompleteness in the actual data and the difficulty in predicting very low permeability values tend to reduce the correlation between core permeability and density from the log. Though the Figure 4.3.2 shows that the predicted mean permeability values deviate from the measured mean values, it is clear that the high permeability and low permeability zones have similar average permeability values. Thus the model closely predicts the high permeability and low permeability zones for the well 15-1107.

Figure 4.3.1 Comparison of Measured and Predicted permeability values for well 15-1107.

Figure 4.3.2 Comparison of flow units for well 15-1107 based on mean permeability from measured and predicted values.

4.4 Discussion of results from Test 4:

In the fourth test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1109, 15-1128, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1108.

The permeability prediction model is given by:

$$\text{Log } K = 16.925 - 6.8787X,$$

Where X is the density from the log of the well.

The comparison of the predicted permeability and measured core permeability at different depths of the well are shown in Figure 4.4.1. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II are shown in Figure 4.4.2. Figure 4.4.1 shows that the predicted permeability and measured permeability at different depths of the well are in good agreement except at some depths.

The Figure 4.4.2 shows that the predicted model divides the well into four flow zones same as the original permeability data. Though the predicted mean permeability values show some deviation from the original mean permeability values but it is clear that the high permeability and low permeability zone yield similar results. Again, the model was successful in predicting the high permeability and low permeability zones for the well 15-1108.

Figure 4.4.1 Comparison of Measured and Predicted permeability values for well 15-1108.

Figure 4.4.2 Comparison of flow units for well 15-1108 based on mean permeability from measured and predicted values.

4.5 Discussion of results from Test 5:

In the fifth test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1128, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1109.

The permeability prediction model is given by:

$$\text{Log } K = 14.934 - 6.0382X,$$

where X is the density from the log of the well.

Figure 4.5.1 presents the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.5.2. Figure 4.5.1 shows that the predicted permeabilities are slightly higher than the measured permeabilities at initial depths of the well but, at deeper intervals of the well they are in good agreement.

The Figure 4.5.2 shows that the predicted model divides the well into two zones same as the prediction with the original permeability data. Though the predicted mean permeability values are off from the original mean permeability values, it is clear that the high permeability and low permeability zone predictions were the same. It can be noted that, for all practical purposes the zonal divisions at correct depth is much more significant than the absolute permeability values at certain depth. Hence, the model predicts the high permeability and low permeability zones within an acceptable accuracy for the well 15-1109.

Figure 4.5.1 Comparison of Measured and Predicted permeability values for well 15-1109.

Figure 4.5.2 Comparison of flow units for well 15-1109 based on mean permeability from measured and predicted values.

4.6 Discussion of results from Test 6:

In the sixth test data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1109, 15-1130, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1128.

The permeability prediction model is given by:

$$\text{Log } K = 15.767 - 6.3953X,$$

where X is the density from the log of the well.

Figure 4.6.1 shows the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.6.2.

Figure 4.6.1 shows that the predicted permeability and measured permeability at different depths of the well are in good agreement. Figure 4.6.2 shows that the predicted model divides the well into two zones whereas the original data shows that the well has three zones. The incompleteness in the actual data and the accuracy involved in the calculation of very low permeability values tend to reduce the correlation between core permeability and density from the log. The flow unit computations based on the few predicted data have forced the well into two statistically significant flow zones. Though the predicted mean permeability values deviate from the original mean permeability values it is clear that the high permeability and low permeability zone predictions are similar. In general, the zonal divisions at correct depth is much more significant than the absolute

permeability values at certain depth and the model for well 15-1128 correctly predicts the high permeability and low permeability zones.

Figure 4.6.1 Comparison of Measured and Predicted permeability values for well 15-1128.

Figure 4.6.2 Comparison of flow units for well 15-1128 based on mean permeability from measured and predicted values.

4.7 Discussion of results from Test 7:

In the seventh test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1109, 15-1128, 15-1132, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1130.

The permeability prediction model is given by:

$$\text{Log } K = 15.546 - 6.3232X,$$

where X is the density from the log of the well.

Figure 4.7.1 shows the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.7.2.

Figure 4.7.1 shows that the predicted permeabilities are low compared to the measured permeabilities at different depths of the well. However, the Figure 4.7.2 shows that the predicted model divides the well into two zones same as the original permeability data. Though the predicted mean permeability values deviate largely from the original mean permeability values, it is clear that the high permeability and low permeability zones are almost unaltered. It can be noted that, for all practical purposes the zonal divisions at correct depth is much more significant than the absolute permeability values at certain depth. Hence, it can be concluded that the model serves the purpose by predicting the high permeability and low permeability zones for the well 15-1130.

Figure 4.7.1 Comparison of Measured and Predicted permeability values for well 15-1130.

Figure 4.7.2 Comparison of flow units for well 15-1130 based on mean permeability from measured and predicted values.

4.8 Discussion of results from Test 8:

In the eighth test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1109, 15-1128, 15-1130, 15-1184, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1132.

The permeability prediction model is given by:

$$\text{Log } K = 15.309 - 6.2094X,$$

where X is the density from the log of the well.

Figure 4.8.1 shows the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.8.2. Figure 4.8.1 shows that the predicted permeabilities are low at initial depths compared to measured permeabilities but at deeper zones of the well they are pretty much in agreement.

The Figure 4.8.2 shows that the predicted model divides the well into two zones same as the original permeability data. Though the predicted mean permeability values deviate from the original mean permeability values, it is clear that the high permeability and low permeability zone predictions are similar. In general, the zonal divisions at correct depth is much more significant than the absolute permeability values at certain depth and the model for well 15-1132 correctly predicts the high permeability and low permeability zones.

Figure 4.8.1 Comparison of Measured and Predicted permeability values for well 15-1132.

Figure 4.8.2 Comparison of flow units for well 15-1132 based on mean permeability from measured and predicted values.

4.9 Discussion of results from Test 9:

In the ninth test, data set is divided into following two data sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1109, 15-1128, 15-1130, 15-1132, 15-1309.

Set II: Validation Data Set with permeability values from well 15-1184.

The permeability prediction model is given by:

$$\text{Log } K = 16.136 - 6.5309X,$$

where X is the density from the log of the well.

Figure 4.9.1 shows the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.9.2. Figure 4.9.1 shows that the predicted permeabilities are slightly higher compared to measured permeabilities but at some depths of the well they are in good agreement.

The Figure 4.9.2 shows that the predicted model divides the well into two zones whereas the original data shows that the well has three zones. Though the predicted mean permeability values deviate from the original mean permeability values, it is clear that the high permeability and low permeability zone predictions are similar. In general, the zonal divisions at correct depth is much more significant than the absolute permeability values at certain depth and the model for well 15-1184 correctly predicts the high permeability and low permeability zones.

Figure 4.9.1 Comparison of Measured and Predicted permeability values for well 15-1184.

Figure 4.9.2 Comparison of flow units for well 15-1184 based on mean permeability from measured and predicted values.

4.10 Discussion of results from Test 10:

In the tenth test, data set is divided into following two sets:

Set I: Development data set with permeability values from wells 15-733, 15-1059, 15-1107, 15-1108, 15-1109, 15-1128, 15-1130, 15-1132, 15-1184.

Set II: Validation Data Set with permeability values from well 15-1309.

The permeability prediction model is given by:

$$\text{Log } K = 16.888 - 6.4548X,$$

where X is the density from the log of the well.

Figure 4.10.1 shows the comparison of the predicted permeability and measured core permeability at different depths of the well. The predicted flow units are compared with the flow units obtained by using measured permeability from data Set II and the results are shown in Figure 4.10.2. Figure 4.10.1 shows that the predicted permeabilities are lower compared to measured permeabilities at initial depths but at deeper zones of the well they are in good agreement.

The Figure 4.10.2 shows that the predicted model divides the well into three zones whereas the original data shows that the well has two zones. Though the predicted mean permeability values deviate from the original mean permeability values, it is clear that the high permeability and low permeability zone predictions are similar. The zonal divisions at correct depth appears to be more significant than the absolute permeability values at certain depth. Thus, it can be concluded that the model for well 15-1309 correctly predicts the high permeability and low permeability zones.

4.11 Correlation of flow units using measured permeability data from cored wells:

The ultimate objective is to predict the flow unit strata of the reservoir through unknown wells given that the flow strata for the adjacent wells are known. After the flow units are identified in the entire ten cored wells, additional wells are randomly selected from the ten cored wells to identify the flow unit strata among wells. Using the method described in Section 3.5 the correlation of flow units among wells are determined as shown in Section F2 of Appendix F. The first set of wells selected for this correlation are 15-1309, 15-1184, 15-1107 and 15-1108 and they show a trend in the north-east direction. All the depths shown in the figures in section 4.11 and section 4.12 are sub sea level depths in feet.

Figure 4.11.1 shows the correlation of flow units from measured permeability data for wells 15-1309, 15-1184, 15-1107 and 15-1108. As shown in Figure 4.11.1 the well 15-1309 has two flow units, the wells 15-1184 and 15-1107 have three flow units and the well 15-1108 has four flow units. From the flow unit correlation shown in Section F2 of Appendix F, the first zone of well 15-1309 correlates with second zone of well 15-1184, the second zone of the well 15-1184 correlates with the second zone of well 15-1107 and the second zone of the well 15-1107 correlates with second, third and fourth zones of the well 15-1108. Figure 4.11.1 clearly tells us that the high permeability zone is a continuous stratum over these wells.

Figure 4.11.1 Correlation of flow units from measured permeability data for wells 15-1309, 15-1184, 15-1107 and 15-1108.

Figure 4.11.2 shows the correlation of flow units from measured permeability data for wells 15-1109, 15-1132 and 15-1108. As shown in Figure 4.11.2 the well 15-1109 has two flow units, the well 15-1132 has three flow units and the well 15-1108 has four flow units. From the flow unit correlation presented in Section F2 of Appendix F, zones of well 15-1109 does not correlate with any zone of well 15-1132, where as the first zone of the well 15-1132 correlates with second, third and fourth zones of the well 15-1108.

Since, the mean of measured permeability values in both zones of the well 15-1109 are very small compared to the mean of measured permeability values in both zones of well 15-1132. Figure 4.11.2 shows that the high permeability zone is a continuous stratum over the wells 15-1132 and 15-1108.

Figure 4.11.2 Correlation of flow units from measured permeability data for wells 15-1109, 15-1132 and 15-1108.

Figure 4.11.3 shows the correlation of flow units from measured permeability data for wells 15-1128, 15-1130 and 15-1108. As shown in Figure 4.11.3 the well 15-1128 has three flow units, the well 15-1130 has two flow units and the well 15-1108 has four flow

units. From the flow unit correlation shown in Section F2 of Appendix F, the first zone of well 15-1128 correlates with the first zone of well 15-1130 and the first zone of the well 15-1130 correlates with second, third and fourth zones of the well 15-1108, respectively. Figure 4.11.3 shows the continuity of the high permeability zone over the wells 15-1128, 15-1130 and 15-1108.

Figure 4.11.3 Correlation of flow units from measured permeability data for wells 15-1128, 15-1130 and 15-1108.

Figure 4.11.4 shows the correlation of flow units from measured permeability data for wells 15-733, 15-1128, 15-1132 and 15-1107. As shown in Figure 4.11.4 the wells 15-733 and 15-1128 have three flow units, the well 15-1132 has two flow units and the well

15-1107 has three flow units. From the flow unit correlation presented in Section F2 of Appendix F, the first zone of well 15-733 correlates with first zone of well 15-1128, the first zone of the well 15-1128 correlates with the first zone of well 15-1132 and the first zone of the well 15-1132 correlates with second zone of the well 15-1107. As shown in Figure 4.11.4 all highly permeable first zones are related in this cross-section.

Figure 4.11.4 Correlation of flow units from measured permeability data for wells 15-733, 15-1128, 15-1132 and 15-1107.

4.12 Correlation of flow units from predicted permeability data for uncored wells:

The permeability prediction model developed with the data from ten cored wells is discussed in Section 3.3.5. The flow units in those wells are identified and the procedure and results are presented in Appendix E. Using the technique described in Section 3.5 the flow units for these uncored wells are correlated with the procedure and calculation given in Section F3 of Appendix F.

Figure 4.12.1 shows the correlation of flow units from predicted permeability data for wells 15-1110, 15-874 and 15-868. As shown in Figure 4.12.1, the wells 15-1110, 15-874 and 15-868 have two flow units. Based on the flow unit correlation given in Section F3 of Appendix F, the first zone of well 15-1110 correlates with the first zone of well 15-874 and the first zone of the well 15-874 further correlates with first zone of the well 15-868. As a result, a continuous high permeability zone exists between the wells 15-1110, 15-874 and 15-868 as shown in Figure 4.12.1.

Figure 4.12.1 Correlation of flow units from predicted permeability data for wells 15-1110, 15-874 and 15-868.

Figure 4.12.2 shows the correlation of flow units from predicted permeability data for wells 15-1621, 15-1639 and 15-1783. As shown in Figure 4.12.2, the wells 15-1621, 15-1639 and 15-1783 have three flow units. From the flow unit correlation presented in Section F3 of Appendix F the second zone of well 15-1621 correlates with the second zone of well 15-1639 and the second zone of the well 15-1639 further correlates with second zone of the well 15-1783. Therefore, the high permeability zones between the wells 15-1110, 15-874 and 15-868 correlate as a single unit as shown in Figure 4.12.2.

Figure 4.12.2 Correlation of flow units from predicted permeability data for wells 15-1621, 15-1639 and 15-1783.

Figure 4.12.3 shows the correlation of flow units from predicted permeability data for wells 15-2150, 15-2215 and 15-1639. As shown in Figure 4.12.3, the wells 15-2150 and 15-2215 have two flow units each and the well 15-1639 has three flow units. From the flow unit correlation given in Section F3 of Appendix F, the second zone of well 15-2150 correlates with the second zone of well 15-2215 and the second zone of the well 15-2215 further correlates with second zone of the well 15-1639. The high permeability zone is shown in Figure 4.12.3 for the wells 15-2150, 15-2215 and 15-1639.

Figure 4.12.3 Correlation of flow units from predicted permeability data for wells 15-2150, 15-2215 and 15-1639.

Figure 4.12.4 shows the correlation of flow units from predicted permeability data for wells 15-1176 and 15-1225. As shown in Figure 4.12.4 the well 15-1176 has two flow units and the well 15-1225 has three flow units. Based on the flow unit correlation

calculations presented in Section F3 of Appendix F, the first zone of well 15-1176 correlates with the second zone of well 15-1225. The correlated permeability zones are shown in Figure 4.12.4 for wells 15-1176 and 15-1225.

Figure 4.12.4 Correlation of flow units from predicted permeability data for wells 15-1176 and 15-1225.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This research provides a solution to dividing a reservoir into flow zones with respect to their physical properties. The following conclusions are made based on the results obtained from the study:

1. A model for predicting the flow units has been developed using density from the log and limited core permeability from ten wells.
2. A linear relationship between density from logs (D) and logarithm of core permeability (K) has been established to predict the permeability in wells without core data.
3. Statistical Zonation Technique has shown how basic statistical tools can be used as a means to uniquely sub-dividing reservoir into volumes that are more homogeneous.
4. A model was developed to extend the application of statistical zonation technique to the wells without core data by utilizing the predicted permeability values from log data.
5. The accuracy of the methodology was verified by comparing the original flow units with the predicted flow units in the wells with core data.
6. Zone predictions with predicted permeability values deviate from zone predictions with measured permeability values where the magnitudes of permeability values are smaller than 1mD.

Recommendations:

1. The correlation between density and permeability is not very strong based on the R^2 values. A better correlation can give accurate predicted permeability.
2. A multiple regression technique using density from the log and core permeability may give a better permeability prediction tool.
3. Further research to determine the minimum number of wells with core data will be beneficial in the application of this method to a new field.

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APPENDIX A

Distribution of Density from the Log and Core Permeability in cored wells.

Figure A. 1 Density from the Log and Core Permeability distribution for well 15-733.

Figure A. 2 Density from the Log and Core Permeability distribution for well 15-1059.

Figure A. 3 Density from the Log and Core Permeability distribution for well 15-1107.

Figure A. 4 Density from the Log and Core Permeability distribution for well 15-1108.

Figure A. 5 Density from the Log and Core Permeability distribution for well 15-1109.

Figure A. 6 Density from the Log and Core Permeability distribution for well 15-1128.

Figure A. 7 Density from the Log and Core Permeability distribution for well 15-1130.

Figure A. 8 Density from the Log and Core Permeability distribution for well 15-1132.

Figure A. 9 Density from the Log and Core Permeability distribution for well 15-1184.

Figure A. 10 Density from the Log and Core Permeability distribution for well 15-1309.

APPENDIX B

Permeability predictions in cored wells using transformation approach.

Figure B.1 Linear correlation between density from well log and logarithm of core permeability from Test 1 (except 15-733).

Figure B. 2 Permeability prediction for well 15-733.

Figure B.3 Linear correlation between density from well log and logarithm of core permeability from Test 2 (except 15-1059).

Figure B. 4 Permeability prediction for well 15-1059.

Figure B.5 Linear correlation between density from well log and logarithm of core permeability from Test 3 (except 15-1107).

Figure B. 6 Permeability prediction for well 15-1107.

Figure B.7 Linear correlation between density from well log and logarithm of core permeability from Test 4 (except 15-1108).

Figure B. 8 Permeability prediction for well 15-1108.

Figure B.9 Linear correlation between density from well log and logarithm of core permeability from Test 5 (except 15-1109).

Figure B. 10 Permeability prediction for well 15-1109.

Figure B.11 Linear correlation between density from well log and logarithm of core permeability from Test 6 (except 15-1128).

Figure B. 12 Permeability prediction for well 15-1128.

Figure B.13 Linear correlation between density from well log and logarithm of core permeability from Test 7 (except 15-1130).

Figure B. 14 Permeability prediction for well 15-1130.

Figure B.15 Linear correlation between density from well log and logarithm of core permeability from Test 8 (except 15-1132).

Figure B. 16 Permeability prediction for well 15-1132.

Figure B.17 Linear correlation between density from well log and logarithm of core permeability from Test 9 (except 15-1184).

Figure B. 18 Permeability prediction for well 15-1184.

Figure B.19 Linear correlation between density from well log and logarithm of core permeability from Test 10 (except 15-1309).

Figure B. 20 Permeability prediction for well 15-1309.

APPENDIX C.

**Determination of Flow Unit by Statistical Zonation Technique using
core permeability.**

Table C. 1 Flow Unit calculation for well 15-733 into two zones.

Sample No.per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2085.5	4.9	4.9	4.25	16.965	0.928	0.9453
2	2086.5	1.2	6.1	3.05	10.631	1.833	0.8276
3	2087.5	2.7	8.8	0.35	16.531	0.990	0.9463
**	**	**	**	**	**	**	**
4	2088.5	0.1	8.9	0.25	10.513	1.850	0.8241
5	2089.5	0.05	8.95	0.2	6.728	2.390	0.6447
6	2090.5	0.05	9	0.15	4.205	2.751	0.3458
7	2091.5	0.05	9.05	0.1	2.403	3.008	0
8	2092.3	0.05	9.1	0.05	1.051	3.201	0
9	2096.5	0.05	9.15	0	--	--	--

Table C. 2 Flow Unit calculation for well 15-733 into three zones.

Sample No.per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2085.5	4.9	4.9	3.9	11.166	0.188	0.9832
**	**	**	**	**	**	**	**
2	2086.5	1.2	6.1	2.7	8.306	1.141	0.8626
3	2087.5	2.7	8.8	0	--	--	--
<u>Group 2</u>							
1	2088.5	0.1	0.1	0.25	8.267	1.154	0.8603
2	2089.5	0.05	0.15	0.2	8.266	1.155	0.8603
3	2090.5	0.05	0.2	0.15	8.266	1.155	0.8603
4	2091.5	0.05	0.25	0.1	8.266	1.155	0.8603
5	2092.3	0.05	0.3	0.05	8.266	1.155	0.8603
6	2096.5	0.05	0.35	0	--	--	--

Table C. 3 Flow Unit calculation for well 15-1059 into two zones.

Sample No.per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2028.5	0.3	0.3	0.65	0.005	0.021	0
2	2029.5	0.3	0.6	0.35	0.016	0.016	0
3	2030.5	0.05	0.65	0.3	0.005	0.021	0
4	2031.25	0.3	0.95	0	--	--	--

Table C. 4 Flow Unit calculation for well 15-1107 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2140.55	0.05	0.05	52.22	20.226	20.014	0.0105
2	2141.9	0.05	0.1	52.17	44.496	17.587	0.6048
3	2144.8	1.6	1.7	50.57	57.431	16.294	0.7163
4	2146.2	2.9	4.6	47.67	61.664	15.870	0.7426
5	2147.65	1.6	6.2	46.07	83.215	13.715	0.8352
**	**	**	**	**	**	**	**
6	2148.9	11	17.2	35.07	26.611	19.376	0.2719
7	2150.2	12.2	29.4	22.87	0.408	21.996	0
8	2151.55	4.5	33.9	18.37	0.336	22.003	0
9	2152.8	11	44.9	7.37	14.427	20.594	0
10	2153.9	4.2	49.1	3.17	18.426	20.194	0
11	2155.1	2.2	51.3	0.97	12.506	20.786	0
12	2156.45	0.97	52.27	0	--	--	--

Table C. 5 Flow Unit calculation for well 15-1107 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2140.55	0.05	0.05	6.15	42.493	15.042	0.6460
2	2141.9	0.05	0.1	6.1	43.968	14.715	0.6653
3	2144.8	1.6	1.7	4.5	43.308	14.861	0.6568
4	2146.2	2.9	4.6	1.6	41.689	15.221	0.6349
5	2147.65	1.6	6.2	0	--	--	--
<u>Group 2</u>							
1	2148.9	11	11	35.07	52.996	12.708	0.7602
2	2150.2	12.2	23.2	22.87	76.868	7.403	0.9037
3	2151.55	4.5	27.7	18.37	60.068	11.137	0.8146
4	2152.8	11	38.7	7.37	86.268	5.314	0.9384
**	**	**	**	**	**	**	**
5	2153.9	4.2	42.9	3.17	76.558	7.472	0.9024
6	2155.1	2.2	45.1	0.97	59.976	11.157	0.8140
7	2156.45	0.97	46.07	0	--	--	--

Table C. 6 Flow Unit calculation for well 15-1107 into four zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2140.55	0.05	0.05	6.15	42.493	15.042	0.6460
2	2141.9	0.05	0.1	6.1	43.968	14.715	0.6653
3	2144.8	1.6	1.7	4.5	43.308	14.861	0.6568
4	2146.2	2.9	4.6	1.6	41.689	15.221	0.6349
5	2147.65	1.6	6.2	0	--	--	--
<u>Group 2</u>							
1	2148.9	11	11	35.07	83.595	13.294	0.8410
2	2150.2	12.2	23.2	22.87	89.836	10.174	0.8868
3	2151.55	4.5	27.7	18.37	83.595	13.294	0.8410
4	2152.8	11	38.7	7.37	--	--	--
<u>Group 3</u>							
1	2153.9	4.2	42.9	3.17	84.704	5.662	0.9332
2	2155.1	2.2	45.1	0.97	84.082	5.800	0.9310
3	2156.45	0.97	46.07	0	--	--	--

Table C. 7 Flow Unit calculation for well 15-1108 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2065.3	0.8	0.8	135.4	42.810	29.465	0.3117
2	2066.9	3.9	4.7	131.5	51.897	28.931	0.4425
3	2069.8	0.2	4.9	131.3	109.145	25.563	0.7658
4	2071.2	3.3	8.2	128	132.738	24.175	0.8179
**	**	**	**	**	**	**	**
5	2072.6	9	17.2	119	94.329	26.435	0.7198
6	2073.75	13	30.2	106	39.975	29.632	0.2587
7	2075.05	12	42.2	94	14.400	31.137	0
8	2076.55	7.5	49.7	86.5	12.627	31.241	0
9	2077.9	18	67.7	68.5	2.140	31.858	0
10	2079	16	83.7	52.5	30.480	30.191	0.0095
11	2080.1	2.8	86.5	49.7	12.627	31.241	0
12	2081.5	3.4	89.9	46.3	3.403	31.783	0
13	2083.1	11	100.9	35.3	14.482	31.132	0
14	2084.55	15	115.9	20.3	65.565	28.127	0.5710
15	2087.2	3.6	119.5	16.7	45.400	29.313	0.3543
16	2088.55	2	121.5	14.7	18.332	30.905	0
17	2089.85	2.5	124	12.2	2.552	31.833	0
18	2091	6.1	130.1	6.1	1.205	31.913	0
19	2092.25	6.1	136.2	0	--	--	--

Table C. 8 Flow Unit calculation for well 15-1108 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group 1							
1	2065.3	0.8	0.8	7.4	67.411	25.556	0.6209
2	2066.9	3.9	4.7	3.5	66.549	25.664	0.6144
3	2069.8	0.2	4.9	3.3	67.411	25.556	0.6209
4	2071.2	3.3	8.2	0	--	--	--
Group 2							
1	2072.6	9	9	119	66.486	25.672	0.6139
2	2073.75	13	22	106	73.389	24.809	0.6620
3	2075.05	12	34	94	81.069	23.849	0.7058
4	2076.55	7.5	41.5	86.5	75.619	24.530	0.6756
5	2077.9	18	59.5	68.5	108.873	20.373	0.8129
6	2079	16	75.5	52.5	148.381	15.435	0.8960
**	**	**	**	**	**	**	**
7	2080.1	2.8	78.3	49.7	112.537	19.915	0.8230
8	2081.5	3.4	81.7	46.3	90.537	22.665	0.7497
9	2083.1	11	92.7	35.3	101.481	21.297	0.7901
10	2084.55	15	107.7	20.3	141.409	16.306	0.8847
11	2087.2	3.6	111.3	16.7	118.174	19.211	0.8374
12	2088.55	2	113.3	14.7	91.121	22.592	0.7521
13	2089.85	2.5	115.8	12.2	73.201	24.832	0.6608
14	2091	6.1	121.9	6.1	69.541	25.290	0.6363
15	2092.25	6.1	128	0	--	--	--

Table C. 9 Flow Unit calculation for well 15-1108 into four zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group 1							
1	2065.3	0.8	0.8	7.4	67.411	25.556	0.6209
2	2066.9	3.9	4.7	3.5	66.549	25.664	0.6144
3	2069.8	0.2	4.9	3.3	67.411	25.556	0.6209
4	2071.2	3.3	8.2	0	--	--	--
Group 2							
1	2072.6	9	9	66.5	147.681	15.523	0.8949
2	2073.75	13	22	53.5	143.737	16.015	0.8886
3	2075.05	12	34	41.5	144.664	15.900	0.8901
4	2076.55	7.5	41.5	34	169.237	12.828	0.9242
**	**	**	**	**	**	**	**
5	2077.9	18	59.5	16	146.981	15.610	0.8938
6	2079	16	75.5	0	--	--	--
Group 3							
1	2080.1	2.8	2.8	49.7	145.152	15.839	0.8909
2	2081.5	3.4	6.2	46.3	149.582	15.285	0.8978
3	2083.1	11	17.2	35.3	139.999	16.483	0.8823
4	2084.55	15	32.2	20.3	157.665	14.274	0.9095
5	2087.2	3.6	35.8	16.7	149.877	15.248	0.8983
6	2088.55	2	37.8	14.7	141.936	16.241	0.8856
7	2089.85	2.5	40.3	12.2	140.068	16.474	0.8824
8	2091	6.1	46.4	6.1	140.016	16.481	0.8823
9	2092.25	6.1	52.5	0	--	--	--

Table C. 10 Flow Unit calculation for well 15-1109 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1915.9	0.26	0.26	0.64	0.015	0.012	0.1446
2	1917.45	0.2	0.46	0.44	0.019	0.011	0.4141
3	1920.4	0.29	0.75	0.15	0.060	0.001	0.9825
**	**	**	**	**	**	**	**
4	1924.65	0.05	0.8	0.1	0.030	0.009	0.7150
5	1925.85	0.05	0.85	0.05	0.012	0.013	0
6	1926.95	0.05	0.9	0	--	--	--

Table C. 11 Flow Unit calculation for well 15-1109 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1915.9	0.26	0.26	0.49	0.030	0.001	0.9551
2	1917.45	0.2	0.46	0.29	0.031	0.001	0.9808
3	1920.4	0.29	0.75	0	--	--	--
<u>Group 2</u>							
1	1924.65	0.05	0.8	0.1	0.030	0.001	0.9533
2	1925.85	0.05	0.85	0.05	0.030	0.001	0.9533
3	1926.95	0.05	0.9	0	--	--	--

Table C. 12 Flow Unit calculation for well 15-1128 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2027.85	3.1	3.1	6.94	4.430	0.444	0.8998
2	2029.25	0.8	3.9	6.14	1.790	0.821	0.5414
3	2030.55	2.2	6.1	3.94	3.790	0.535	0.8588
4	2031.65	1.5	7.6	2.44	4.431	0.444	0.9050
**	**	**	**	**	**	**	**
5	2032.85	0.38	7.98	2.06	2.597	0.706	0.7282
6	2034.2	0.89	8.87	1.17	2.369	0.738	0.6883
7	2035.6	0.33	9.2	0.84	1.244	0.899	0.2772
8	2036.9	0.42	9.62	0.42	0.544	0.999	0
9	2038.05	0.42	10.04	0	--	--	--

Table C. 13 Flow Unit calculation for well 15-1128 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2027.85	3.1	3.1	4.5	3.175	0.198	0.9377
**	**	**	**	**	**	**	**
2	2029.25	0.8	3.9	3.7	2.220	0.516	0.7675
3	2030.55	2.2	6.1	1.5	2.322	0.482	0.7923
4	2031.65	1.5	7.6	0	--	--	--
<u>Group 2</u>							
1	2032.85	0.38	0.38	2.06	2.223	0.515	0.7681
2	2034.2	0.89	1.27	1.17	2.251	0.506	0.7753
3	2035.6	0.33	1.6	0.84	2.223	0.515	0.7682
4	2036.9	0.42	2.02	0.42	2.218	0.517	0.7669
5	2038.05	0.42	2.44	0	--	--	--

Table C. 14 Flow Unit calculation for well 15-1130 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1886	4.8	4.8	73.92	0.22	7.07	0
2	1887.25	11	15.8	62.92	16.23	5.83	0.6405
3	1888.3	2.5	18.3	60.42	2.72	6.87	0
4	1889.35	2.4	20.7	58.02	0.03	7.08	0
5	1890.6	3.7	24.4	54.32	1.02	7.00	0
6	1892.05	6	30.4	48.32	0.33	7.06	0
7	1893.35	6	36.4	42.32	0.03	7.08	0
8	1894.5	7.4	43.8	34.92	0.88	7.01	0
9	1895.75	5.7	49.5	29.22	1.43	6.97	0
10	1897.1	8.2	57.7	21.02	8.17	6.45	0.2105
11	1898.4	8.2	65.9	12.82	22.77	5.33	0.7658
**	**	**	**	**	**	**	**
12	1899.5	3.3	69.2	9.52	16.14	5.84	0.6381
13	1900.85	3.8	73	5.72	13.16	6.07	0.5387
14	1902.1	3.8	76.8	1.92	11.87	6.17	0.4801
15	1903.35	1.4	78.2	0	--	--	--

Table C. 15 Flow Unit calculation for well 15-1130 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1886	4.8	4.8	61.1	10.530	5.918	0.4380
2	1887.25	11	15.8	50.1	14.205	5.306	0.6265
3	1888.3	2.5	18.3	47.6	9.775	6.044	0.3817
4	1889.35	2.4	20.7	45.2	11.843	5.699	0.5187
5	1890.6	3.7	24.4	41.5	15.407	5.105	0.6686
6	1892.05	6	30.4	35.5	15.388	5.108	0.6680
7	1893.35	6	36.4	29.5	15.771	5.045	0.6801
8	1894.5	7.4	43.8	22.1	13.654	5.397	0.6047
9	1895.75	5.7	49.5	16.4	15.715	5.054	0.6784
10	1897.1	8.2	57.7	8.2	12.434	5.601	0.5496
11	1898.4	8.2	65.9	0	--	--	--
<u>Group 2</u>							
1	1899.5	3.3	3.3	9	9.784	6.042	0.3824
2	1900.85	3.8	7.1	5.2	10.202	5.973	0.4145
3	1902.1	3.8	10.9	1.4	11.621	5.736	0.5064
4	1903.35	1.4	12.3	0	--	--	--

Table C. 16 Flow Unit calculation for well 15-1132 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1994.2	10	10	44.55	40.119	7.494	0.8132
2	1995.6	3.8	13.8	40.75	21.050	9.083	0.5685
3	1997.05	5.4	19.2	35.35	23.932	8.843	0.6305
4	1998.4	5.4	24.6	29.95	28.440	8.467	0.7023
5	1999.8	7.5	32.1	22.45	49.532	6.709	0.8645
6	2001.3	8.2	40.3	14.25	83.514	3.877	0.9536
7	2002.6	5.4	45.7	8.85	96.994	2.754	0.9716
**	**	**	**	**	**	**	**
8	2004	2.8	48.5	6.05	87.581	3.538	0.9596
9	2005.4	2.2	50.7	3.85	76.024	4.502	0.9408
10	2006.55	1.5	52.2	2.35	61.314	5.727	0.9066
11	2007.7	1.1	53.3	1.25	46.233	6.984	0.8489
12	2009.05	1	54.3	0.25	33.189	8.071	0.7568
13	2010.4	0.2	54.5	0.05	15.933	9.509	0.4032
14	2011.55	0.05	54.55	0	--	--	--

Table C. 17 Flow Unit calculation for well 15-1132 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1994.2	10	10	35.7	55.527	1.726	0.9689
2	1995.6	3.8	13.8	31.9	48.690	2.969	0.9390
3	1997.05	5.4	19.2	26.5	48.541	2.996	0.9383
4	1998.4	5.4	24.6	21.1	49.166	2.883	0.9414
5	1999.8	7.5	32.1	13.6	48.600	2.986	0.9386
6	2001.3	8.2	40.3	5.4	49.240	2.869	0.9417
7	2002.6	5.4	45.7	0	--	--	--
<u>Group 2</u>							
1	2004	2.8	2.8	6.05	49.873	2.754	0.9448
2	2005.4	2.2	5	3.85	50.635	2.616	0.9483
3	2006.55	1.5	6.5	2.35	50.635	2.616	0.9483
4	2007.7	1.1	7.6	1.25	50.383	2.661	0.9472
5	2009.05	1	8.6	0.25	50.314	2.674	0.9469
6	2010.4	0.2	8.8	0.05	49.357	2.848	0.9423
7	2011.55	0.05	8.85	0	--	--	--

Table C. 18 Flow Unit calculation for well 15-1184 into two zones.

Sample No. per Group	Core Depth, Ft	Cum.Sum of K, K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R	
1	1873	2.1	2.1	88.1	2.369	4.055	0
2	1874	1.7	3.8	86.4	6.342	3.882	0.3878
3	1875	3.9	7.7	82.5	3.697	3.997	0
4	1876	2.3	10	80.2	5.846	3.904	0.3322
5	1877	4.8	14.8	75.4	2.624	4.044	0
6	1878	5.6	20.4	69.8	0.342	4.143	0
7	1879	3.8	24.2	66	0.221	4.149	0
8	1880	8	32.2	58	2.046	4.069	0
9	1881	7.2	39.4	50.8	8.333	3.796	0.5445
10	1882	5.9	45.3	44.9	14.168	3.542	0.7500
11	1883	4	49.3	40.9	14.998	3.506	0.7662
12	1884	6.3	55.6	34.6	24.261	3.103	0.8721
13	1885	5.2	60.8	29.4	30.945	2.813	0.9091
14	1886	3.2	64	26.2	29.533	2.874	0.9027
15	1887	3.4	67.4	22.8	29.393	2.880	0.9020
16	1888	4.8	72.2	18	36.361	2.577	0.9291
**	**	**	**	**	**	**	**
17	1889	2.8	75	15.2	34.321	2.666	0.9223
18	1890	3.3	78.3	11.9	35.393	2.619	0.9260
19	1891	3	81.3	8.9	35.638	2.609	0.9268
20	1892	2.8	84.1	6.1	35.641	2.609	0.9268
21	1893	2.1	86.2	4	32.389	2.750	0.9151
22	1894	2.2	88.4	1.8	30.846	2.817	0.9087
23	1895	0.6	89	1.2	19.670	3.303	0.8321
24	1896	1	90	0.2	12.098	3.632	0.6998
25	1897	0.2	90.2	0	--	--	--

Table C. 19 Flow Unit calculation for well 15-1184 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
<u>Group 1</u>							
1	1873	2.1	2.1	70.1	21.285	2.412	0.8867
2	1874	1.7	3.8	68.4	25.981	1.985	0.9236
3	1875	3.9	7.7	64.5	25.170	2.059	0.9182
4	1876	2.3	10	62.2	28.981	1.713	0.9409
**	**	**	**	**	**	**	**
5	1877	4.8	14.8	57.4	26.945	1.898	0.9296
6	1878	5.6	20.4	51.8	24.121	2.154	0.9107
7	1879	3.8	24.2	48	25.111	2.064	0.9178
8	1880	8	32.2	40	20.082	2.522	0.8744
9	1881	7.2	39.4	32.8	18.367	2.677	0.8542
10	1882	5.9	45.3	26.9	18.185	2.694	0.8518
11	1883	4	49.3	22.9	18.197	2.693	0.8520
12	1884	6.3	55.6	16.6	18.531	2.663	0.8563
13	1885	5.2	60.8	11.4	19.118	2.609	0.8635
14	1886	3.2	64	8.2	18.375	2.677	0.8543
15	1887	3.4	67.4	4.8	18.225	2.690	0.8524
16	1888	4.8	72.2	0	--	--	--
<u>Group 2</u>							
1	1889	2.8	2.8	15.2	18.540	2.662	0.8564
2	1890	3.3	6.1	11.9	19.598	2.566	0.8691
3	1891	3	9.1	8.9	20.583	2.476	0.8797
4	1892	2.8	11.9	6.1	21.603	2.383	0.8897
5	1893	2.1	14	4	21.780	2.367	0.8913
6	1894	2.2	16.2	1.8	22.590	2.294	0.8985
7	1895	0.6	16.8	1.2	20.700	2.465	0.8809
8	1896	1	17.8	0.2	20.003	2.529	0.8736
9	1897	0.2	18	0	--	--	--

Table C. 20 Flow Unit calculation for well 15-1184 into four zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
<u>Group 1</u>							
1	1873	2.1	2.1	7.9	11.088	3.339	0.6988
2	1874	1.7	3.8	6.2	11.701	3.283	0.7194
3	1875	3.9	7.7	2.3	11.008	3.347	0.6960
4	1876	2.3	10	0	--	--	--
<u>Group 2</u>							
1	1877	4.8	4.8	57.4	11.061	3.342	0.6979
2	1878	5.6	10.4	51.8	10.981	3.349	0.6950
3	1879	3.8	14.2	48	11.386	3.312	0.7091
4	1880	8	22.2	40	11.384	3.312	0.7090
5	1881	7.2	29.4	32.8	13.061	3.160	0.7581
6	1882	5.9	35.3	26.9	13.921	3.082	0.7786
7	1883	4	39.3	22.9	12.541	3.207	0.7443
8	1884	6.3	45.6	16.6	14.184	3.058	0.7844
9	1885	5.2	50.8	11.4	14.808	3.001	0.7973
10	1886	3.2	54	8.2	12.389	3.221	0.7400
11	1887	3.4	57.4	4.8	11.061	3.342	0.6979
12	1888	4.8	62.2	0	--	--	--
<u>Group 3</u>							
1	1889	2.8	2.8	15.2	18.540	2.662	0.8564
2	1890	3.3	6.1	11.9	19.598	2.566	0.8691
3	1891	3	9.1	8.9	20.583	2.476	0.8797
4	1892	2.8	11.9	6.1	21.603	2.383	0.8897
5	1893	2.1	14	4	21.780	2.367	0.8913
6	1894	2.2	16.2	1.8	22.590	2.294	0.8985
7	1895	0.6	16.8	1.2	20.700	2.465	0.8809
8	1896	1	17.8	0.2	20.003	2.529	0.8736
9	1897	0.2	18	0	--	--	--

Table C. 21 Flow Unit calculation for well 15-1309 into two zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1961.5	9.6	9.6	79.8	17.174	7.357	0.5716
2	1962.5	7.5	17.1	72.3	20.060	7.151	0.6435
3	1963.5	3.8	20.9	68.5	7.023	8.082	0.0000
4	1964.5	9.1	30	59.4	19.508	7.190	0.6314
5	1965.5	9.1	39.1	50.3	36.248	5.995	0.8346
6	1966.5	5.9	45	44.4	35.114	6.076	0.8270
7	1967.5	5.5	50.5	38.9	32.933	6.231	0.8108
8	1968.5	5.9	56.4	33	34.223	6.139	0.8206
9	1969.5	4.2	60.6	28.8	27.009	6.655	0.7536
10	1970.5	7	67.6	21.8	36.660	5.965	0.8373
11	1971.5	7.1	74.7	14.7	50.976	4.943	0.9030
12	1972.5	5.7	80.4	9	59.408	4.340	0.9269
13	1973.5	5.5	85.9	3.5	72.162	3.429	0.9525
**	**	**	**	**	**	**	**
14	1974.5	3.4	89.3	0.1	70.089	3.577	0.9490
15	1980.5	0.05	89.35	0.05	32.708	6.247	0.8090
16	1981.5	0.05	89.4	0	--	--	--

Table C. 22 Flow Unit calculation for well 15-1309 into three zones.

Sample No. per Group	Core Depth, Ft	K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1961.5	9.6	9.6	76.3	40.931	2.947	0.9280
2	1962.5	7.5	17.1	68.8	40.539	3.007	0.9258
3	1963.5	3.8	20.9	65	36.332	3.654	0.8994
4	1964.5	9.1	30	55.9	38.381	3.339	0.9130
5	1965.5	9.1	39.1	46.8	42.051	2.775	0.9340
6	1966.5	5.9	45	40.9	40.517	3.011	0.9257
7	1967.5	5.5	50.5	35.4	38.871	3.264	0.9160
8	1968.5	5.9	56.4	29.5	38.115	3.380	0.9113
9	1969.5	4.2	60.6	25.3	36.312	3.658	0.8993
10	1970.5	7	67.6	18.3	36.583	3.616	0.9012
11	1971.5	7.1	74.7	11.2	37.281	3.509	0.9059
12	1972.5	5.7	80.4	5.5	36.745	3.591	0.9023
13	1973.5	5.5	85.9	0	--	--	--
<u>Group 2</u>							
1	1974.5	3.4	3.4	0.1	39.822	3.118	0.9217
2	1980.5	0.05	3.45	0.05	37.016	3.549	0.9041
3	1981.5	0.05	3.5	0	--	--	--

Figure C. 1 Flow Unit identification in well 15-733.

Figure C. 2 Flow Unit identification in well 15-1059.

Figure C. 3 Flow Unit identification in well 15-1107.

Figure C. 4 Flow Unit identification in well 15-1108.

Figure C. 5 Flow Unit identification in well 15-1109.

Figure C. 6 Flow Unit identification in well 15-1128.

Figure C. 7 Flow Unit identification in well 15-1130.

Figure C. 8 Flow Unit identification in well 15-1132.

Figure C. 9 Flow Unit identification in well 15-1184.

Figure C. 10 Flow Unit identification in well 15-1309.

APPENDIX D.

**Determination of Flow Unit by Statistical Zonation Technique using
predicted permeability for cored wells.**

Table D. 1 Flow Unit calculation with Predicted K for well 15-733 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2085.5	3.48	3.48	5.18	7.118	0.495	0.9304
2	2086.5	2.18	5.65	3.00	8.953	0.233	0.9740
**	**	**	**	**	**	**	**
3	2087.5	1.15	6.80	1.85	7.672	0.416	0.9458
4	2088.5	0.65	7.45	1.21	5.836	0.678	0.8838
5	2089.5	0.42	7.86	0.79	4.201	0.912	0.7829
6	2090.5	0.19	8.05	0.60	2.606	1.140	0.5625
7	2091.5	0.13	8.18	0.47	1.357	1.318	0.0289
8	2092.3	0.29	8.47	0.18	0.680	1.415	0.0000
9	2096.5	0.18	8.65	0	--	--	--

Table D. 2 Flow Unit calculation with Predicted K for well 15-733 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2085.5	3.48	3.48	2.18	4.898	0.131	0.9732
2	2086.5	2.18	5.65	0	--	--	--
<u>Group 2</u>							
1	2087.5	1.15	1.15	1.85	4.777	0.172	0.9641
2	2088.5	0.65	1.79	1.21	4.783	0.170	0.9645
3	2089.5	0.42	2.21	0.79	4.725	0.189	0.9599
4	2090.5	0.19	2.40	0.60	4.613	0.227	0.9509
5	2091.5	0.13	2.53	0.47	4.529	0.255	0.9438
6	2092.3	0.29	2.81	0.18	4.511	0.260	0.9423
7	2096.5	0.18	3.00	0	--	--	--

Table D. 3 Flow Unit calculation with Predicted K for well 15-1059 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2028.5	0.16	0.16	0.26	0.004	0.003	0.1611
2	2029.5	0.11	0.27	0.14	0.004	0.003	0.3133
3	2030.5	0.02	0.29	0.12	0.001	0.005	0
4	2031.25	0.12	0.41	0.00	--	--	--

Table D. 4 Flow Unit calculation with Predicted K for well 15-1107 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2140.55	0.24	0.24	53.03	19.273	6.613	0.6569
2	2141.9	0.31	0.54	52.72	41.704	4.370	0.8952
**	**	**	**	**	**	**	**
3	2144.8	5.16	5.70	47.57	25.789	5.961	0.7688
4	2146.2	6.49	12.19	41.08	11.617	7.379	0.3648
5	2147.65	7.18	19.37	33.90	2.742	8.266	0
6	2148.9	7.71	27.08	26.19	0.066	8.534	0
7	2150.2	7.18	34.25	19.01	3.470	8.193	0
8	2151.55	6.22	40.47	12.80	9.223	7.618	0.1740
9	2152.8	5.08	45.55	7.71	13.965	7.144	0.4884
10	2153.9	4.60	50.15	3.11	19.944	6.546	0.6718
11	2155.1	1.59	51.74	1.52	9.278	7.613	0.1795
12	2156.45	1.52	53.27	0	--	--	--

Table D. 5 Flow Unit calculation with Predicted K for well 15-1107 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2140.55	0.24	0.24	0.31	20.853	4.855	0.7672
2	2141.9	0.31	0.54	0	--	--	--
<u>Group 2</u>							
1	2144.8	5.16	5.16	47.57	20.859	4.854	0.7673
2	2146.2	6.49	11.65	41.08	21.233	4.771	0.7753
3	2147.65	7.18	18.83	33.90	23.006	4.377	0.8097
4	2148.9	7.71	26.54	26.19	27.031	3.483	0.8712
5	2150.2	7.18	33.71	19.01	31.656	2.455	0.9225
6	2151.55	6.22	39.93	12.80	35.184	1.671	0.9525
7	2152.8	5.08	45.01	7.71	36.499	1.378	0.9622
8	2153.9	4.60	49.61	3.11	38.117	1.019	0.9733
**	**	**	**	**	**	**	**
9	2155.1	1.59	51.20	1.52	28.664	3.120	0.8912
10	2156.45	1.52	52.72	0	--	--	--

Table D. 6 Flow Unit calculation with Predicted K for well 15-1107 into four zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2140.55	0.24	0.24	0.31	20.853	4.855	0.7672
2	2141.9	0.31	0.54	0	--	--	--
<u>Group 2</u>							
1	2144.8	5.16	5.16	44.45	38.665	0.897	0.9768
2	2146.2	6.49	11.65	37.96	38.233	0.993	0.9740
3	2147.65	7.18	18.83	30.79	38.057	1.032	0.9729
4	2148.9	7.71	26.54	23.08	38.791	0.869	0.9776
5	2150.2	7.18	33.71	15.90	39.994	0.602	0.9850
6	2151.55	6.22	39.93	9.68	40.509	0.487	0.9880
**	**	**	**	**	**	**	**
7	2152.8	5.08	45.01	4.60	39.512	0.709	0.9821
8	2153.9	4.60	49.61	0	--	--	--
<u>Group 3</u>							
1	2155.1	1.59	1.59	1.52	38.045	1.035	0.9728
2	2156.45	1.52	3.11	0	--	--	--

Table D. 7 Flow Unit calculation with Predicted K for well 15-1108 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2065.3	3.03	3.03	105.23	7.488	12.892	0
2	2066.9	3.67	6.70	101.56	12.298	12.609	0
3	2069.8	7.03	13.73	94.53	4.469	13.070	0
4	2071.2	7.73	21.46	86.80	0.558	13.300	0
5	2072.6	9.65	31.11	77.15	1.870	13.223	0
6	2073.75	9.50	40.61	67.65	10.056	12.741	0
7	2075.05	10.78	51.40	56.87	29.966	11.570	0.6139
8	2076.55	9.50	60.90	47.37	50.613	10.356	0.7954
9	2077.9	6.92	67.81	40.45	57.693	9.939	0.8277
10	2079	6.81	74.62	33.64	65.713	9.467	0.8559
11	2080.1	8.24	82.86	25.40	87.934	8.160	0.9072
12	2081.5	7.26	90.12	18.15	106.888	7.045	0.9341
13	2083.1	7.73	97.85	10.42	137.638	5.236	0.9620
14	2084.55	6.60	104.44	3.82	165.191	3.616	0.9781
**	**	**	**	**	**	**	**
15	2087.2	1.29	105.73	2.53	129.997	5.686	0.9563
16	2088.55	0.61	106.34	1.92	91.158	7.971	0.9126
17	2089.85	1.21	107.55	0.71	63.833	9.578	0.8500
18	2091	0.57	108.13	0.13	32.682	11.410	0.6509
19	2092.25	0.13	108.26	0	--	--	--

Table D. 8 Flow Unit calculation with Predicted K for well 15-1108 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2065.3	3.03	3.03	101.41	93.141	2.523	0.9729
2	2066.9	3.67	6.70	97.74	102.281	1.381	0.9865
**	**	**	**	**	**	**	**
3	2069.8	7.03	13.73	90.71	98.454	1.859	0.9811
4	2071.2	7.73	21.46	82.98	94.874	2.307	0.9757
5	2072.6	9.65	31.11	73.33	88.548	3.098	0.9650
6	2073.75	9.50	40.61	63.83	85.104	3.528	0.9585
7	2075.05	10.78	51.40	53.05	82.693	3.830	0.9537
8	2076.55	9.50	60.90	43.55	82.810	3.815	0.9539
9	2077.9	6.92	67.81	36.63	82.666	3.833	0.9536
10	2079	6.81	74.62	29.82	82.595	3.842	0.9535
11	2080.1	8.24	82.86	21.58	82.730	3.825	0.9538
12	2081.5	7.26	90.12	14.33	82.698	3.829	0.9537
13	2083.1	7.73	97.85	6.60	82.996	3.792	0.9543
14	2084.55	6.60	104.44	0	--	--	--
<u>Group 2</u>							
1	2087.2	1.29	1.29	2.53	82.768	3.820	0.9538
2	2088.55	0.61	1.90	1.92	82.653	3.834	0.9536
3	2089.85	1.21	3.11	0.71	82.875	3.807	0.9541
4	2091	0.57	3.69	0.13	82.844	3.811	0.9540
5	2092.25	0.13	3.82	0	--	--	--

Table D. 9 Flow Unit calculation with Predicted K for well 15-1108 into four zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group 1							
1	2065.3	3.03	3.03	3.67	100.922	1.551	0.9846
2	2066.9	3.67	6.70	0	--	--	--
Group 2							
1	2069.8	7.03	7.03	90.71	101.500	1.479	0.9854
2	2071.2	7.73	14.76	82.98	101.524	1.476	0.9855
3	2072.6	9.65	24.41	73.33	100.821	1.563	0.9845
4	2073.75	9.50	33.91	63.83	101.153	1.522	0.9850
5	2075.05	10.78	44.69	53.05	103.520	1.226	0.9882
6	2076.55	9.50	54.19	43.55	105.541	0.973	0.9908
**	**	**	**	**	**	**	**
7	2077.9	6.92	61.11	36.63	103.696	1.204	0.9884
8	2079	6.81	67.92	29.82	102.250	1.385	0.9865
9	2080.1	8.24	76.15	21.58	102.628	1.338	0.9870
10	2081.5	7.26	83.41	14.33	101.976	1.419	0.9861
11	2083.1	7.73	91.14	6.60	102.127	1.400	0.9863
12	2084.55	6.60	97.74	0	--	--	--
Group 3							
1	2087.2	1.29	1.29	2.53	82.768	3.820	0.9538
2	2088.55	0.61	1.90	1.92	82.653	3.834	0.9536
3	2089.85	1.21	3.11	0.71	82.875	3.807	0.9541
4	2091	0.57	3.69	0.13	82.844	3.811	0.9540
5	2092.25	0.13	3.82	0	--	--	--

Table D. 10 Flow Unit calculation with Predicted K for well 15-1109 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1915.9	0.88	0.88	3.66	0.018	0.393	0
2	1917.45	1.62	2.50	2.04	0.730	0.215	0.7057
3	1920.4	1.07	3.56	0.97	1.123	0.117	0.8961
**	**	**	**	**	**	**	**
4	1924.65	0.65	4.21	0.32	1.059	0.133	0.8748
5	1925.85	0.24	4.45	0.08	0.544	0.261	0.5193
6	1926.95	0.08	4.53	0	--	--	--

Table D. 11 Flow Unit calculation with Predicted K for well 15-1109 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1915.9	0.88	0.88	2.69	0.634	0.107	0.8305
2	1917.45	1.62	2.50	1.07	0.573	0.148	0.7411
3	1920.4	1.07	3.56	0	--	--	--
<u>Group 2</u>							
1	1924.65	0.65	0.65	0.32	0.640	0.103	0.8385
2	1925.85	0.24	0.89	0.08	0.605	0.127	0.7907
3	1926.95	0.08	0.97	0	--	--	--

Table D. 12 Flow Unit calculation with Predicted K for well 15-1128 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2027.85	1.32	1.32	7.08	0.169	0.219	0
2	2029.25	1.58	2.90	5.51	0.683	0.146	0.7864
3	2030.55	1.32	4.22	4.19	1.006	0.100	0.9008
4	2031.65	1.09	5.31	3.09	1.117	0.084	0.9248
5	2032.85	0.96	6.27	2.14	1.148	0.080	0.9306
6	2034.2	0.89	7.15	1.25	1.202	0.072	0.9402
**	**	**	**	**	**	**	**
7	2035.6	0.72	7.88	0.53	1.151	0.079	0.9313
8	2036.9	0.37	8.25	0.16	0.677	0.147	0.7833
9	2038.05	0.16	8.41	0	--	--	--

Table D. 13 Flow Unit calculation with Predicted K for well 15-1128 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	2027.85	1.32	1.32	5.83	0.611	0.081	0.8682
2	2029.25	1.58	2.90	4.26	0.700	0.051	0.9274
3	2030.55	1.32	4.22	2.93	0.739	0.038	0.9407
4	2031.65	1.09	5.31	1.84	0.711	0.047	0.9337
5	2032.85	0.96	6.27	0.89	0.657	0.065	0.9006
6	2034.2	0.89	7.15	0	--	--	--
<u>Group 2</u>							
1	2035.6	0.72	0.72	0.53	0.671	0.061	0.9096
2	2036.9	0.37	1.09	0.16	0.651	0.067	0.8970
3	2038.05	0.16	1.25	0	--	--	--

Table D. 14 Flow Unit calculation with Predicted K for well 15-1130 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1886	1.88	1.88	25.50	0.003	0.204	0
2	1887.25	2.03	3.91	23.47	0.039	0.201	0
3	1888.3	2.35	6.27	21.12	0.259	0.184	0.2897
4	1889.35	2.18	8.44	18.94	0.443	0.170	0.6160
5	1890.6	2.16	10.60	16.79	0.648	0.154	0.7619
6	1892.05	1.97	12.57	14.81	0.726	0.148	0.7961
7	1893.35	1.97	14.54	12.84	0.835	0.140	0.8325
8	1894.5	2.16	16.70	10.68	1.176	0.114	0.9034
9	1895.75	2.03	18.73	8.65	1.472	0.091	0.9383
10	1897.1	1.97	20.71	6.68	1.800	0.066	0.9636
11	1898.4	1.84	22.55	4.84	2.075	0.044	0.9786
12	1899.5	1.65	24.20	3.18	2.197	0.035	0.9841
**	**	**	**	**	**	**	**
13	1900.85	1.25	25.45	1.93	1.701	0.073	0.9570
14	1902.1	1.11	26.56	0.83	1.070	0.122	0.8863
15	1903.35	0.83	27.38	0	--	--	--

Table D. 15 Flow Unit calculation with Predicted K for well 15-1130 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1886	1.88	1.88	22.32	1.109	0.036	0.9674
2	1887.25	2.03	3.91	20.29	1.103	0.037	0.9663
3	1888.3	2.35	6.27	17.94	1.109	0.036	0.9673
4	1889.35	2.18	8.44	15.76	1.125	0.034	0.9702
5	1890.6	2.16	10.60	13.61	1.144	0.030	0.9734
6	1892.05	1.97	12.57	11.63	1.135	0.032	0.9720
7	1893.35	1.97	14.54	9.66	1.130	0.033	0.9710
8	1894.5	2.16	16.70	7.50	1.158	0.028	0.9758
9	1895.75	2.03	18.73	5.47	1.173	0.025	0.9783
10	1897.1	1.97	20.71	3.50	1.185	0.024	0.9801
11	1898.4	1.84	22.55	1.65	1.170	0.026	0.9778
12	1899.5	1.65	24.20	0	--	--	--
<u>Group 2</u>							
1	1900.85	1.25	1.25	1.93	1.125	0.034	0.9701
2	1902.1	1.11	2.35	0.83	1.140	0.031	0.9727
3	1903.35	0.83	3.18	0	--	--	--

Table D. 16 Flow Unit calculation with Predicted K for well 15-1132 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1994.2	3.36	3.36	31.00	0.890	1.852	0.0000
2	1995.6	3.72	7.08	27.28	2.755	1.697	0.3839
3	1997.05	3.83	10.91	23.46	5.331	1.482	0.7220
4	1998.4	3.46	14.37	19.99	7.251	1.322	0.8177
5	1999.8	3.32	17.69	16.68	9.116	1.167	0.8720
6	2001.3	3.46	21.15	13.22	12.022	0.925	0.9231
7	2002.6	3.36	24.51	9.85	15.348	0.647	0.9578
8	2004	3.13	27.64	6.72	18.696	0.369	0.9803
9	2005.4	2.29	29.93	4.44	19.108	0.334	0.9825
**	**	**	**	**	**	**	**
10	2006.55	1.90	31.83	2.54	18.548	0.381	0.9795
11	2007.7	1.47	33.29	1.07	16.793	0.527	0.9686
12	2009.05	0.76	34.05	0.31	12.322	0.900	0.9270
13	2010.4	0.21	34.26	0.11	5.936	1.432	0.7588
14	2011.55	0.11	34.36	0	--	--	--

Table D. 17 Flow Unit calculation with Predicted K for well 15-1132 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1994.2	3.36	3.36	26.56	9.555	0.364	0.9619
2	1995.6	3.72	7.08	22.85	9.614	0.354	0.9632
3	1997.05	3.83	10.91	19.02	9.772	0.325	0.9667
4	1998.4	3.46	14.37	15.56	9.811	0.318	0.9676
5	1999.8	3.32	17.69	12.24	9.807	0.319	0.9675
6	2001.3	3.46	21.15	8.78	9.911	0.300	0.9698
7	2002.6	3.36	24.51	5.42	10.043	0.276	0.9726
8	2004	3.13	27.64	2.29	10.162	0.254	0.9750
9	2005.4	2.29	29.93	0	--	--	--
<u>Group 2</u>							
1	2006.55	1.90	1.90	2.54	10.192	0.249	0.9756
2	2007.7	1.47	3.36	1.07	10.607	0.173	0.9837
3	2009.05	0.76	4.12	0.31	10.444	0.203	0.9806
4	2010.4	0.21	4.33	0.11	9.935	0.295	0.9703
5	2011.55	0.11	4.44	0	--	--	--

Table D. 18 Flow Unit calculation with Predicted K for well 15-1184 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
1	1873	1.93	1.93	121.90	9.491	3.188	0.6641
2	1874	4.77	6.71	117.13	5.568	3.359	0.3967
3	1875	5.38	12.09	111.75	2.912	3.474	0
4	1876	4.63	16.72	107.12	2.853	3.477	0
5	1877	5.07	21.78	102.05	2.224	3.504	0
6	1878	6.07	27.85	95.98	0.764	3.568	0
7	1879	6.54	34.40	89.44	0.015	3.600	0
8	1880	7.38	41.78	82.06	0.850	3.564	0
9	1881	7.72	49.50	74.34	4.199	3.419	0.1859
10	1882	6.45	55.95	67.89	6.849	3.303	0.5177
11	1883	7.61	63.55	60.29	13.334	3.021	0.7734
12	1884	7.27	70.82	53.02	20.753	2.699	0.8700
13	1885	6.74	77.56	46.27	27.795	2.393	0.9139
14	1886	6.64	84.21	39.63	35.843	2.043	0.9430
**	**	**	**	**	**	**	**
15	1887	4.43	88.63	35.20	34.230	2.113	0.9383
16	1888	4.10	92.74	31.10	31.559	2.229	0.9294
17	1889	4.10	96.84	26.99	29.342	2.325	0.9207
18	1890	4.49	101.34	22.50	29.402	2.323	0.9210
19	1891	4.99	106.33	17.51	32.701	2.179	0.9334
20	1892	4.36	110.69	13.15	33.741	2.134	0.9367
21	1893	3.87	114.55	9.28	32.995	2.167	0.9343
22	1894	3.75	118.30	5.53	32.947	2.169	0.9342
23	1895	2.61	120.92	2.92	26.531	2.448	0.9077
24	1896	1.99	122.91	0.93	16.897	2.866	0.8304
25	1897	0.93	123.84	0	--	--	--

Table D. 19 Flow Unit calculation with Predicted K for well 15-1184 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1873	1.93	1.93	82.27	26.884	1.321	0.9509
2	1874	4.77	6.71	77.50	26.187	1.384	0.9471
3	1875	5.38	12.09	72.12	25.448	1.451	0.9430
4	1876	4.63	16.72	67.49	27.354	1.278	0.9433
5	1877	5.07	21.78	62.42	28.611	1.164	0.9473
6	1878	6.07	27.85	56.35	27.811	1.237	0.9455
7	1879	6.54	34.40	49.81	26.405	1.364	0.9483
8	1880	7.38	41.78	42.43	23.784	1.603	0.9326
9	1881	7.72	49.50	34.71	21.262	1.832	0.9138
10	1882	6.45	55.95	28.26	21.013	1.855	0.9117
11	1883	7.61	63.55	20.66	19.369	2.004	0.8965
12	1884	7.27	70.82	13.39	18.458	2.087	0.8869
13	1885	6.74	77.56	6.64	18.134	2.116	0.8833
14	1886	6.64	84.21	0	--	--	--
<u>Group 2</u>							
1	1887	4.43	4.43	35.20	18.294	2.102	0.8851
2	1888	4.10	8.53	31.10	18.458	2.087	0.8869
3	1889	4.10	12.64	26.99	18.687	2.066	0.8894
4	1890	4.49	17.13	22.50	19.372	2.004	0.8966
5	1891	4.99	22.12	17.51	21.013	1.855	0.9117
6	1892	4.36	26.48	13.15	22.257	1.741	0.9218
7	1893	3.87	30.34	9.28	23.082	1.666	0.9278
8	1894	3.75	34.09	5.53	24.295	1.556	0.9359
9	1895	2.61	36.71	2.92	23.533	1.625	0.9309
10	1896	1.99	38.70	0.93	21.862	1.777	0.9187
11	1897	0.93	39.63	0	--	--	--

Table D. 20 Flow Unit calculation with Predicted K for well 15-1309 into two zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1961.5	0.21	0.21	54.74	11.114	4.442	0.6003
2	1962.5	0.74	0.95	54.00	20.033	3.805	0.8101
3	1963.5	1.65	2.60	52.34	24.327	3.499	0.8562
**	**	**	**	**	**	**	**
4	1964.5	2.91	5.51	49.43	22.534	3.627	0.8391
5	1965.5	4.16	9.68	45.27	16.337	4.069	0.7509
6	1966.5	5.69	15.36	39.58	7.320	4.713	0.3561
7	1967.5	7.01	22.37	32.57	0.706	5.186	0
8	1968.5	5.60	27.98	26.97	0.063	5.232	0
9	1969.5	5.60	33.58	21.36	1.816	5.106	0
10	1970.5	4.76	38.34	16.61	4.264	4.932	0
11	1971.5	3.81	42.15	12.80	5.558	4.839	0.1294
12	1972.5	3.53	45.68	9.27	6.663	4.760	0.2856
13	1973.5	4.69	50.37	4.58	13.447	4.276	0.6820
14	1974.5	4.10	54.47	0.48	23.346	3.569	0.8471
15	1980.5	0.40	54.86	0.08	12.003	4.379	0.6352
16	1981.5	0.08	54.94	0	--	--	--

Table D. 21 Flow Unit calculation with Predicted K for well 15-1309 into three zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group 1</u>							
1	1961.5	0.21	0.21	2.40	12.491	3.717	0.7024
2	1962.5	0.74	0.95	1.65	12.628	3.696	0.7073
3	1963.5	1.65	2.60	0	--	--	--
<u>Group 2</u>							
1	1964.5	2.91	2.91	49.43	12.835	3.664	0.7145
2	1965.5	4.16	7.07	45.27	12.446	3.724	0.7008
3	1966.5	5.69	12.76	39.58	12.265	3.752	0.6941
4	1967.5	7.01	19.77	32.57	14.587	3.395	0.7673
5	1968.5	5.60	25.37	26.97	16.629	3.081	0.8147
6	1969.5	5.60	30.98	21.36	19.362	2.660	0.8626
7	1970.5	4.76	35.74	16.61	20.991	2.410	0.8852
8	1971.5	3.81	39.54	12.80	20.901	2.423	0.8841
9	1972.5	3.53	43.08	9.27	20.611	2.468	0.8803
10	1973.5	4.69	47.77	4.58	24.358	1.892	0.9223
11	1974.5	4.10	51.87	0.48	29.123	1.158	0.9602
**	**	**	**	**	**	**	**
12	1980.5	0.40	52.26	0.08	20.601	2.470	0.8801
13	1981.5	0.08	52.34	0	--	--	--

Table D. 22 Flow Unit calculation with Predicted K for well 15-1309 into four zones.

Sample No. per Group	Core Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group 1							
1	1961.5	0.21	0.21	2.40	12.491	3.717	0.7024
2	1962.5	0.74	0.95	1.65	12.628	3.696	0.7073
3	1963.5	1.65	2.60	0	--	--	--
Group 2							
1	1964.5	2.91	2.91	48.95	29.783	1.057	0.9645
2	1965.5	4.16	7.07	44.79	29.691	1.071	0.9639
3	1966.5	5.69	12.76	39.10	28.433	1.265	0.9555
4	1967.5	7.01	19.77	32.10	28.158	1.307	0.9536
5	1968.5	5.60	25.37	26.49	28.588	1.241	0.9566
6	1969.5	5.60	30.98	20.89	29.320	1.128	0.9615
7	1970.5	4.76	35.74	16.13	29.461	1.107	0.9624
8	1971.5	3.81	39.54	12.32	28.757	1.215	0.9578
9	1972.5	3.53	43.08	8.79	28.121	1.313	0.9533
10	1973.5	4.69	47.77	4.10	28.203	1.300	0.9539
11	1974.5	4.10	51.87	0	--	--	--
Group 3							
1	1980.5	0.40	0.40	0.08	28.020	1.328	0.9526
2	1981.5	0.08	0.48	0	--	--	--

Figure D. 1 Flow Unit identification with predicted permeability in well 15-733.

Figure D. 2 Flow Unit identification with predicted permeability in well 15-1059.

Figure D. 3 Flow Unit identification with predicted permeability in well 15-1107.

Figure D. 4 Flow Unit identification with predicted permeability in well 15-1108.

Figure D. 5 Flow Unit identification with predicted permeability in well 15-1109.

Figure D. 6 Flow Unit identification with predicted permeability in well 15-1128.

Figure D. 7 Flow Unit identification with predicted permeability in well 15-1130.

Figure D. 8 Flow Unit identification with predicted permeability in well 15-1132.

Figure D. 9 Flow Unit identification with predicted permeability in well 15-1184.

Figure D. 10 Flow Unit identification with predicted permeability in well 15-1309.

APPENDIX E.

**Determination of Flow Unit by Statistical Zonation Technique using
predicted permeability for Uncored Wells.**

Table E. 1 Flow Unit calculation with Predicted K for well 15-868 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1959	1.44	1.44	11.76	0.063	0.347	0
2	1960	2.74	2.74	10.46	0.070	0.346	0
3	1961	4.64	4.64	8.56	0.495	0.299	0.3959
4	1962	6.51	6.51	6.69	1.152	0.226	0.8035
5	1963	8.06	8.06	5.14	1.557	0.181	0.8837
6	1964	9.42	9.42	3.78	1.805	0.154	0.9149
7	1965	10.59	10.59	2.61	1.887	0.144	0.9235
8	1966	11.85	11.85	1.35	2.329	0.095	0.9590
**	**	**	**	**	**	**	**
9	1967	12.72	12.72	0.48	2.247	0.105	0.9535
10	1968	13.15	13.15	0.05	1.460	0.192	0.8685
11	1969	13.20	13.20	0	--	--	--

Table E. 2 Flow Unit calculation with Predicted K for well 15-868 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
Group1							
1	1959	1.44	1.44	10.41	1.165	0.107	0.9081
2	1960	1.30	2.74	9.11	1.181	0.103	0.9127
3	1961	1.90	4.64	7.21	1.174	0.105	0.9108
4	1962	1.87	6.51	5.34	1.250	0.086	0.9312
5	1963	1.55	8.06	3.79	1.278	0.079	0.9382
6	1964	1.36	9.42	2.44	1.257	0.084	0.9331
7	1965	1.17	10.59	1.26	1.192	0.100	0.9157
8	1966	1.26	11.85	0	--	--	--

Table E. 3 Flow Unit calculation with Predicted K for well 15-874 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1850	0.61	0.61	2.55	0.144	0.038	0.7350
2	1851	0.61	1.22	1.95	0.314	0.023	0.9278
3	1852	0.61	1.82	1.34	0.518	0.004	0.9920
**	**	**	**	**	**	**	**
4	1853	0.19	2.01	1.15	0.390	0.016	0.9595
5	1854	0.09	2.10	1.06	0.256	0.028	0.8905
6	1855	0.02	2.13	1.03	0.138	0.039	0.7202
7	1856	0.09	2.22	0.94	0.082	0.044	0.4692
8	1857	0.29	2.51	0.65	0.104	0.042	0.5980
9	1858	0.16	2.67	0.49	0.085	0.044	0.4889
10	1859	0.12	2.80	0.37	0.057	0.046	0.1991
11	1860	0.12	2.92	0.24	0.035	0.048	0
12	1861	0.12	3.04	0.12	0.016	0.050	0
13	1862	0.12	3.16	0	--	--	--

Table E. 4 Flow Unit calculation with Predicted K for well 15-1110 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1934	0.59	0.59	2.90	0.065	0.058	0.0968
2	1935	0.73	1.33	2.16	0.246	0.036	0.8545
3	1936	0.53	1.86	1.63	0.313	0.027	0.9127
**	**	**	**	**	**	**	**
4	1937	0.05	1.91	1.58	0.110	0.053	0.5200
5	1938	0.06	1.97	1.52	0.020	0.064	0
6	1939	0.22	2.19	1.30	0.004	0.066	0
7	1940	0.41	2.60	0.89	0.012	0.065	0
8	1941	0.43	3.04	0.45	0.038	0.062	0
9	1942	0.40	3.44	0.05	0.100	0.054	0.4584
10	1943	0.05	3.49	0	--	--	--

Table E. 5 Flow Unit calculation with Predicted K for well 15-1110 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group1</u>							
1	1934	0.59	0.59	1.27	0.157	0.031	0.8024
2	1935	0.73	1.33	0.53	0.162	0.030	0.8172
3	1936	0.53	1.86	0	--	--	--
<u>Group2</u>							
1	1937	0.05	0.05	1.58	0.176	0.026	0.8535
2	1938	0.06	0.11	1.52	0.200	0.019	0.9063
3	1939	0.22	0.33	1.30	0.195	0.020	0.8967
4	1940	0.41	0.74	0.89	0.167	0.028	0.8304
5	1941	0.43	1.18	0.45	0.157	0.031	0.8006
6	1942	0.40	1.58	0.05	0.176	0.026	0.8547
7	1943	0.05	1.63	0	--	--	--

Table E. 6 Flow Unit calculation with Predicted K for well 15-1176 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2140	2.47	2.47	126.08	8.682	10.840	0
2	2141	4.98	7.46	121.09	5.785	10.972	0
3	2142	6.03	13.48	115.06	2.547	11.119	0
4	2143	6.98	20.46	108.09	0.281	11.222	0
5	2144	8.43	28.89	99.66	1.126	11.184	0
6	2145	11.30	40.19	88.36	14.408	10.580	0.2657
7	2146	9.34	49.53	79.02	29.230	9.906	0.6611
8	2147	7.84	57.37	71.18	39.545	9.437	0.7614
9	2148	6.30	63.67	64.88	42.509	9.303	0.7812
10	2149	7.29	70.96	57.59	51.871	8.877	0.8289
11	2150	8.43	79.39	49.16	70.346	8.037	0.8857
12	2151	8.07	87.46	41.08	89.624	7.161	0.9201
13	2152	7.84	95.30	33.24	110.621	6.207	0.9439
14	2153	7.84	103.14	25.40	135.913	5.057	0.9628
15	2154	6.48	109.63	18.92	152.460	4.305	0.9718
16	2155	6.03	115.65	12.89	168.247	3.587	0.9787
17	2156	5.21	120.86	7.69	179.180	3.090	0.9828
**	**	**	**	**	**	**	**
18	2157	3.22	124.08	4.47	170.086	3.504	0.9794
19	2158	1.59	125.67	2.88	144.352	4.673	0.9676
20	2159	0.77	126.44	2.11	111.928	6.147	0.9451
21	2160	0.47	126.91	1.63	79.363	7.627	0.9039
22	2161	0.59	127.50	1.04	50.980	8.918	0.8251
23	2162	0.83	128.33	0.22	27.543	9.983	0.6375
24	2163	0.22	128.55	0	--	--	--

Table E. 7 Flow Unit calculation with Predicted K for well 15-1176 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group1</u>							
1	2140	2.47	2.47	118.39	101.017	2.149	0.97873
2	2141	4.98	7.46	113.41	102.550	2.003	0.98047
3	2142	6.03	13.48	107.38	102.048	2.051	0.9799
4	2143	6.98	20.46	100.40	100.000	2.246	0.97754
5	2144	8.43	28.89	91.97	95.865	2.640	0.97246
6	2145	11.30	40.19	80.67	90.374	3.163	0.9650
7	2146	9.34	49.53	71.33	89.597	3.237	0.9639
8	2147	7.84	57.37	63.49	89.619	3.235	0.9639
9	2148	6.30	63.67	57.19	89.602	3.236	0.9639
10	2149	7.29	70.96	49.90	89.592	3.237	0.9639
11	2150	8.43	79.39	41.47	89.771	3.220	0.9641
12	2151	8.07	87.46	33.40	90.244	3.175	0.9648
13	2152	7.84	95.30	25.56	90.946	3.108	0.9658
14	2153	7.84	103.14	17.72	92.228	2.986	0.9676
15	2154	6.48	109.63	11.23	92.114	2.997	0.9675
16	2155	6.03	115.65	5.21	91.512	3.054	0.9666
17	2156	5.21	120.86	0	--	--	--
<u>Group2</u>							
1	2157	3.22	3.22	4.47	92.204	2.988	0.9676
2	2158	1.59	4.81	2.88	91.980	3.010	0.9673
3	2159	0.77	5.58	2.11	91.110	3.093	0.9661
4	2160	0.47	6.05	1.63	90.393	3.161	0.9650
5	2161	0.59	6.64	1.04	90.054	3.193	0.9645
6	2162	0.83	7.47	0.22	90.041	3.194	0.9645
7	2163	0.22	7.69	0	--	--	--

Table E. 8 Flow Unit calculation with Predicted K for well 15-1225 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2081	0.56	0.56	89.15	10.507	7.356	0.2999
2	2082	0.53	1.09	88.63	22.246	6.823	0.6933
3	2083	0.45	1.54	88.17	35.627	6.215	0.8256
4	2084	0.77	2.31	87.40	47.938	5.655	0.8820
5	2085	1.93	4.24	85.48	52.758	5.436	0.8970
**	**	**	**	**	**	**	**
6	2086	4.31	8.55	81.17	42.829	5.887	0.8625
7	2087	6.12	14.66	75.05	26.697	6.620	0.7520
8	2088	5.21	19.87	69.85	18.886	6.976	0.6306
9	2089	5.36	25.23	64.48	12.581	7.262	0.4228
10	2090	5.36	30.59	59.12	7.900	7.475	0.0539
11	2091	6.30	36.89	52.83	3.003	7.697	0.0000
12	2092	5.94	42.83	46.89	0.686	7.803	0.0000
13	2093	7.61	50.44	39.27	0.573	7.808	0.0000
14	2094	9.07	59.52	30.20	8.844	7.432	0.1597
15	2095	7.50	67.02	22.70	21.310	6.865	0.6778
16	2096	5.85	72.87	16.84	31.998	6.380	0.8006
17	2097	4.84	77.71	12.00	40.471	5.994	0.8519
18	2098	3.61	81.33	8.39	43.815	5.842	0.8667
19	2099	3.12	84.45	5.26	45.539	5.764	0.8734
20	2100	2.47	86.92	2.79	44.355	5.818	0.8688
21	2101	1.85	88.77	0.95	40.153	6.009	0.8503
22	2102	0.66	89.43	0.28	28.212	6.552	0.7678
23	2103	0.23	89.66	0.06	14.121	7.192	0.4907
24	2104	0.06	89.72	0	--	--	--

Table E. 9 Flow Unit calculation with Predicted K for well 15-1225 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
Group1							
1	2081	0.56	0.56	3.67	26.429	5.690	0.7847
2	2082	0.53	1.09	3.15	26.532	5.680	0.7859
3	2083	0.45	1.54	2.70	26.796	5.655	0.7890
4	2084	0.77	2.31	1.93	27.108	5.625	0.7925
5	2085	1.93	4.24	0	--	--	--
Group2							
1	2086	4.31	4.31	81.17	26.399	5.693	0.7844
2	2087	6.12	10.42	75.05	26.946	5.641	0.7907
3	2088	5.21	15.63	69.85	27.280	5.609	0.7944
4	2089	5.36	20.99	64.48	27.801	5.559	0.8000
5	2090	5.36	26.35	59.12	28.401	5.502	0.8063
6	2091	6.30	32.65	52.83	30.278	5.323	0.8242
7	2092	5.94	38.59	46.89	32.078	5.152	0.8394
8	2093	7.61	46.20	39.27	37.641	4.622	0.8772
9	2094	9.07	55.28	30.20	49.465	3.496	0.9293
10	2095	7.50	62.78	22.70	59.800	2.512	0.9580
11	2096	5.85	68.63	16.84	65.961	1.925	0.9708
12	2097	4.84	73.47	12.00	69.339	1.603	0.9769
**	**	**	**	**	**	**	**
13	2098	3.61	77.09	8.39	68.538	1.680	0.9755
14	2099	3.12	80.21	5.26	66.664	1.858	0.9721
15	2100	2.47	82.68	2.79	62.969	2.210	0.9649
16	2101	1.85	84.53	0.95	57.543	2.727	0.9526
17	2102	0.66	85.19	0.28	47.591	3.675	0.9228
18	2103	0.23	85.42	0.06	36.780	4.704	0.8721
19	2104	0.06	85.48	0	--	--	--

Table E. 10 Flow Unit calculation with Predicted K for well 15-1243 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1988	0.42	0.42	113.30	21.385	7.781	0.6362
2	1989	0.66	1.09	112.64	42.445	6.778	0.8403
3	1990	1.09	2.18	111.55	61.420	5.874	0.9044
4	1991	2.30	4.47	109.25	70.890	5.423	0.9235
**	**	**	**	**	**	**	**
5	1992	4.77	9.24	104.48	61.234	5.883	0.9039
6	1993	7.08	16.32	97.40	40.164	6.887	0.8285
7	1994	7.84	24.16	89.56	22.429	7.731	0.6553
8	1995	8.94	33.10	80.62	7.982	8.419	0
9	1996	8.94	42.05	71.68	1.101	8.747	0
10	1997	8.19	50.24	63.49	0.111	8.794	0
11	1998	8.19	58.43	55.30	2.841	8.664	0
12	1999	7.18	65.61	48.12	6.861	8.472	0
13	2000	6.77	72.38	41.34	11.621	8.246	0.2905
14	2001	6.03	78.41	35.31	15.406	8.065	0.4765
15	2002	5.21	83.62	30.11	17.116	7.984	0.5335
16	2003	5.21	88.83	24.90	19.373	7.877	0.5934
17	2004	5.60	94.43	19.30	24.250	7.644	0.6848
18	2005	6.48	100.91	12.81	36.246	7.073	0.8049
19	2006	5.60	106.51	7.21	47.794	6.523	0.8635
20	2007	3.36	109.87	3.85	46.229	6.598	0.8573
21	2008	2.54	112.42	1.31	40.333	6.879	0.8295
22	2009	0.92	113.33	0.39	21.667	7.767	0.6415
23	2010	0.39	113.72	0	--	--	--

Table E. 11 Flow Unit calculation with Predicted K for well 15-1243 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group1</u>							
1	1988	0.42	0.42	4.05	35.769	5.662	0.8417
2	1989	0.66	1.09	3.39	36.108	5.628	0.8441
3	1990	1.09	2.18	2.30	36.372	5.602	0.8460
4	1991	2.30	4.47	0	--	--	--
<u>Group2</u>							
1	1992	4.77	4.77	104.48	35.952	5.644	0.8430
2	1993	7.08	11.85	97.40	35.479	5.691	0.8396
3	1994	7.84	19.69	89.56	36.621	5.577	0.8477
4	1995	8.94	28.63	80.62	40.463	5.193	0.8717
5	1996	8.94	37.57	71.68	46.006	4.638	0.8992
6	1997	8.19	45.76	63.49	50.895	4.150	0.9185
7	1998	8.19	53.95	55.30	56.685	3.571	0.9370
8	1999	7.18	61.14	48.12	60.177	3.221	0.9465
9	2000	6.77	67.91	41.34	63.010	2.938	0.9534
10	2001	6.03	73.94	35.31	63.963	2.843	0.9556
11	2002	5.21	79.15	30.11	62.717	2.967	0.9527
12	2003	5.21	84.35	24.90	62.098	3.029	0.9512
13	2004	5.60	89.95	19.30	63.598	2.879	0.9547
14	2005	6.48	96.44	12.81	69.915	2.248	0.9679
15	2006	5.60	102.04	7.21	74.917	1.747	0.9767
**	**	**	**	**	**	**	**
16	2007	3.36	105.40	3.85	70.974	2.142	0.9698
17	2008	2.54	107.94	1.31	64.476	2.791	0.9567
18	2009	0.92	108.86	0.39	50.597	4.179	0.9174
19	2010	0.39	109.25	0	--	--	--

Table E. 12 Flow Unit calculation with Predicted K for well 15-1621 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
1	2080	2.70	2.70	43.60	0.491	1.539	0
2	2081	2.58	5.28	41.02	0.862	1.521	0
3	2082	2.51	7.79	38.51	1.173	1.506	0
4	2083	2.10	9.89	36.40	1.026	1.513	0
5	2084	1.67	11.56	34.74	0.571	1.535	0
6	2085	0.94	12.50	33.80	0.040	1.560	0
7	2086	1.09	13.59	32.71	0.051	1.560	0
8	2087	1.34	14.93	31.37	0.264	1.550	0
9	2088	1.19	16.12	30.18	0.728	1.528	0
10	2089	1.93	18.05	28.25	0.767	1.526	0
11	2090	4.18	22.23	24.07	0.001	1.562	0
12	2091	4.24	26.47	19.82	0.937	1.518	0
13	2092	4.12	30.60	15.70	3.469	1.397	0.5973
14	2093	2.90	33.50	12.80	5.162	1.316	0.7450
15	2094	2.74	36.24	10.06	6.998	1.229	0.8244
16	2095	3.17	39.40	6.89	10.640	1.056	0.9008
17	2096	2.62	42.03	4.27	13.738	0.908	0.9339
**	**	**	**	**	**	**	**
18	2097	1.48	43.51	2.79	13.524	0.918	0.9321
19	2098	1.06	44.57	1.73	12.090	0.986	0.9184
20	2099	0.68	45.25	1.05	9.549	1.108	0.8840
21	2100	0.56	45.81	0.48	6.874	1.235	0.8204
22	2101	0.33	46.14	0.15	3.613	1.390	0.6152
23	2102	0.15	46.30	0	--	--	--

Table E. 13 Flow Unit calculation with Predicted K for well 15-1621 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group1							
1	2080	2.70	2.70	39.33	6.896	0.951	0.86214
2	2081	2.58	5.28	36.74	6.901	0.950	0.86231
3	2082	2.51	7.79	34.24	6.897	0.951	0.86217
4	2083	2.10	9.89	32.13	6.869	0.953	0.8612
5	2084	1.67	11.56	30.47	6.960	0.944	0.86432
6	2085	0.94	12.50	29.52	7.569	0.883	0.88329
7	2086	1.09	13.59	28.43	8.543	0.786	0.908
8	2087	1.34	14.93	27.10	9.643	0.676	0.92989
9	2088	1.19	16.12	25.91	11.304	0.510	0.95489
10	2089	1.93	18.05	23.98	12.276	0.413	0.96638
**	**	**	**	**	**	**	**
11	2090	4.18	22.23	19.80	10.041	0.636	0.93664
12	2091	4.24	26.47	15.55	8.311	0.809	0.90264
13	2092	4.12	30.60	11.43	7.257	0.915	0.8740
14	2093	2.90	33.50	8.53	7.119	0.928	0.8696
15	2094	2.74	36.24	5.79	7.071	0.933	0.8680
16	2095	3.17	39.40	2.62	6.881	0.952	0.8616
17	2096	2.62	42.03	0	--	--	--
Group2							
1	2097	1.48	1.48	2.79	7.225	0.918	0.8730
2	2098	1.06	2.54	1.73	7.337	0.907	0.8764
3	2099	0.68	3.22	1.05	7.264	0.914	0.8742
4	2100	0.56	3.79	0.48	7.201	0.920	0.8722
5	2101	0.33	4.12	0.15	7.056	0.935	0.8675
6	2102	0.15	4.27	0	--	--	--

Table E. 14 Flow Unit calculation with Predicted K for well 15-1639 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
1	1977	0.58	0.58	61.15	3.017	1.269	0.5795
2	1978	0.73	1.32	60.41	5.725	1.161	0.7973
3	1979	1.26	2.58	59.15	6.870	1.115	0.8377
4	1980	1.40	3.98	57.75	7.840	1.076	0.8628
5	1981	1.72	5.69	56.04	8.086	1.066	0.8682
6	1982	1.67	7.36	54.37	8.668	1.043	0.8797
7	1983	1.93	9.29	52.44	8.705	1.041	0.8804
8	1984	2.90	12.19	49.54	6.615	1.125	0.8299
9	1985	3.08	15.27	46.46	4.702	1.201	0.7445
10	1986	3.17	18.43	43.30	3.116	1.265	0.5940
11	1987	3.03	21.47	40.26	2.081	1.306	0.3721
12	1988	3.03	24.50	37.23	1.293	1.338	0
13	1989	3.03	27.53	34.20	0.711	1.361	0
14	1990	3.67	31.20	30.53	0.097	1.386	0
15	1991	3.41	34.61	27.12	0.015	1.389	0
16	1992	3.46	38.07	23.66	0.339	1.376	0
17	1993	4.43	42.50	19.23	2.097	1.306	0.3774
18	1994	3.78	46.28	15.45	4.375	1.215	0.7224
19	1995	3.41	49.69	12.04	6.929	1.112	0.8395
20	1996	2.90	52.59	9.14	9.081	1.026	0.8870
21	1997	2.40	54.99	6.74	10.428	0.972	0.9068
22	1998	2.07	57.06	4.67	11.229	0.940	0.9163
**	**	**	**	**	**	**	**
23	1999	1.62	58.68	3.05	10.904	0.953	0.9126
24	2000	1.26	59.94	1.79	9.644	1.004	0.8959
25	2001	0.83	60.77	0.96	7.041	1.108	0.8426
26	2002	0.67	61.44	0.29	4.145	1.224	0.7048
27	2003	0.29	61.73	0	--	--	--

Table E. 15 Flow Unit calculation with Predicted K for well 15-1639 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
<u>Group1</u>							
1	1977	0.58	0.58	56.48	7.735	0.803	0.8962
2	1978	0.73	1.32	55.75	9.735	0.636	0.9347
3	1979	1.26	2.58	54.48	10.838	0.544	0.9498
4	1980	1.40	3.98	53.09	11.869	0.458	0.9614
5	1981	1.72	5.69	51.37	12.468	0.408	0.9672
6	1982	1.67	7.36	49.70	13.328	0.337	0.9747
7	1983	1.93	9.29	47.78	13.858	0.293	0.9789
**	**	**	**	**	**	**	**
8	1984	2.90	12.19	44.87	12.814	0.380	0.9704
9	1985	3.08	15.27	41.80	11.750	0.468	0.9602
10	1986	3.17	18.43	38.63	10.776	0.549	0.9490
11	1987	3.03	21.47	35.60	10.152	0.601	0.9408
12	1988	3.03	24.50	32.56	9.639	0.644	0.93317
13	1989	3.03	27.53	29.53	9.213	0.680	0.92623
14	1990	3.67	31.20	25.86	8.183	0.766	0.90645
15	1991	3.41	34.61	22.45	7.550	0.818	0.89163
16	1992	3.46	38.07	19.00	6.965	0.867	0.87553
17	1993	4.43	42.50	14.56	5.943	0.952	0.8398
18	1994	3.78	46.28	10.79	5.641	0.977	0.8267
19	1995	3.41	49.69	7.38	5.646	0.977	0.8270
20	1996	2.90	52.59	4.47	5.755	0.968	0.8318
21	1997	2.40	54.99	2.07	5.756	0.968	0.8319
22	1998	2.07	57.06	0	--	--	--
<u>Group2</u>							
1	1999	1.62	1.62	3.05	5.907	0.955	0.8383
2	2000	1.26	2.88	1.79	6.042	0.944	0.8438
3	2001	0.83	3.71	0.96	5.956	0.951	0.8403
4	2002	0.67	4.38	0.29	5.875	0.958	0.8370
5	2003	0.29	4.67	0	--	--	--

Table E. 16 Flow Unit calculation with Predicted K for well 15-1649 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2181	0.35	0.35	6.69	0.008	0.123	0
2	2182	0.62	0.97	6.07	0.005	0.123	0
3	2183	1.11	2.08	4.97	0.235	0.106	0.5462
4	2184	1.06	3.14	3.91	0.630	0.078	0.8759
5	2185	0.75	3.88	3.16	0.821	0.065	0.9214
6	2186	0.61	4.49	2.56	0.910	0.058	0.9361
7	2187	0.64	5.12	1.92	1.059	0.048	0.9551
8	2188	0.60	5.72	1.32	1.211	0.037	0.9597
9	2189	0.34	6.06	0.98	1.119	0.043	0.9614
**	**	**	**	**	**	**	**
10	2190	0.27	6.33	0.71	0.995	0.052	0.9475
11	2191	0.12	6.46	0.59	0.757	0.069	0.9086
12	2192	0.13	6.59	0.46	0.565	0.083	0.8532
13	2193	0.20	6.79	0.26	0.465	0.090	0.8063
14	2194	0.13	6.92	0.12	0.329	0.100	0.6971
15	2195	0.08	7.01	0.04	0.172	0.111	0.3564
16	2196	0.04	7.05	0	--	--	--

Table E. 17 Flow Unit calculation with Predicted K for well 15-1783 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1994	0.92	0.92	53.73	2.989	2.101	0.2973
2	1995	1.30	2.21	52.44	4.941	1.998	0.5957
3	1996	1.57	3.79	50.86	6.289	1.927	0.6936
4	1997	2.17	5.95	48.70	6.134	1.935	0.6845
5	1998	2.95	8.90	45.75	4.442	2.024	0.5444
6	1999	4.18	13.08	41.57	1.498	2.179	0
7	2000	4.18	17.26	37.39	0.195	2.248	0
8	2001	3.83	21.09	33.56	0.015	2.257	0
9	2002	4.18	25.28	29.37	0.670	2.223	0
10	2003	3.61	28.89	25.76	1.569	2.175	0
11	2004	3.17	32.06	22.59	2.250	2.139	0.0493
12	2005	4.50	36.56	18.09	5.525	1.967	0.6440
13	2006	5.28	41.84	12.81	12.963	1.576	0.8784
14	2007	3.61	45.46	9.19	17.449	1.340	0.9232
15	2008	2.70	48.15	6.49	19.405	1.237	0.9363
**	**	**	**	**	**	**	**
16	2009	1.44	49.59	5.06	16.618	1.383	0.9168
17	2010	1.16	50.75	3.90	13.089	1.569	0.8801
18	2011	0.88	51.63	3.02	8.899	1.790	0.7989
19	2012	1.72	53.34	1.31	8.390	1.816	0.7835
20	2013	0.73	54.08	0.57	4.323	2.030	0.5303
21	2014	0.57	54.65	0	--	--	--

Table E. 18 Flow Unit calculation with Predicted K for well 15-1783 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group1							
1	1994	0.92	0.92	47.24	12.525	0.992	0.9208
2	1995	1.30	2.21	45.94	14.806	0.738	0.9501
3	1996	1.57	3.79	44.37	16.821	0.514	0.9694
4	1997	2.17	5.95	42.20	17.791	0.407	0.9771
**	**	**	**	**	**	**	**
5	1998	2.95	8.90	39.26	17.379	0.452	0.9740
6	1999	4.18	13.08	35.07	15.010	0.716	0.9523
7	2000	4.18	17.26	30.89	13.337	0.901	0.9324
8	2001	3.83	21.09	27.06	12.522	0.992	0.9208
9	2002	4.18	25.28	22.88	11.519	1.103	0.9042
10	2003	3.61	28.89	19.26	11.251	1.133	0.8993
11	2004	3.17	32.06	16.10	11.508	1.105	0.9040
12	2005	4.50	36.56	11.60	10.507	1.216	0.8843
13	2006	5.28	41.84	6.31	9.706	1.305	0.8656
14	2007	3.61	45.46	2.70	9.843	1.290	0.8690
15	2008	2.70	48.15	0	--	--	--
Group2							
1	2009	1.44	1.44	5.06	9.779	1.297	0.8674
2	2010	1.16	2.60	3.90	9.772	1.298	0.8672
3	2011	0.88	3.47	3.02	9.719	1.303	0.8659
4	2012	1.72	5.19	1.31	9.978	1.275	0.8722
5	2013	0.73	5.92	0.57	9.858	1.288	0.8693
6	2014	0.57	6.49	0	--	--	--

Table E. 19 Flow Unit calculation with Predicted K for well 15-2150 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
1	1870	5.36	5.36	112.14	0.738	6.449	0
2	1871	6.30	11.66	105.85	3.718	6.325	0
3	1872	5.60	17.26	100.24	5.166	6.265	0
4	1873	4.31	21.57	95.94	3.598	6.330	0
5	1874	3.61	25.18	92.32	1.654	6.411	0
6	1875	6.77	31.96	85.55	5.073	6.269	0
7	1876	9.34	41.30	76.21	18.250	5.720	0.6866
8	1877	8.43	49.73	67.77	33.282	5.093	0.8470
9	1878	8.07	57.81	59.70	49.865	4.402	0.9117
10	1879	6.68	64.48	53.02	60.445	3.961	0.9345
11	1880	5.77	70.25	47.26	66.450	3.711	0.9441
12	1881	4.18	74.43	43.07	63.139	3.849	0.9390
13	1882	4.18	78.61	38.89	60.688	3.951	0.9349
14	1883	3.78	82.39	35.12	56.564	4.123	0.9271
15	1884	4.37	86.76	30.75	56.695	4.118	0.9274
16	1885	5.60	92.36	25.14	65.332	3.758	0.9425
17	1886	6.77	99.14	18.37	84.550	2.957	0.9650
18	1887	5.60	104.74	12.77	98.767	2.365	0.9761
19	1888	4.37	109.11	8.40	105.573	2.081	0.9803
**	**	**	**	**	**	**	**
20	1889	2.30	111.41	6.10	95.704	2.492	0.9740
21	1890	1.28	112.69	4.82	78.262	3.219	0.9589
22	1891	1.19	113.88	3.63	61.682	3.910	0.9366
23	1892	1.03	114.91	2.60	45.246	4.595	0.8985
24	1893	1.14	116.04	1.46	31.104	5.184	0.8333
25	1894	0.83	116.87	0.64	15.692	5.826	0.6287
26	1895	0.64	117.51	0	--	--	--

Table E. 20 Flow Unit calculation with Predicted K for well 15-2215 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1925	2.58	2.58	98.54	1.776	2.807	0
2	1926	3.61	6.20	94.92	1.356	2.825	0
3	1927	4.18	10.38	90.74	0.626	2.855	0
4	1928	4.84	15.22	85.90	0.034	2.880	0
5	1929	4.98	20.20	80.91	0.142	2.875	0
6	1930	4.84	25.04	76.07	0.633	2.855	0
7	1931	5.60	30.65	70.47	2.289	2.786	0
8	1932	7.50	38.15	62.97	8.940	2.509	0.7194
9	1933	6.77	44.92	56.19	16.728	2.184	0.8694
10	1934	4.31	49.23	51.89	17.370	2.157	0.8758
11	1935	6.03	55.26	45.86	24.529	1.859	0.9242
12	1936	6.03	61.28	39.83	33.054	1.504	0.9545
13	1937	4.98	66.27	34.85	37.966	1.299	0.9658
**	**	**	**	**	**	**	**
14	1938	3.12	69.39	31.73	34.556	1.441	0.9583
15	1939	3.46	72.85	28.27	33.187	1.498	0.9549
16	1940	2.58	75.43	25.69	28.338	1.700	0.9400
17	1941	3.67	79.10	22.02	28.646	1.688	0.9411
18	1942	3.03	82.13	18.99	26.553	1.775	0.9332
19	1943	3.12	85.25	15.86	25.229	1.830	0.9275
20	1944	2.70	87.95	13.17	22.406	1.948	0.9131
21	1945	1.96	89.91	11.21	16.798	2.181	0.8702
22	1946	2.44	92.34	8.77	13.593	2.315	0.8297
23	1947	3.36	95.70	5.41	14.734	2.267	0.8461
24	1948	3.56	99.27	1.85	19.018	2.089	0.8902
25	1949	1.36	100.62	0.50	11.979	2.382	0.8011
26	1950	0.50	101.12	0	--	--	--

Table E. 21 Flow Unit calculation with Predicted K for well 15-2430 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1942	0.34	0.34	64.63	11.327	3.577	0.6842
2	1943	0.84	1.18	63.79	20.534	3.002	0.8538
3	1944	1.23	2.40	62.57	28.397	2.510	0.9116
4	1945	2.40	4.80	60.17	29.838	2.420	0.9189
**	**	**	**	**	**	**	**
5	1946	3.61	8.42	56.55	25.683	2.680	0.8957
6	1947	5.06	13.47	51.50	16.738	3.239	0.8065
7	1948	5.44	18.92	46.05	9.429	3.696	0.6081
8	1949	4.50	23.41	41.56	6.710	3.866	0.4239
9	1950	3.89	27.30	37.67	5.969	3.912	0.3446
10	1951	4.84	32.14	32.83	3.513	4.065	0
11	1952	5.60	37.75	27.22	0.897	4.229	0
12	1953	5.77	43.51	21.46	0.010	4.284	0
13	1954	5.68	49.20	15.77	1.434	4.195	0
14	1955	5.85	55.05	9.92	6.564	3.875	0.4097
15	1956	5.13	60.18	4.79	14.600	3.372	0.7690
16	1957	2.86	63.04	1.93	15.757	3.300	0.7906
17	1958	1.38	64.42	0.55	9.919	3.665	0.6305
18	1959	0.55	64.97	0	--	--	--

Table E. 22 Flow Unit calculation with Predicted K for well 15-2430 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group1							
1	1942	0.34	0.34	4.46	15.414	2.515	0.8368
2	1943	0.84	1.18	3.63	15.669	2.481	0.8416
3	1944	1.23	2.40	2.40	15.878	2.453	0.8455
4	1945	2.40	4.80	0	--	--	--
Group2							
1	1946	3.61	3.61	56.55	15.171	2.548	0.8321
2	1947	5.06	8.67	51.50	14.921	2.581	0.8270
3	1948	5.44	14.11	46.05	15.234	2.539	0.8333
4	1949	4.50	18.61	41.56	15.272	2.534	0.8341
5	1950	3.89	22.50	37.67	15.078	2.560	0.8302
6	1951	4.84	27.34	32.83	15.271	2.534	0.8340
7	1952	5.60	32.94	27.22	16.086	2.426	0.8492
8	1953	5.77	38.71	21.46	17.652	2.217	0.8744
9	1954	5.68	44.40	15.77	20.002	1.904	0.9048
10	1955	5.85	50.25	9.92	24.173	1.347	0.9443
11	1956	5.13	55.38	4.79	28.857	0.723	0.9749
**	**	**	**	**	**	**	**
12	1957	2.86	58.24	1.93	27.891	0.852	0.9695
13	1958	1.38	59.62	0.55	22.487	1.572	0.9301
14	1959	0.55	60.17	0	--	--	--

Table E. 23 Flow Unit calculation with Predicted K for well 15-2001 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	2186	0.79	0.79	16.71	0.002	0.072	0
2	2187	1.19	1.98	15.52	0.054	0.069	0
3	2188	1.06	3.04	14.47	0.113	0.066	0.4172
4	2189	1.19	4.23	13.27	0.248	0.059	0.7628
5	2190	1.11	5.34	12.17	0.359	0.053	0.8523
**	**	**	**	**	**	**	**
6	2191	0.64	5.97	11.53	0.220	0.060	0.7255
7	2192	0.49	6.46	11.05	0.084	0.067	0.1939
8	2193	0.42	6.88	10.62	0.009	0.071	0
9	2194	0.68	7.56	9.94	0.001	0.072	0
10	2195	0.71	8.28	9.23	0.001	0.072	0
11	2196	0.79	9.07	8.44	0.002	0.072	0
12	2197	0.96	10.03	7.48	0.000	0.072	0
13	2198	0.90	10.93	6.58	0.002	0.072	0
14	2199	0.94	11.87	5.64	0.009	0.071	0
15	2200	1.11	12.98	4.53	0.052	0.069	0
16	2201	1.14	14.12	3.39	0.159	0.064	0.6001
17	2202	0.89	15.00	2.50	0.214	0.061	0.7172
18	2203	0.94	15.95	1.56	0.345	0.054	0.8442
19	2204	0.77	16.71	0.79	0.424	0.050	0.8431
20	2205	0.48	17.19	0.31	0.287	0.057	0.8027
21	2206	0.31	17.51	0	--	--	--

Table E. 24 Flow Unit calculation with Predicted K for well 15-2001 into three zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD²	W, mD²	Zonation Index, R
Group1							
1	2186	0.79	0.79	4.55	0.227	0.051	0.77722
2	2187	1.19	1.98	3.36	0.189	0.055	0.71014
3	2188	1.06	3.04	2.30	0.190	0.055	0.7125
4	2189	1.19	4.23	1.11	0.180	0.056	0.6904
5	2190	1.11	5.34	0	--	--	--
Group2							
1	2191	0.64	0.64	11.53	0.188	0.055	0.7070
2	2192	0.49	1.12	11.05	0.225	0.051	0.7733
3	2193	0.42	1.54	10.62	0.291	0.044	0.8501
4	2194	0.68	2.23	9.94	0.290	0.044	0.8493
5	2195	0.71	2.94	9.23	0.287	0.044	0.8469
6	2196	0.79	3.73	8.44	0.271	0.046	0.8315
7	2197	0.96	4.69	7.48	0.231	0.050	0.7821
8	2198	0.90	5.59	6.58	0.210	0.053	0.7496
9	2199	0.94	6.53	5.64	0.192	0.055	0.7154
10	2200	1.11	7.64	4.53	0.179	0.056	0.6885
11	2201	1.14	8.78	3.39	0.204	0.053	0.7394
12	2202	0.89	9.67	2.50	0.228	0.051	0.7785
13	2203	0.94	10.61	1.56	0.286	0.044	0.8462
14	2204	0.77	11.38	0.79	0.331	0.039	0.8822
**	**	**	**	**	**	**	**
15	2205	0.48	11.86	0.31	0.287	0.044	0.8472
16	2206	0.31	12.17	0	--	--	--

Table E. 25 Flow Unit calculation with Predicted K for well 87-2102 into two zones.

Sample No. per Group	Depth, Ft	Predicted K, mD	Cum.Sum of K, mD	Grand Sum Minus Cum. Sum, mD	B, mD ²	W, mD ²	Zonation Index, R
1	1989	3.36	3.36	55.70	0.174	3.218	0
2	1990	2.99	6.35	52.71	0.109	3.221	0
3	1991	6.68	13.02	46.03	6.804	2.849	0.5812
4	1992	6.58	19.60	39.45	18.972	2.173	0.8854
5	1993	5.52	25.12	33.93	28.619	1.637	0.9428
6	1994	4.63	29.76	29.30	34.514	1.310	0.9620
7	1995	4.06	33.82	25.24	37.999	1.116	0.9706
8	1996	3.51	37.33	21.73	39.136	1.053	0.9731
**	**	**	**	**	**	**	**
9	1997	2.30	39.63	19.43	34.408	1.316	0.9618
10	1998	2.23	41.86	17.20	30.401	1.539	0.9494
11	1999	2.26	44.12	14.94	27.373	1.707	0.9377
12	2000	2.37	46.49	12.57	25.452	1.813	0.9288
13	2001	2.30	48.78	10.27	23.761	1.907	0.9197
14	2002	2.30	51.08	7.97	22.598	1.972	0.9127
15	2003	2.07	53.16	5.90	20.950	2.064	0.9015
16	2004	1.85	55.00	4.06	18.799	2.183	0.8839
17	2005	1.36	56.36	2.70	14.885	2.401	0.8387
18	2006	1.19	57.55	1.51	10.747	2.630	0.7553
19	2007	0.81	58.36	0.69	5.375	2.929	0.4551
20	2008	0.69	59.06	0	--	--	--

APPENDIX F

**Sample Calculation for correlation of flow units for both cored wells
and wells without cores.**

F1. Sample Calculation to identify flow unit for well 15-733:

Variance between zones:

$$B = \frac{1}{L-1} \sum_{i=1}^L m_i (\bar{k}_i - \bar{k}_{..})^2$$

$$B = \frac{1}{2-1} \left[\frac{4.9^2}{1} + \frac{(4.25)^2}{9-2} + \frac{(9.15)^2}{9} \right] = 16.965$$

Variance within zones:

$$W = \frac{1}{N-L} \sum_{i=1}^L m_i \sum_{j=1}^{m_i} (\bar{k}_{ij} - \bar{k}_{i..})^2$$

$$W = \frac{1}{9-2} \left[\frac{4.9^2}{2} + (1.2)^2 + (2.7)^2 + \dots + (0.05)^2 + \frac{(4.9)^2}{1} + \frac{(4.25)^2}{9-1} \right] = 0.93$$

The zonation index:

$$R = \frac{B+W}{B}$$

$$R = \frac{16.965 + 0.93}{16.965} = 0.9453$$

F2.Sample calculation for flow unit correlation from well to well using ten cored well data:

The correlation of flow units is performed as follows:

1. Rank well zone means in the order of decreasing magnitude of permeability as shown below.

Table F.1 Rank of measured Core Permeability Means for ten cored wells in the order of decreasing magnitude.

Zone No.	Zone Mean	No. of Data Points
3-1108	17.00	2
2-1108	10.38	4
2-1107	9.68	4
1-1309	6.61	13
1-1132	6.53	7
1-1130	5.99	11
4-1108	5.83	9
2-1184	5.18	12
1-733	4.90	1
1-1128	3.10	1
2-1130	3.08	4
1-1184	2.50	4
3-1107	2.46	3
1-1108	2.05	4
3-1184	2.00	9
2-733	1.95	2
2-1128	1.50	3
2-1132	1.26	7
1-1107	1.24	5
2-1309	1.17	3
3-1128	0.49	5
1-1109	0.25	3
1-1059	0.24	4
3-733	0.06	6
2-1109	0.05	3

2. Calculate with Eq. 2 using all the permeability data in the entire reservoir.

$$W = \frac{1}{129} \left[\frac{4.9^2}{25} + \frac{(1.2)^2}{25} + \frac{(2.7)^2}{25} + \dots + \frac{(0.5)^2}{25} + \frac{(4.9)^2}{1} + \frac{(3.9)^2}{2} + \dots + \frac{(3.5)^2}{3} \right] = 8.0238$$

3. Calculate the standard deviation from step 2

$$S = \sqrt{8.0238} = 2.8326$$

4. Select the Z-Values⁹ for a 99% probability level ($Z_{v,p}$)

P	2	3	4	5	6	7	8	9
$Z_{v,p}$	3.7180	3.8751	3.9826	4.0619	4.1249	4.1761	4.2201	4.2571
	10	11	12	13	14	15	16	17
	4.2901	4.3189	4.3449	4.3686	4.3896	4.4091	4.4271	4.4431
	18	19	20	21	22	23	24	25
	4.4585	4.4725	5.1567	5.1942	5.2317	5.2653	5.2988	5.3297

5. Multiply the Z-values in step-4 by the standard deviation in step-3

P	2	3	4	5	6	7	8	9
$F'p = SZ_{v,p}$	10.5316	10.9765	11.2811	11.5056	11.6841	11.8293	11.9539	12.0588
	10	11	12	13	14	15	16	17
	12.1522	12.2336	12.3073	12.3745	12.4340	12.4891	12.5401	12.5854
	18	19	20	21	22	23	24	25
	12.6292	12.6689	14.6068	14.7131	14.8194	14.9144	15.0094	15.0969

6. Test the significant differences among well-flow unit means. First, the largest mean is compared with each of the smaller means. In order for the means of flow unit 3 of 15-1108 and flow unit 2 of 15-1109 to be significantly different.

$$(17 - 0.05) \sqrt{\frac{2(2)(3)}{2 \cdot 3}} = 26.258$$

must be greater than $F_{25} = 15.10$. Since the condition is satisfied, flow unit 3 of 15-1108 and flow unit 2 of 15-1109 represented by the means 17 mD and 0.05 mD are significantly different.

Table F. 2 Comparison of the mean of flow unit 3 of well 15-1108.

Flow Unit	Well	Core Perm (mD)	Number of Data in Zone	F'p for 17.00	F'p
3	15-1108	17.00	2	0	
2	15-1108	10.38	4	10.82	10.53
2	15-1107	9.68	4	11.96	10.98
1	15-1309	6.61	13	19.35	11.28
1	15-1132	6.53	7	18.47	11.51
1	15-1130	5.99	11	20.25	11.68
4	15-1108	5.83	9	20.20	11.83
2	15-1184	5.18	12	21.88	11.95
1	15-733	4.90	1	13.97	12.06
1	15-1128	3.10	1	16.05	12.15
2	15-1130	3.08	4	22.74	12.23
1	15-1184	2.50	4	23.68	12.31
3	15-1107	2.46	3	22.53	12.37
1	15-1108	2.05	4	24.41	12.43
3	15-1184	2.00	9	27.14	12.49
2	15-733	1.95	2	21.28	12.54
2	15-1128	1.50	3	24.01	12.59
2	15-1132	1.26	7	27.76	12.63
1	15-1107	1.24	5	26.64	12.67
2	15-1309	1.17	3	24.53	14.61
3	15-1128	0.49	5	27.91	14.71
1	15-1109	0.25	3	25.95	14.82
1	15-1059	0.24	4	27.37	14.91
3	15-733	0.06	6	29.34	15.01
2	15-1109	0.05	3	26.26	15.10

At the completion of the test, the mean of flow unit 3 of 15-1108 is compared with the mean of the other zones and found that the flow unit 3 of 15-1108 is significantly different from the means of the other zones. In the next step, the next largest mean of flow unit 2 of 15-1108 is compared with the smallest mean flow unit 2 of 15-1109.

$$(10.38 - 0.05) \sqrt{\frac{2(4)(3)}{4 + 3}} = 19.1189$$

Table F. 3 Comparison of the mean of flow unit 2 of well 15-1108.

Flow Unit	Well	Core Perm (mD)	Number of Data in Zone	F'p for 10.38	F'p
3	15-1108	17.00	2	--	--
2	15-1108	10.38	4	0	
2	15-1107	9.68	4	1.40	10.53
1	15-1309	6.61	13	9.32	10.98
1	15-1132	6.53	7	8.68	11.28
1	15-1130	5.99	11	10.62	11.51
4	15-1108	5.83	9	10.69	11.68
2	15-1184	5.18	12	12.72	11.83
1	15-733	4.90	1	6.93	11.95
1	15-1128	3.10	1	9.20	12.06
2	15-1130	3.08	4	14.60	12.15
1	15-1184	2.50	4	15.75	12.23
3	15-1107	2.46	3	14.66	12.31
1	15-1108	2.05	4	16.65	12.37
3	15-1184	2.00	9	19.71	12.43
2	15-733	1.95	2	13.76	12.49
2	15-1128	1.50	3	16.43	12.54
2	15-1132	1.26	7	20.56	12.59
1	15-1107	1.24	5	19.26	12.63
2	15-1309	1.17	3	17.05	12.67
3	15-1128	0.49	5	20.84	14.61
1	15-1109	0.25	3	18.75	14.71
1	15-1059	0.24	4	20.28	14.82
3	15-733	0.06	6	22.60	14.91
2	15-1109	0.05	3	19.12	15.01

In the next step, the mean of flow unit 2 of 15-1108 is compared with the mean of the other zones until the difference is not significant. We find the comparisons are significant until flow unit 1 of 15-1128 is reached.

$$(10.38 - 3.1) \sqrt{\frac{2(4)(1)}{4 - 1}} = 9.2022 = F'_{10}(12.06)$$

Then the next largest mean is compared with the smaller mean as follows.

Table F.4 Comparison of the mean of flow unit 2 of well 15-1130.

Flow Unit	Well	Core Perm (mD)	Number of Data in Zone	F'p for 3.08	F'p
2	15-1130	3.08	4	0	
1	15-1184	2.50	4	1.15	10.53
3	15-1107	2.46	3	1.14	10.98
1	15-1108	2.05	4	2.05	11.28
3	15-1184	2.00	9	2.53	11.51
2	15-733	1.95	2	1.84	11.68
2	15-1128	1.50	3	2.92	11.83
2	15-1132	1.26	7	4.09	11.95
1	15-1107	1.24	5	3.87	12.06
2	15-1309	1.17	3	3.53	12.15
3	15-1128	0.49	5	5.45	12.23
1	15-1109	0.25	3	5.23	12.31
1	15-1059	0.24	4	5.68	12.37
3	15-733	0.06	6	6.61	12.43
2	15-1109	0.05	3	5.60	12.49

The calculations are carried out until a non significant difference is found.

$$(3.08 - 0.05) \sqrt{\frac{2(4)(3)}{4 + 3}} = 5.60 - F'_{15}(12.49)$$

The means which are not significantly different are distinguished as follows.

Table F. 5 Final divisions of core permeability means into two groups.

Group 1		Group 2	
Flow Unit	Well	Flow Unit	Well
3	15-1108	2	15-1130
2	15-1108	1	15-1184
2	15-1107	3	15-1107
1	15-1309	1	15-1108
1	15-1132	3	15-1184
1	15-1130	2	15-733
4	15-1108	2	15-1128
2	15-1184	2	15-1132
1	15-733	1	15-1107
1	15-1128	2	15-1309
		3	15-1128
		1	15-1109
		1	15-1059
		3	15-733
		2	15-1109

F3. Sample calculation for flow unit correlation from well to well using fifteen well data without cores:

The correlation of flow units is performed as follows:

1. Rank well zone means in the order of decreasing magnitude of permeability as shown below.

Table F.6 Rank of predicted permeability Means for fifteen wells with no cores in the order of decreasing magnitude.

Zone	Zone Mean	No. of Data in zone
1-1176	7.11	17
2-1243	6.80	15
2-1225	6.12	12
2150-1	5.74	19
2215-1	5.1	13
2430-2	5.03	11
1-87-2102	4.67	8
2-1783	3.84	11
2-1621	3.43	7
2-1639	3.19	15
2215-2	2.68	13
2-87-2102	1.81	12
1-1621	1.80	10
3-1243	1.80	4
3-1225	1.71	7
2430-3	1.6	3
1-1783	1.49	4
1-868	1.48	8
1-1639	1.33	7
2150-2	1.2	7
2430-1	1.2	4
1-1243	1.12	4
2-1176	1.10	7
3-1783	1.08	6
1-2001	1.07	5
3-1639	0.93	5
1-1225	0.85	5
2-2001	0.81	14
3-1621	0.71	6
1-1649	0.67	9
1-1110	0.62	3
1-874	0.61	3
2-868	0.45	3
3-2001	0.40	2
2-1110	0.23	7
2-1649	0.14	7
2-874	0.13	10

2. Calculate with Eq. 2 using all the permeability data in the entire reservoir.

$$W = \frac{1}{303} \left[\frac{1.44^2}{37} + (1.3)^2 + (1.90)^2 + \dots + (0.310)^2 + \frac{(11.85)^2}{8} + \frac{(1.35)^2}{3} + \dots + \frac{(0.791)^2}{2} \right] = 1.0256$$

3. Calculate the standard deviation from step 2

$$S = \sqrt{1.0256} = 1.0127$$

4. Select the Z-Values⁹ for a 99% probability level ($Z_{v,p}$)

P	2	3	4	5	6	7	8	9
Z _{v,p}	3.643	3.796	3.9	3.978	4.04	4.091	4.135	4.172
	10	11	12	13	14	15	16	17
	4.205	4.235	4.261	4.285	4.307	4.327	4.345	4.363
	18	19	20	21	22	23	24	25
	4.379	4.394	5.012	5.0465	5.081	5.1125	5.144	2.572
	26	27	28	29	30	31	32	33
	5.201	5.227	5.253	5.277	5.301	5.3235	5.346	2.673
	34	35	36	37				
	5.388	5.4075	5.427	2.7135				

5. Multiply the Z-values in step-4 by the standard deviation in step-3

P	2	3	4	5	6	7	8	9
F'p=SZ _{v,p}	3.6868	3.8416	3.9468	4.0258	4.0885	4.1401	4.1847	4.2221
	10	11	12	13	14	15	16	17
	4.2555	4.2859	4.3122	4.3365	4.3587	4.3790	4.3972	4.4154
	18	19	20	21	22	23	24	25
	4.4316	4.4468	5.0722	5.1071	5.1420	5.1739	5.2058	5.2346
	26	27	28	29	30	31	32	33
	5.2635	5.2898	5.3161	5.3404	5.3647	5.3874	5.4102	5.4315
	34	35	36	37				
	5.4527	5.4724	5.4922	5.5104				

6. Test the significant differences among well-flow unit means. First, the largest mean is compared with each of the smaller means. In order for the means of flow unit 1 of 1176 and flow unit 2 of 874 to be significantly different.

$$(7.11 - 0.13) \sqrt{\frac{2(17)(10)}{17 + 10}} = 24.767$$

must be greater than $F_{37} = 5.5104$. Since the condition is satisfied, flow unit 1 of 15-1176 and flow unit 2 of 15-874 represented by the means 7.11 mD and 0.13 mD are significantly different.

After the test is completed, the mean of flow unit 1 of 15-1176 is compared with the mean of the other flow units until the difference is not significant. It was found that the comparisons are significant until flow unit 2 of 15-1225 is reached as shown in Table C.7.

Table F. 7 Comparison of the mean of flow unit 1 of well 15-1176.

Flow Unit	Well	Predicted Perm (mD)	Number of Data in Zone	F'p for 7.11	F'p
1	15-1176	7.11	17		
2	15-1243	6.80	15	1.22	3.69
2	15-1225	6.12	12	3.70	3.84
1	15-2150	5.74	19	5.80	3.95
1	15-2215	5.1	13	7.71	4.03
2	15-2430	5.03	11	7.60	4.09
1	87-2102	4.67	8	8.05	4.14
2	15-1783	3.84	11	11.95	4.18
2	15-1621	3.43	7	11.60	4.22
2	15-1639	3.19	15	15.67	4.26
2	15-2215	2.68	13	17.00	4.29
2	87-2102	1.81	12	19.88	4.31
1	15-1621	1.80	10	18.82	4.34
3	15-1243	1.80	4	13.50	4.36
3	15-1225	1.71	7	16.99	4.38
3	15-2430	1.6	3	12.44	4.40
1	15-1783	1.49	4	14.30	4.42
1	15-868	1.48	8	18.57	4.43
1	15-1639	1.33	7	18.21	4.45
2	15-2150	1.2	7	18.61	5.07
1	15-2430	1.2	4	15.04	5.11
1	15-1243	1.12	4	15.25	5.14
2	15-1176	1.10	7	18.93	5.17
3	15-1783	1.08	6	17.96	5.21
1	15-2001	1.07	5	16.80	5.23
3	15-1639	0.93	5	17.17	5.26
1	15-1225	0.85	5	17.41	5.29
2	15-2001	0.81	14	24.67	5.32
3	15-1621	0.71	6	19.06	5.34
1	15-1649	0.67	9	22.08	5.36
1	15-1110	0.62	3	14.66	5.39
1	15-874	0.61	3	14.68	5.41
2	15-868	0.45	3	15.04	5.43
3	15-2001	0.40	2	12.70	5.45
2	15-1110	0.23	7	21.66	5.47
2	15-1649	0.14	7	21.95	5.49
2	15-874	0.13	10	24.77	5.51

In the next step, the next largest mean of flow unit 1 of 15-2150 is compared with the smallest mean (flow unit 2 of 15-874).

$$(5.74 - 0.13) \sqrt{\frac{2(19)(10)}{19 + 10}} = 24.77$$

Table F. 8 Comparison of the mean of flow unit 1 of well 15-2150.

Flow Unit	Well	Predicted Perm (mD)	Number of Data in Zone	F'p for 5.74	F'p
1	15-2150	5.74	19		
1	15-2215	5.1	13	2.51	3.69
2	15-2430	5.03	11	2.65	3.84
1	87-2102	4.67	8	3.59	3.95
2	15-1783	3.84	11	7.09	4.03
2	15-1621	3.43	7	7.40	4.09
2	15-1639	3.19	15	10.46	4.14
2	15-2215	2.68	13	12.02	4.18
2	87-2102	1.81	12	15.07	4.22
1	15-1621	1.80	10	14.25	4.26
3	15-1243	1.80	4	10.12	4.29
3	15-1225	1.71	7	12.88	4.31
3	15-2430	1.6	3	9.42	4.34
1	15-1783	1.49	4	10.93	4.36
1	15-868	1.48	8	14.29	4.38
1	15-1639	1.33	7	14.12	4.40
2	15-2150	1.2	7	14.52	4.42
1	15-2430	1.2	4	11.67	4.43
1	15-1243	1.12	4	11.88	4.45
2	15-1176	1.10	7	14.85	5.07
3	15-1783	1.08	6	14.07	5.11
1	15-2001	1.07	5	13.15	5.14
3	15-1639	0.93	5	13.52	5.17
1	15-1225	0.85	5	13.76	5.21
2	15-2001	0.81	14	19.78	5.23
3	15-1621	0.71	6	15.19	5.26
1	15-1649	0.67	9	17.71	5.29
1	15-1110	0.62	3	11.65	5.32
1	15-874	0.61	3	11.68	5.34
2	15-868	0.45	3	12.04	5.36
3	15-2001	0.40	2	10.17	5.39
2	15-1110	0.23	7	17.62	5.41
2	15-1649	0.14	7	17.91	5.43
2	15-874	0.13	10	20.31	5.45

At the completion of the test, it was found that the comparisons are significant until flow unit 2 of 87-2102 is reached as shown in Table F.8. At this point, another comparison was begun with the next largest mean using the smaller mean. The comparisons continued until the differences are not significant and less than the values of corresponding F_p values. Therefore, these groups of flow units are significantly correlated with each other.

Finally, the means distinguished as separate groups, which are not significantly different are shown in Table F.9.

Table F. 9 Final division of core permeability means into five groups.

Group 1		Group 4	
Flow Unit	Well	Flow Unit	Well
1	15-1176	2	15-2215
2	15-1243	2	87-2102
2	15-1225	1	15-1621
Group 2		3	15-1243
Flow Unit	Well	3	15-1225
1	15-2150	3	15-2430
1	15-2215	1	15-1783
2	15-2430	1	15-868
1	87-2102	1	15-1639
Group 3		2	15-2150
Flow Unit	Well	1	15-2430
2	15-1783	1	15-1243
2	15-1621	2	15-1176
2	15-1639	3	15-1783
Group 5		1	15-2001
Flow Unit	Well	3	15-1639
2	15-1110	1	15-1225
2	15-1649	2	15-2001
2	15-874	3	15-1621
		1	15-1649
		1	15-1110
		1	15-874
		2	15-868
		3	15-2001