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Determination of flow units of Yamama Formation in the West Qurna oil field, Southern Iraq

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Abstract
The major objective of this paper is to recognize the flow units of Yamama Formation in the west Qurna oil field, south of Iraq. To attain this objective, four wells namely, WQ-23, WQ-148, WQ-60, and WQ-203 are selected and analyzed. The two techniques that proposed by some scientists to identify flow units are tested and verified. Results are also enhanced using well logs interpretation and the flow areas are proposed through the studying of the behavior of different well logs. Results of applying the two proposed techniques identify six flow reservoir units for the wells WQ-23, WQ-148, WQ-60, and WQ-203, respectively. This study also shows that the flow reservoir properties in the Yamama Formation improved towards the northeast of the West Qurna oil field.

Keywords: Flow units, Carbonate reservoir, Yamama Formation, West Qurna oil field.

تحديد وحدات الجريان من تكوين اليمامة في حقل غرب القرنة النفطي، جنوبي العراق

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الخلاصة
إن الهدف الاساسي لهذه الدراسة هو تحديد وحدات الجريان لتكوين اليمامة في حقل غرب القرنة في جنوب العراق. لتحقيق هذا الهدف، أختيرت وحللت أربعة آبار هي WQ-23, WQ-148, WQ-60 and WQ-203. لتحليل وحدات الجريان في تكوين اليمامة أستخدمت التقنيات المقترحة من قبل بعض الباحثين. عززت النتائج بتفسيرات الجس البئري وأقترحت وحدات الجريان من خلال دراسة سلوك المجسات المختلفة. حددت نتائج تطبيق الطريقتين ست وحدات جريان في الآبار WQ-23، WQ-148، WQ-60 و WQ-203. بينت الدراسة أيضاً بان خصائص الجريان المكمنية في حقل اليمامة تتحسن بأتجاه الشمال الشرقي من الحقل.

Introduction

Many scientists know the flow unit, [1] which is defined as "a mappable part of the total reservoir, where the geological and petrophysical properties that influence fluid flow are consistent and proportionally predicted by the characteristics of other rock sizes". While [2] defined as a " a

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stratigraphically, continuous separation of a similar reservoir process that honors the geological framework and preserves the characteristics of the rock type." The definition identifies porosity, permeability and bed thickness data to determine the flow unit. . Flow units of cores were determined in terms of sedimentary environment, texture, capillary curves and petrophysical properties [3]. Several authors have various methods of flow units, based on descriptions of pore geometry, rock fabric depositional environment and diagenetic process. These methods include relationships between reservoir quality and rock type using two methods.

The flow unit is a method for classifying rock types in the pore range according to flow characteristics based on geological parameters and flow physics. These units are part of the complete reservoir, which is characterized by fixed geological and petrophysical properties that affect the fluid flow, and are clearly different from other sections [4].

The typing of rock and flow unit determination in carbonates was difficult because of the complexity of pore networks that are the product of changes of facies and digenetic processes. The first step to identify the rock type and determination of flow unit is an analysis of facies depending on core tests and thin section studies.

Rock typing methods are based on Winland's r35 [5] flow zone indicator (FZI), [6] and rock fabrics number (RFN), [7].

Several techniques for determining the flow unit are suggested in the literature, such as the modified Lorenz scheme used by Gunter et al. [2]. The amount of information required by each method varies basing on the data and tools available. This leads to the interpretation of the different flow unit of the same tank [8]. A simplified variation of Lorenz's modified locking technique is to determine the flow unit by drawing a normal cumulative flow capacity as a function of depth.

The Winland method is an experimental relationship between pore throat radius, porosity and permeability from the 35% mercury saturation point in the capillary pressure in some clastic reservoirs. Winland equation, as:

$$\text{Log } r35 = 0.732 + 0.588 \log K_{air} - 0.864 \log \phi_{core} \quad [1]$$

Where:

r35: the pore throat radius at 35% mercury saturation.

K air: air permeability (mD).

ϕ: porosity of core (%).

Pittman was found from the Winland method to be more graphically accurate; Pittman method is also called ''apex method''. They are several methods and technologies have been use for predicting the flow units of carbonate extreme heterogeneity that characterizes carbonate reservoirs.

Geological Setting

West Qurna (WQ) is one of the giant oil field in Iraq. The West Qurna field is located in Southern Iraq approximately 70 km NW of Basra city (Figure-1) in Zubair subzone within Mesopotamia zone according to the tectonic subdivision of Iraq. The West Qurna oil field is associated with elongated double plunging asymmetrical anticline trending in a northwest-southeast direction. This field is represents the north extension of North Rumaila Field. The Yamama Formation is of Berriasian-Valanginian age [9]. The formation widely distribution in Iraq, it is represents reservoirs in southern Iraq and it is product in the some oil fields. In study area the contacts of the formation with the overlying Ratawi Formation and the underlying Sulaiy Formation are conformable, Figure-2.

The Yamama Formation in southern Iraq comprises outer shelf argillaceous limestones and oolitic, pelloidal, pelletal and pseudo-oolitic shoal limestones [10]. The Sadooni [11] suggests "in SE Iraq, the formation comprises three depositional cycles. Cycle tops contain oolitic grainstone inner-ramp facies which pass down into finer-grained peloidal facies and middle-ramp bioclastic/coral/stromotoporoid pack-wackestoncs. Outer-ramp cycle bases comprise thick grey shales with stringers of chalky micrite [12], Figure-3. Al-Siddiki [13] has divided the Yamama Formation into five rocks units with different petrophysical properties, three of this units are reservoir (YA, YB and YC) separated by two units rocks (CI and CII).

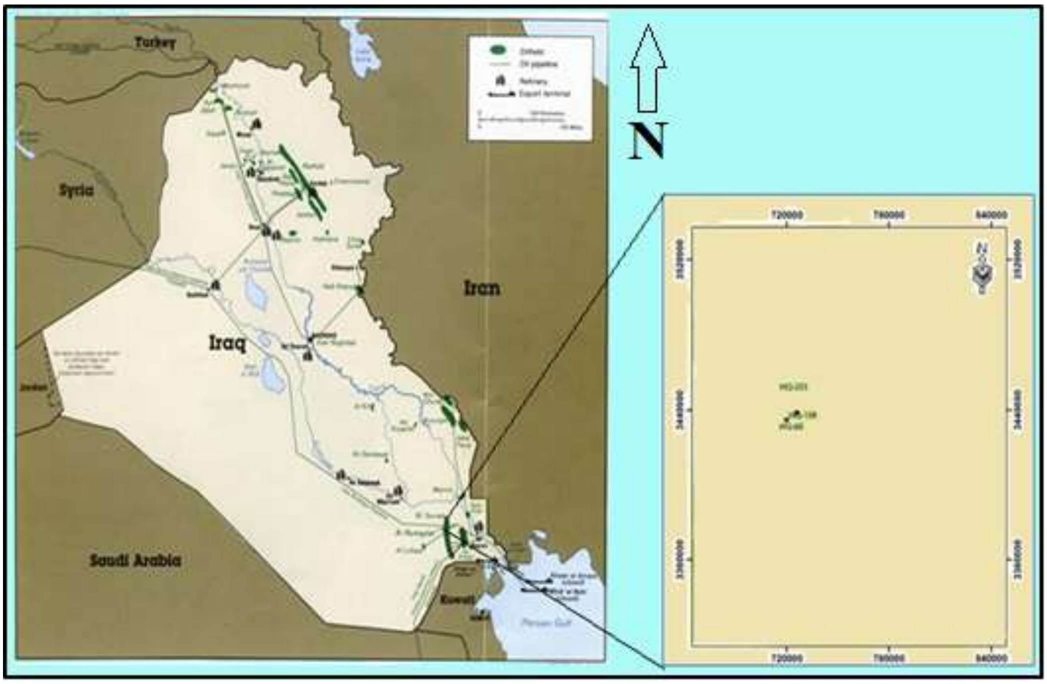

Figure 1- A Location map of the study area

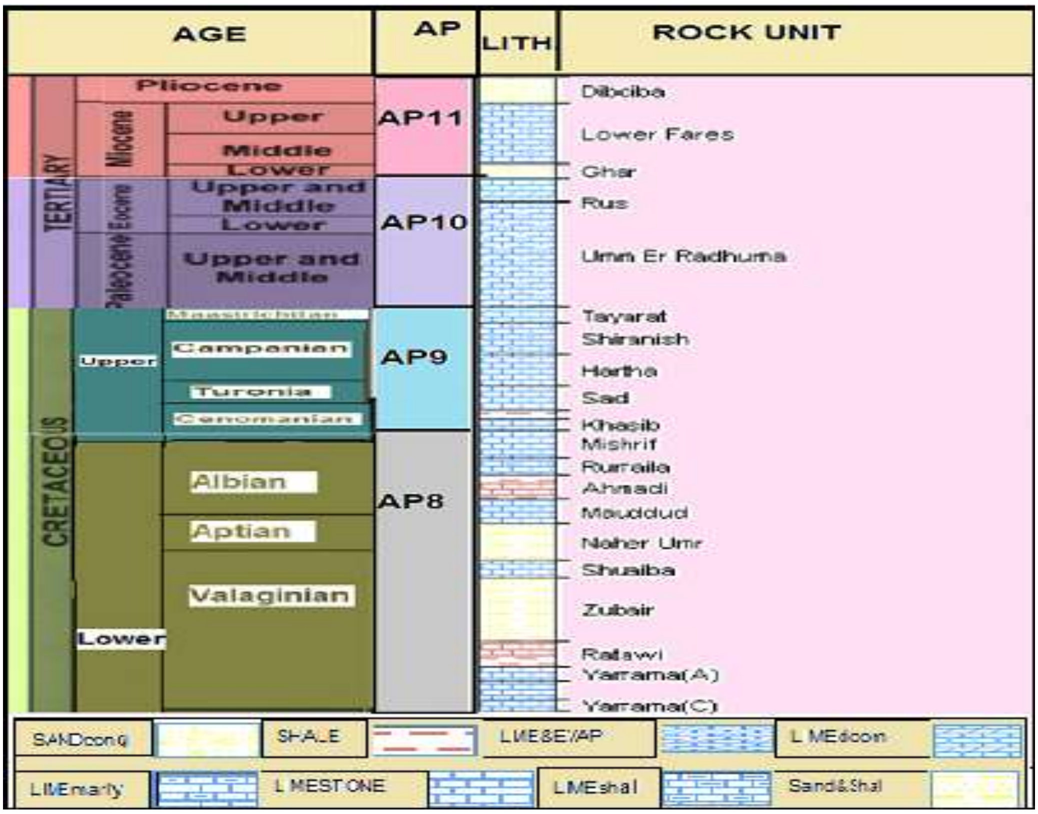

Figure 2- Stratigraphic column in southern Iraq (WQ-60).

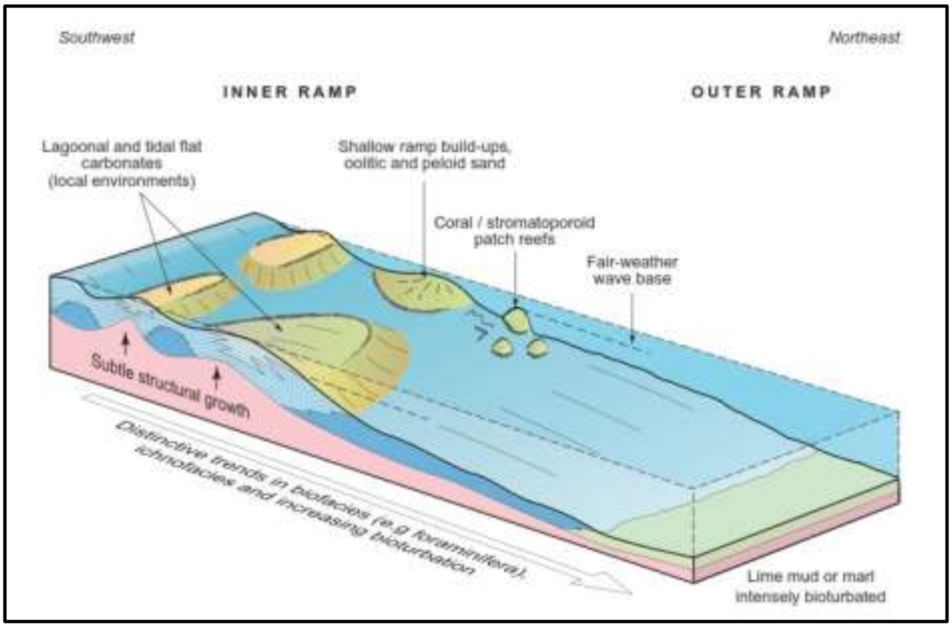

Figure 3- Facies model for the Yamama Formation ramp system in SE Iraq [11].

Materials and Methods

The research methodology used two methods:

1. Gunter et al. [2] method of flow unit characterization. This method for flow units based on petrophysical rock/pores types, storage capacity, flow capacity, it is requires only porosity and permeability data. Gunter et al. [2]. Construct the stratigraphic modified Lorenz plot (SML) plot. The SML plot is a cross plot that relate the cumulative flow capacity (CFC) and cumulative storage capacity (CSC). The CFC is a product of the permeability (k) and layer thickness (h), while CSC is a term that used to describe the product of average porosity (ϕ) and layer thickness [14]. To create SML plot, the values of ϕ, k, and h should be arranged in a stratigraphic order [15]. The following equations were used to estimate CFC and CSC [16]:

CFC = k1 (h1+h0) + k2 (h2-h1) +⋯+ ki (hi-hi-1)/ ∑ki (h1-hi-1)ϕ (1)

CSC = (ϕh) cum = ϕ1 (h1-h0) + ϕ2 (h2-h1) +⋯+ ϕki (hi-hi-1)/∑ ϕki (hi-hi-1) (2)

Where:

k: permeability (mD).

h: thickness of the layer (ft).

ϕ: effective porosity (%).

2. Amaefule et al. [6] introduced the concepts of Reservoir quality index (RQI) and Flow zone indicator (FZI) to derive flow units. The RQI and FZI is written mathematically as:

$$RQI = 0.0314\sqrt{\frac{k}{\phi_e}} \quad (\mu m)$$

$$RQI = FZI(\phi_z)$$

The ϕ_z is the ratio of pore to grain volumes and defined mathematically as:

$$\phi_z = \frac{\phi_e}{1-\phi_e}$$

Results and Discussions

Results of applying Ameefule et al. [6] indicated that the Yammam Formation can be classified into six flow units in WQ-203, WQ-60, WQ-148 and WQ-23 wells Figures-(4, 5, 6, 7, 10, 11, 12, 13, 16, 17, 18, 19, 22, 23, 24 and 25). From Winland plot, the Yammam Formation can be classified into five rock groups according to the values of k and ϕ (Figures 8, 9, 14, 15, 20, 21, 26 and 27). These groups are: mega-porous, macro-porous, meso-porous, micro-porous, and nano-porous. The meso, mircro, and nano groups are more frequently exist within the formation.

On the other hand, the pore throat size (r35) calculated from core k and ϕ values revealed that Yamama reservoir units can be categorized into three types macro pore, meso pore, and, micro pore. Results also enhanced using well logs interpretation and the flow areas that proposed by studying the behavior of different well logs (Figures 28, 29, 30, and 31)

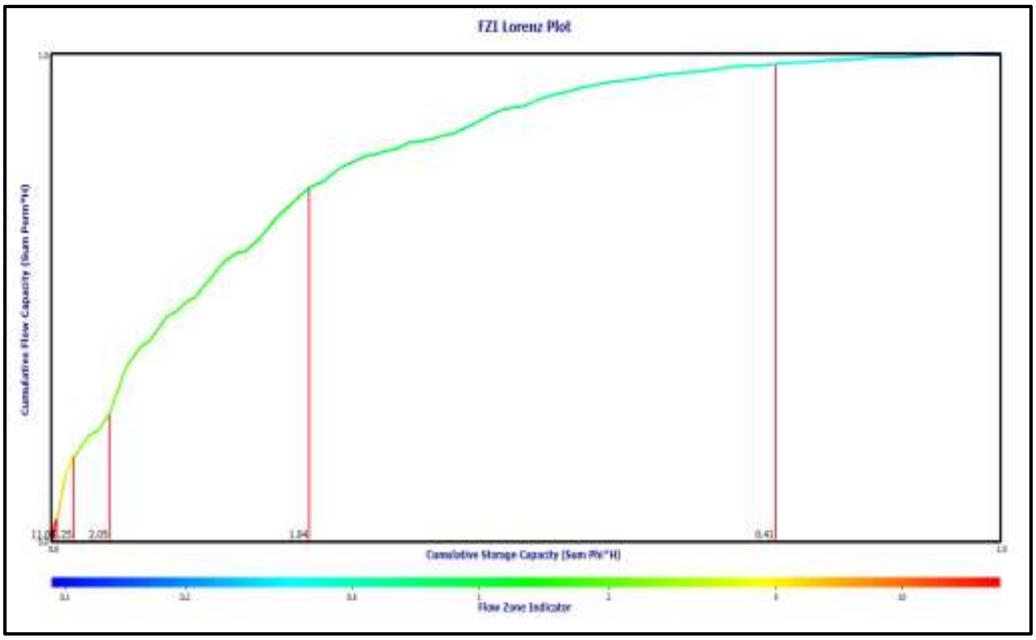

Figure 4- SML plot of the WQ-203.

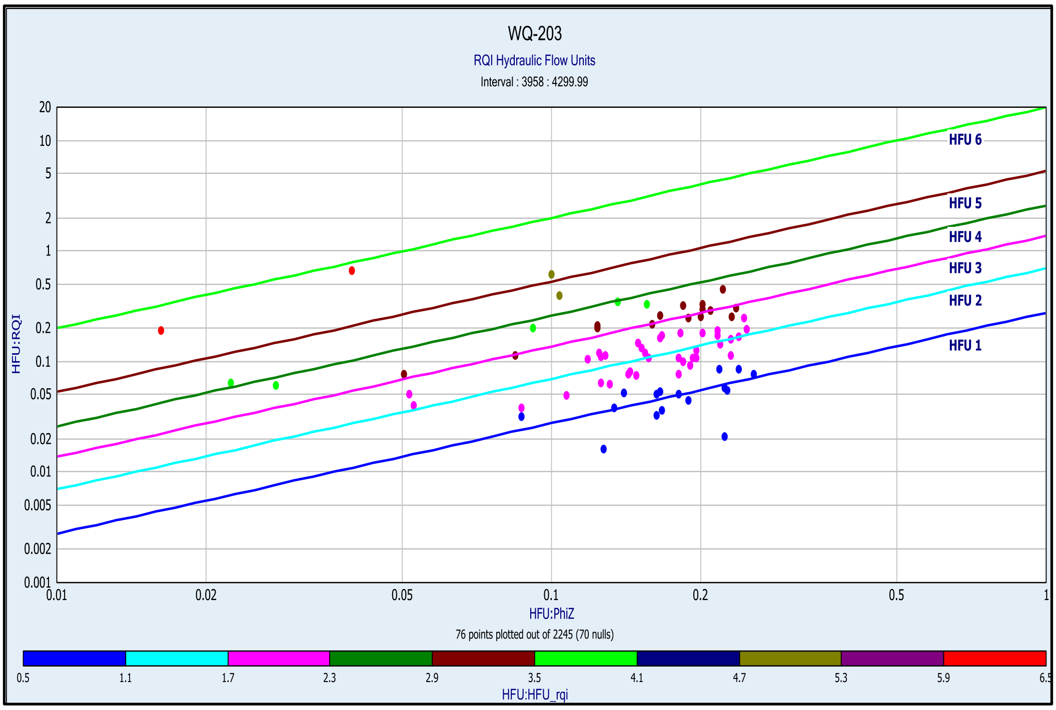

Figure 5- Log-log plot of RQI versus ϕz.

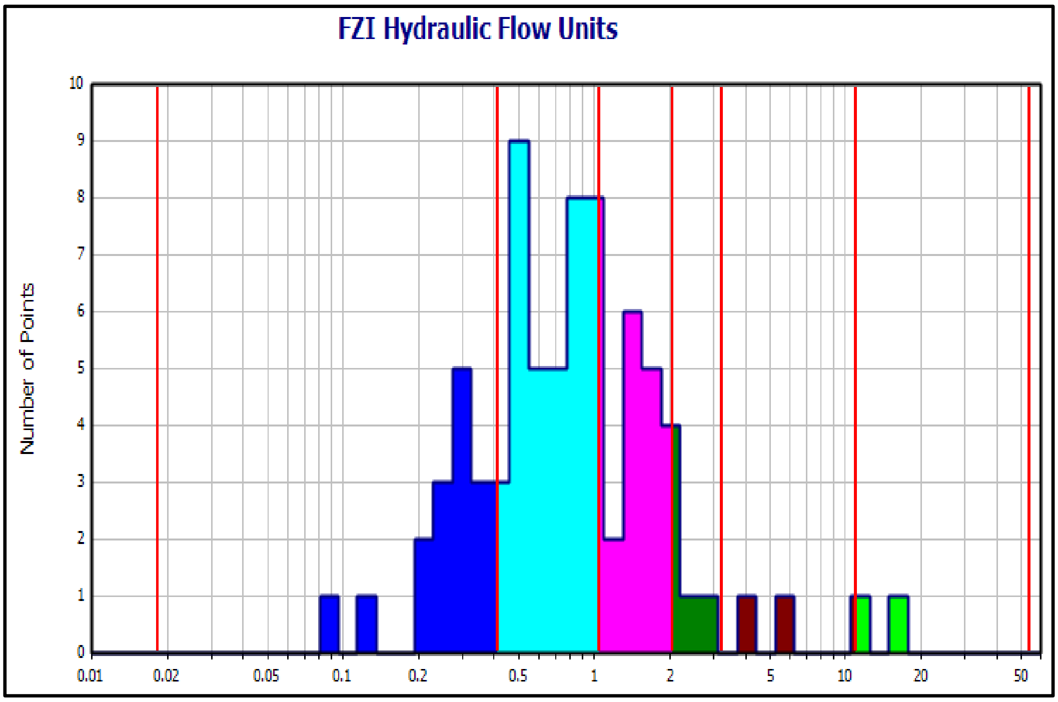

Figure 6- Histogram hydraulic flow units of WQ-203.

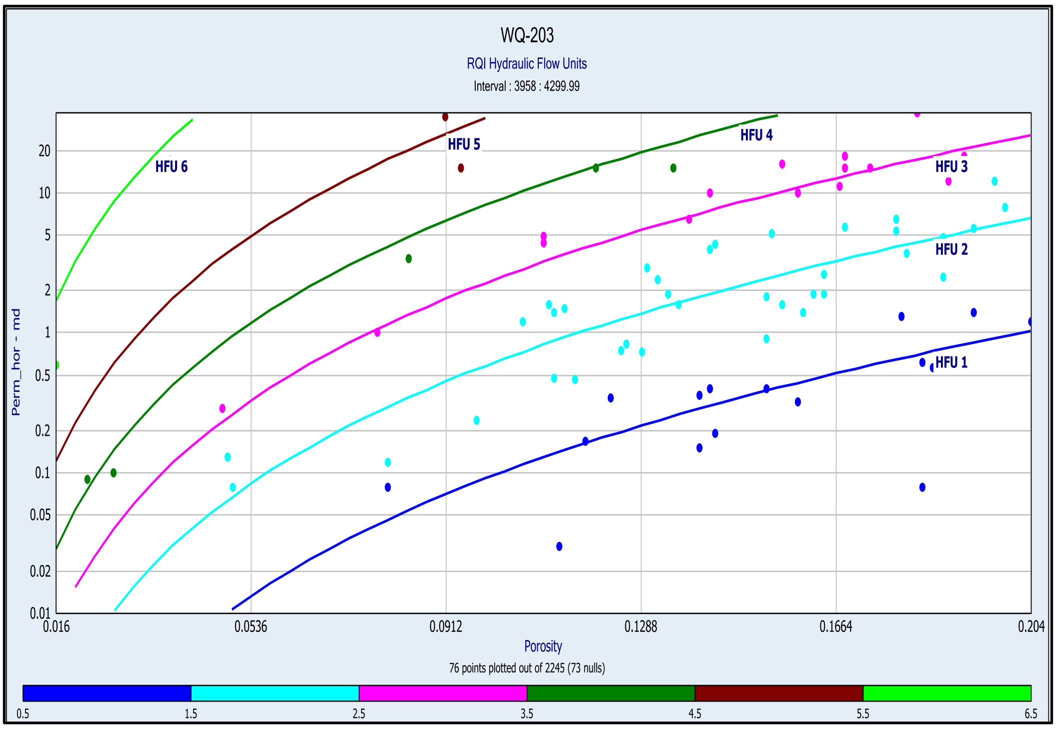

Figure 7- Flow units (Leverett's reservoir quality index).

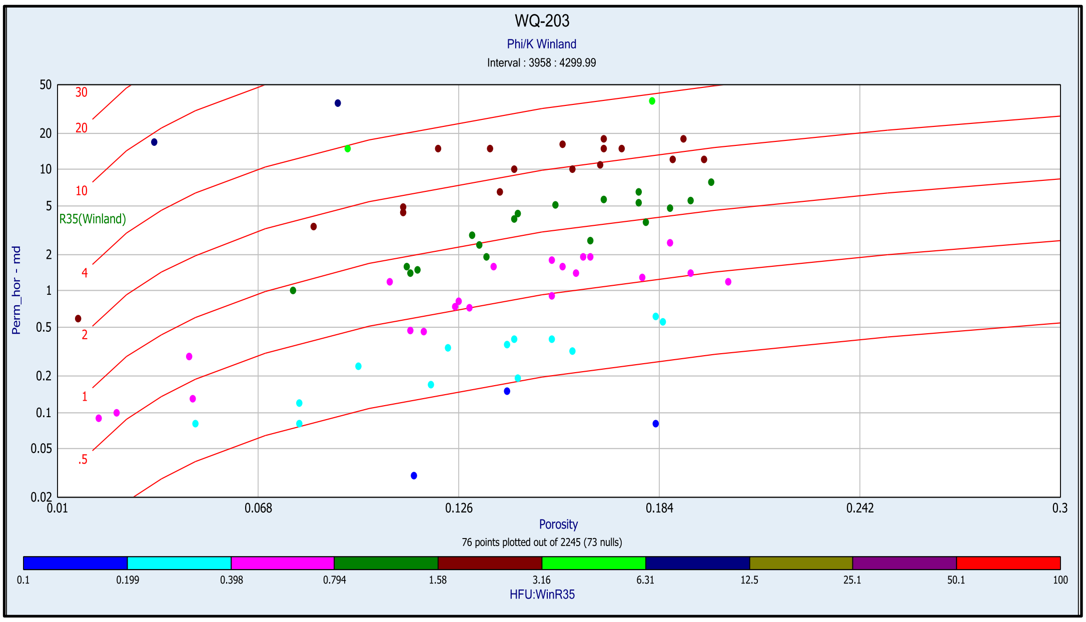

Figure 8- Winland's plot.

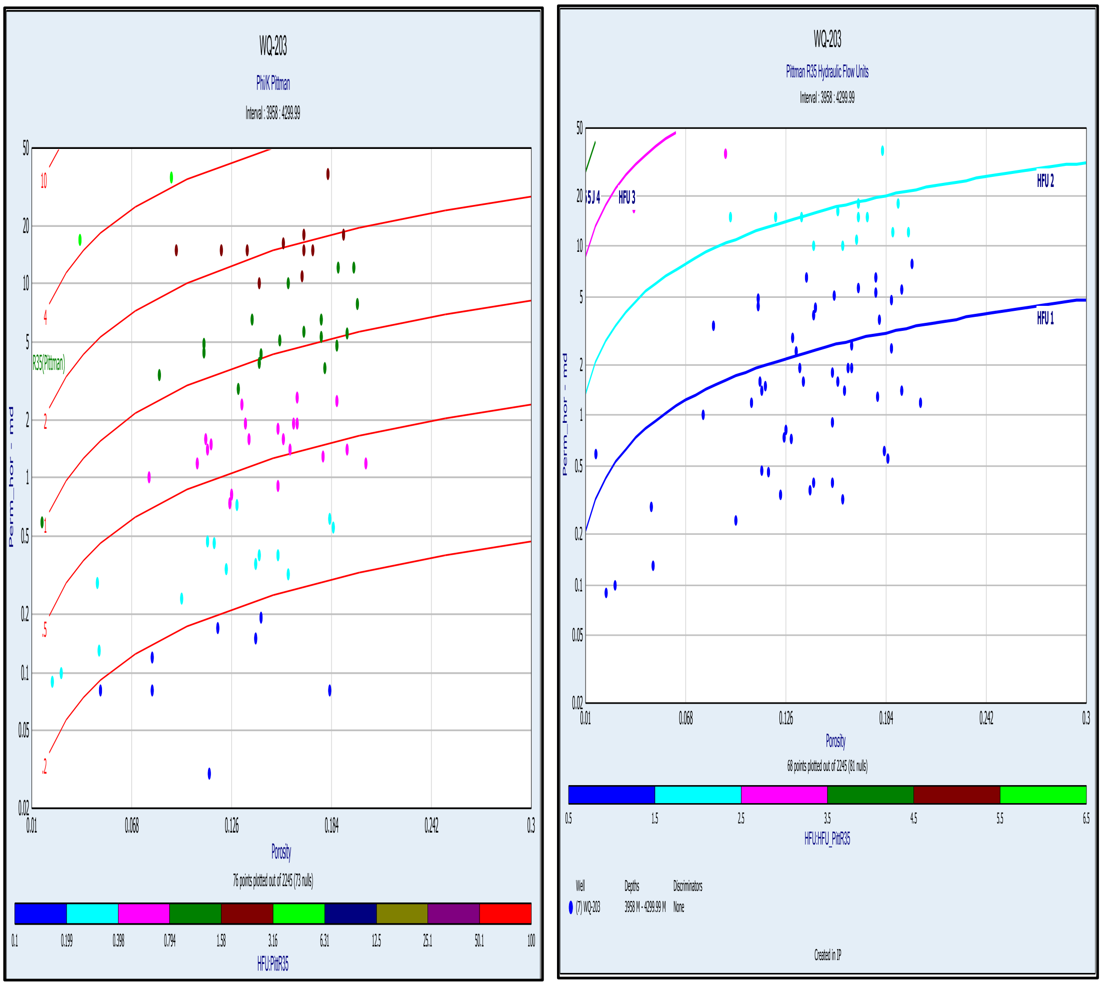

Figure 9- Pittman's plot (r35).

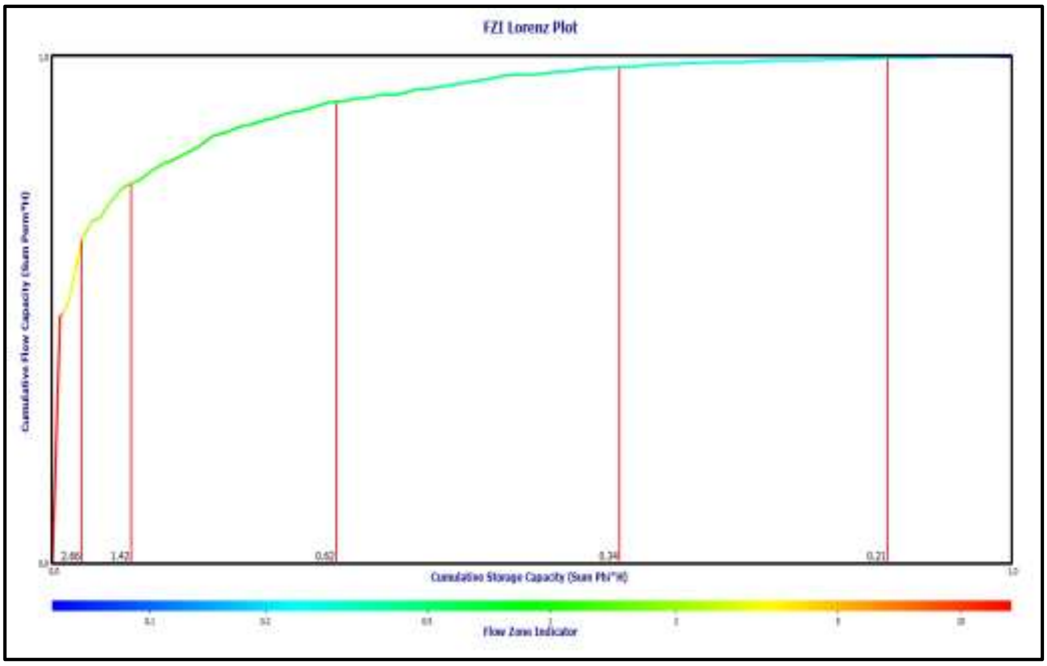

Figure 10- SML plot of the WQ-60.

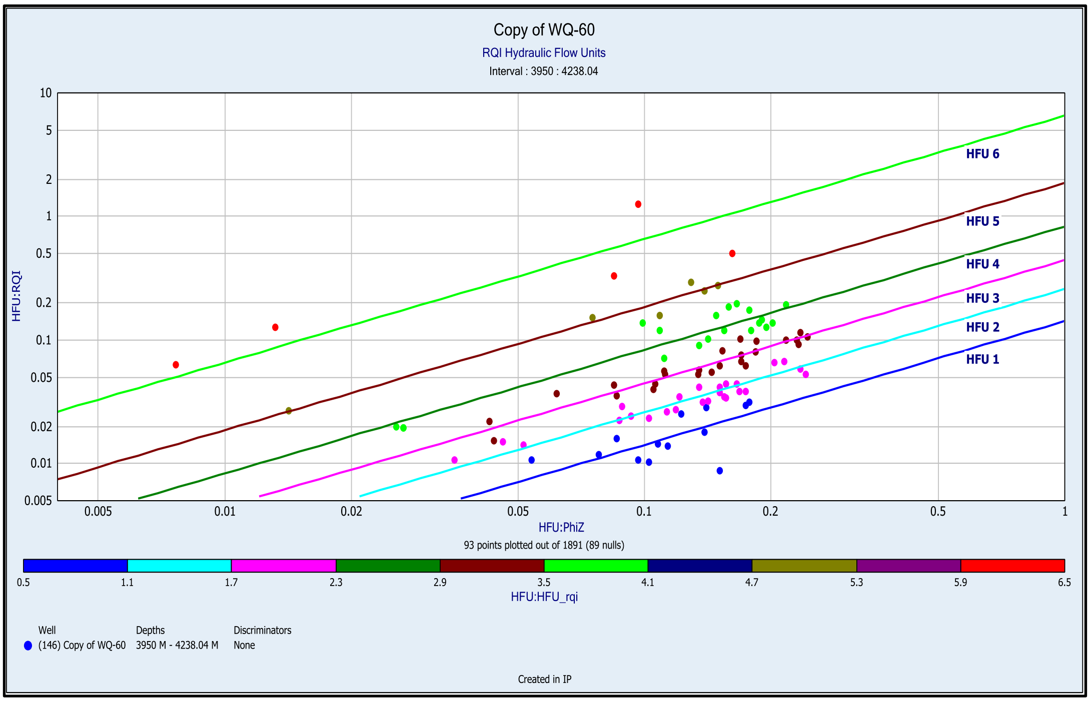

Figure 11- Log-log plot of RQI versus ϕz.

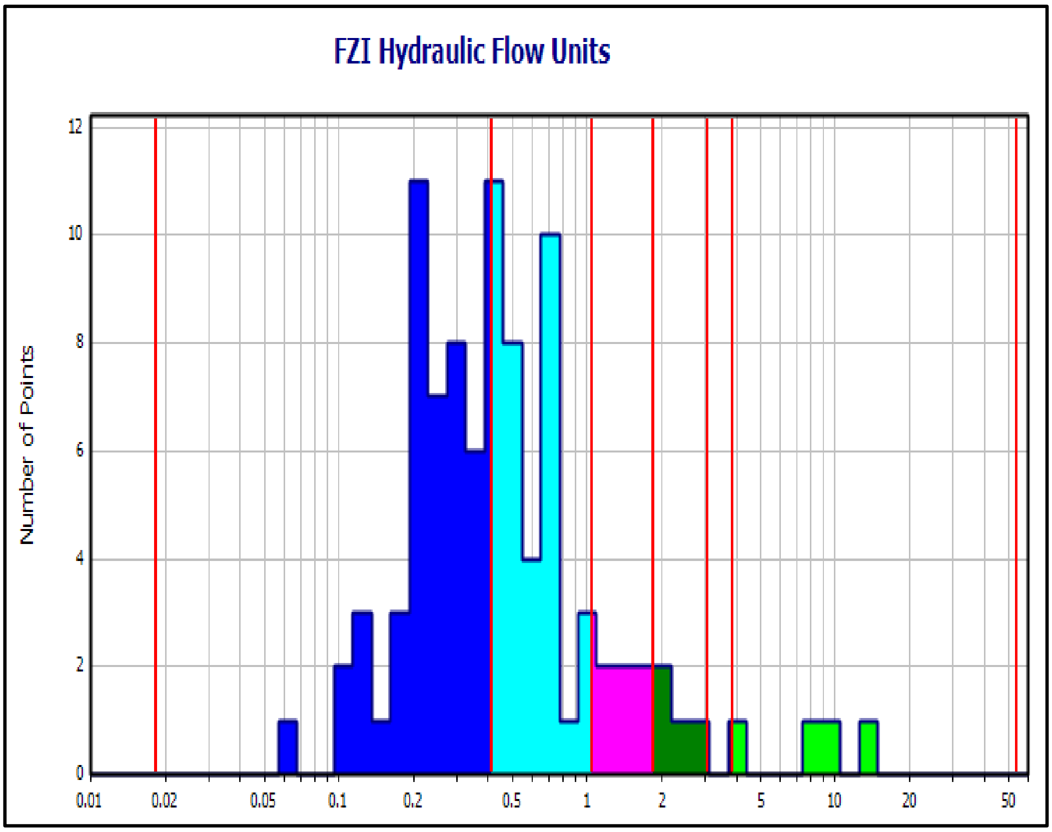

Figure 12- Histogram hydraulic flow units of WQ-60.

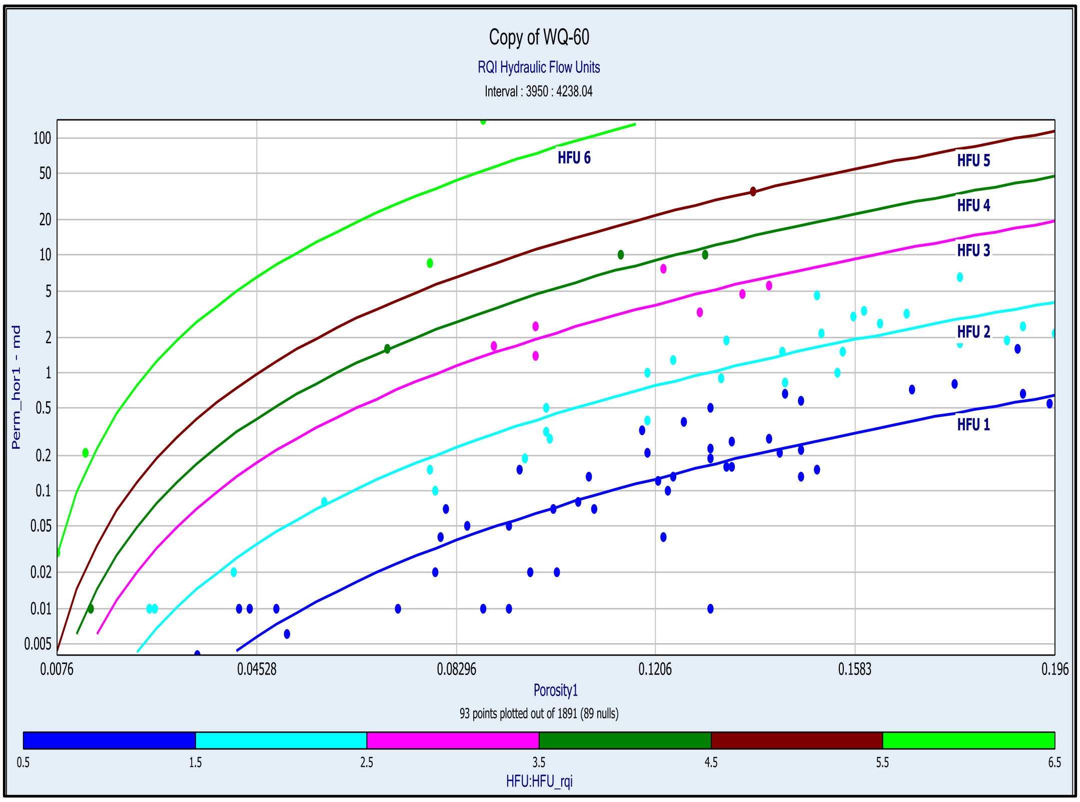

Figure 13- Flow units (Leverett's reservoir quality index).

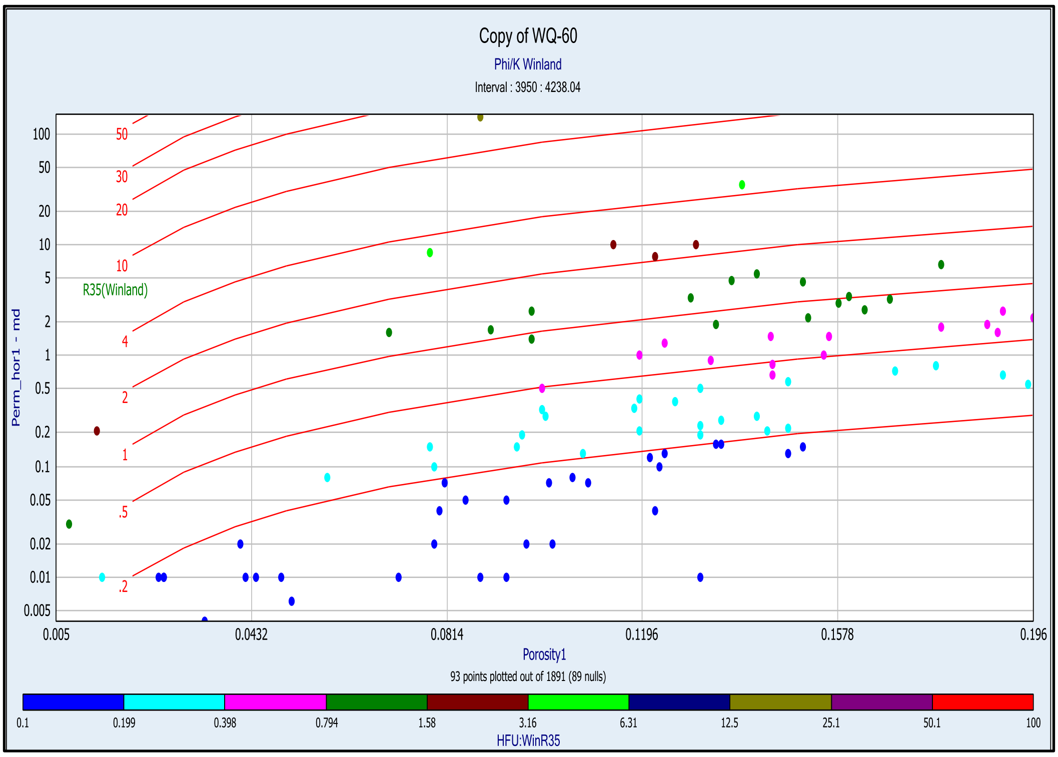

Figure 14- Winland's plot.

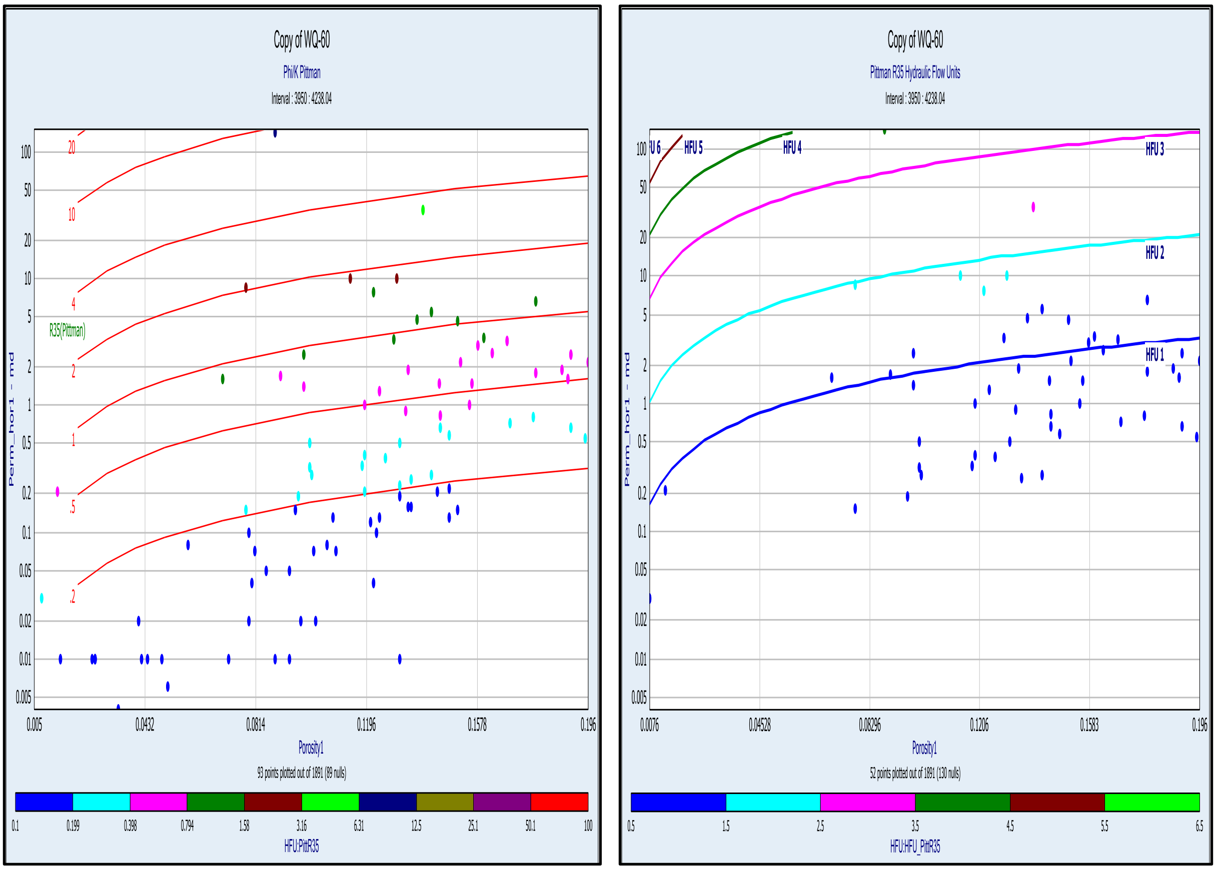

Figure 15- Pittman's plot (r35).

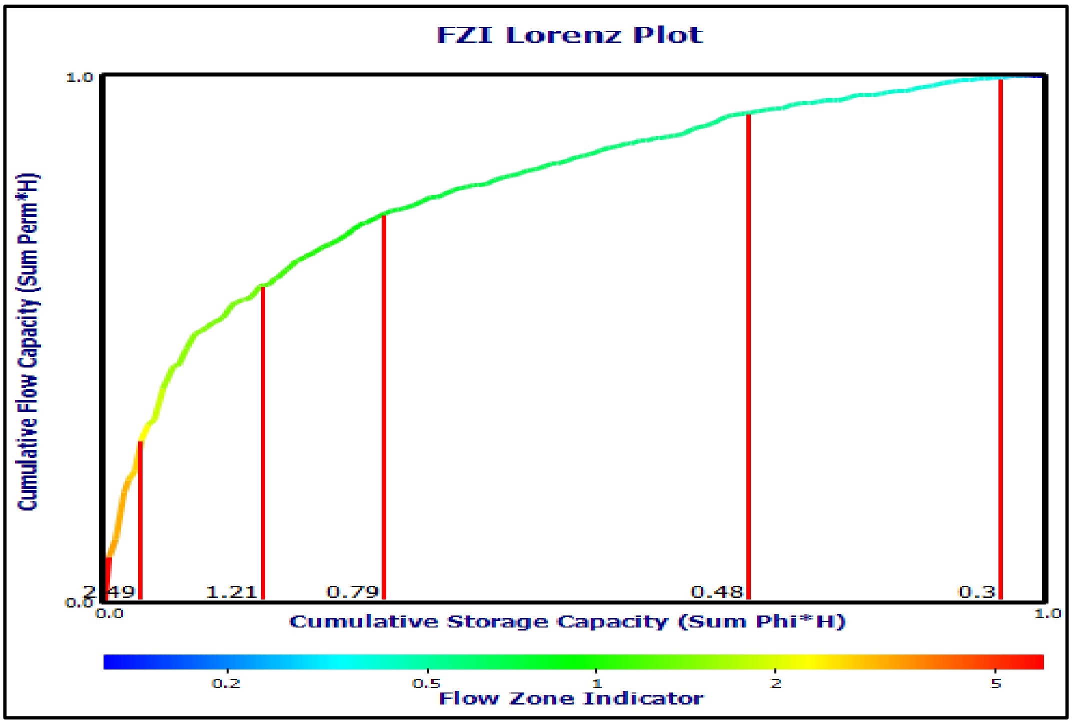

Figure 16- SML plot of the WQ-203.

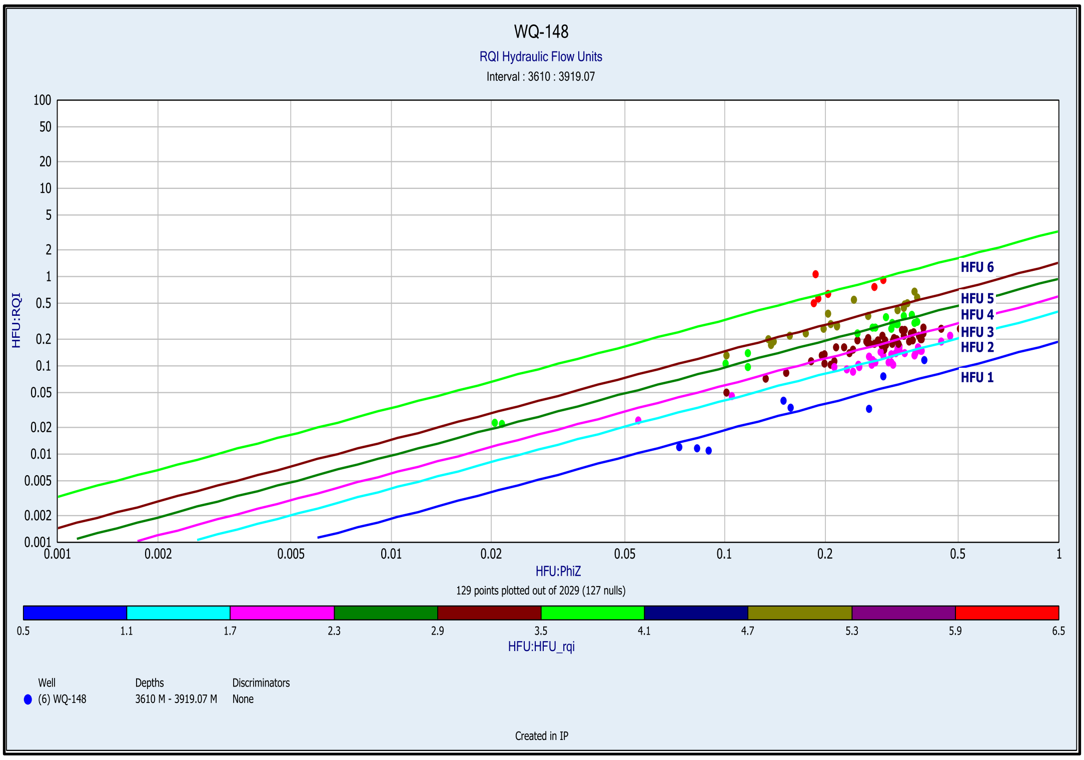

Figure 17- Log-log plot of RQI versus Φz.

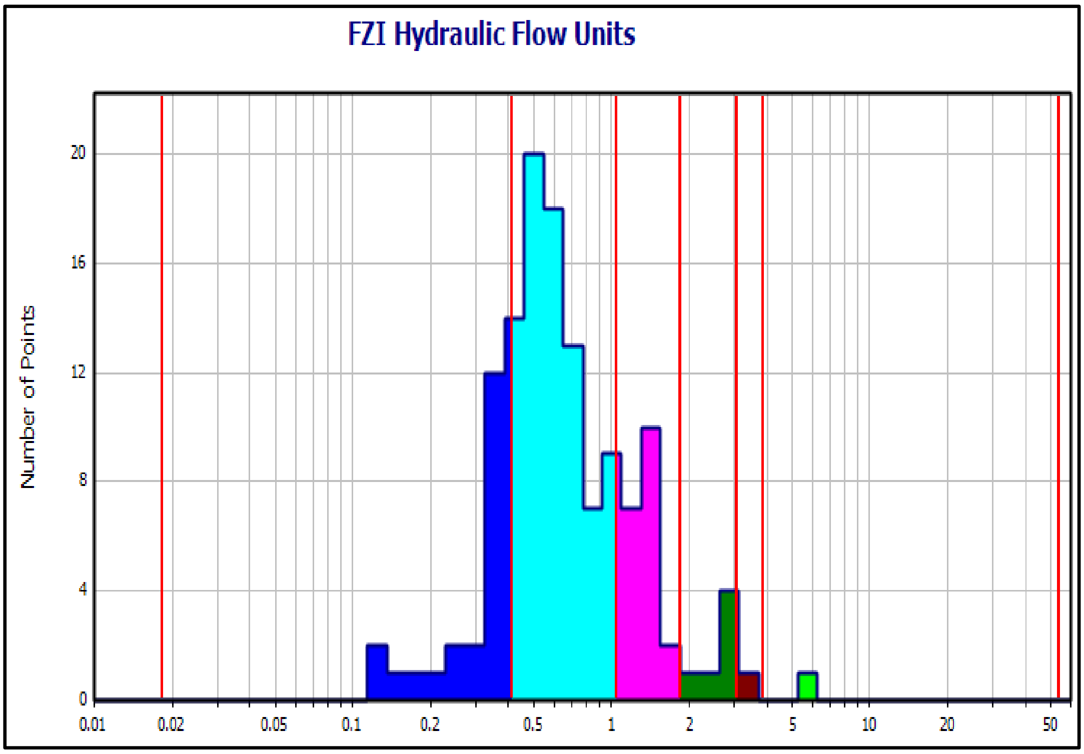

Figure 18- Histogram hydraulic flow units of WQ-148.

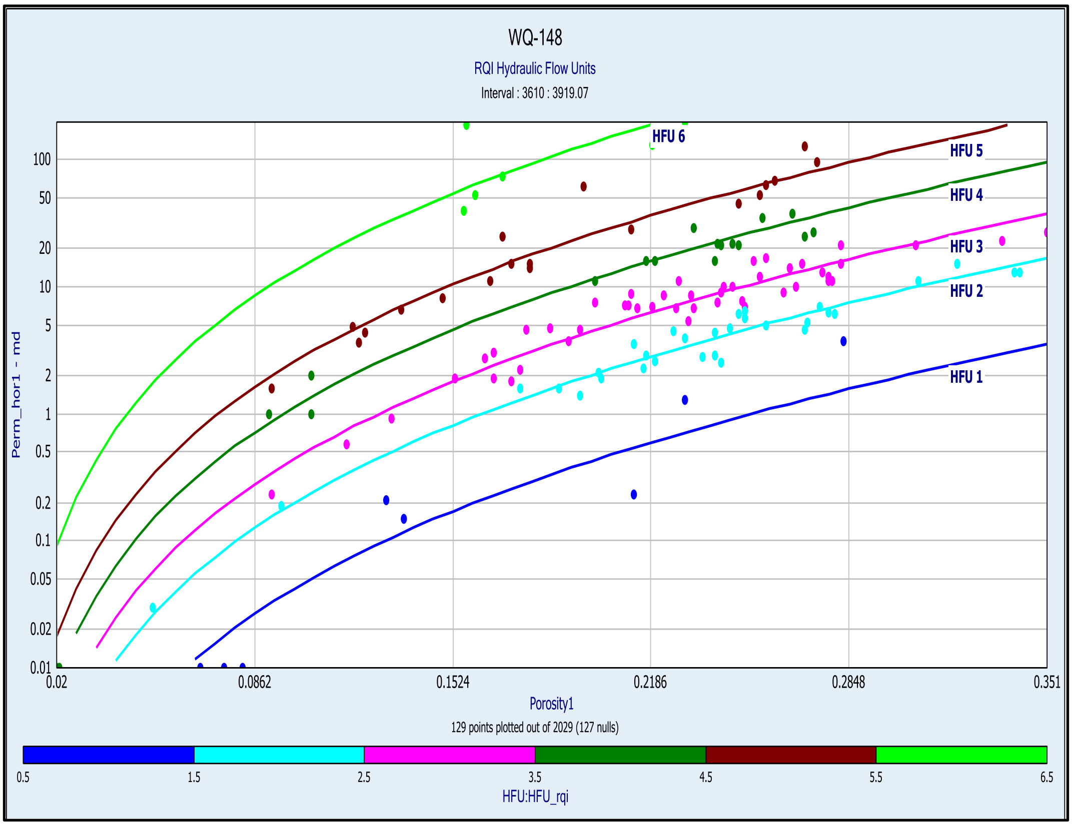

Figure 19- Flow units (Leverett's reservoir quality index).

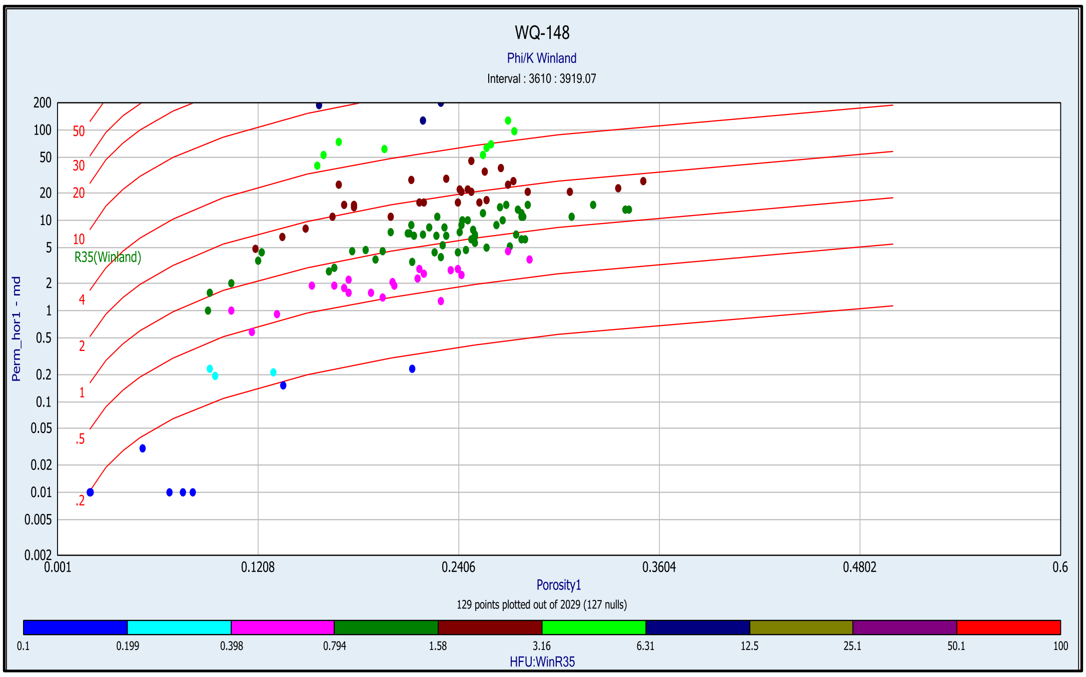

Figure 20- Winland's plot.

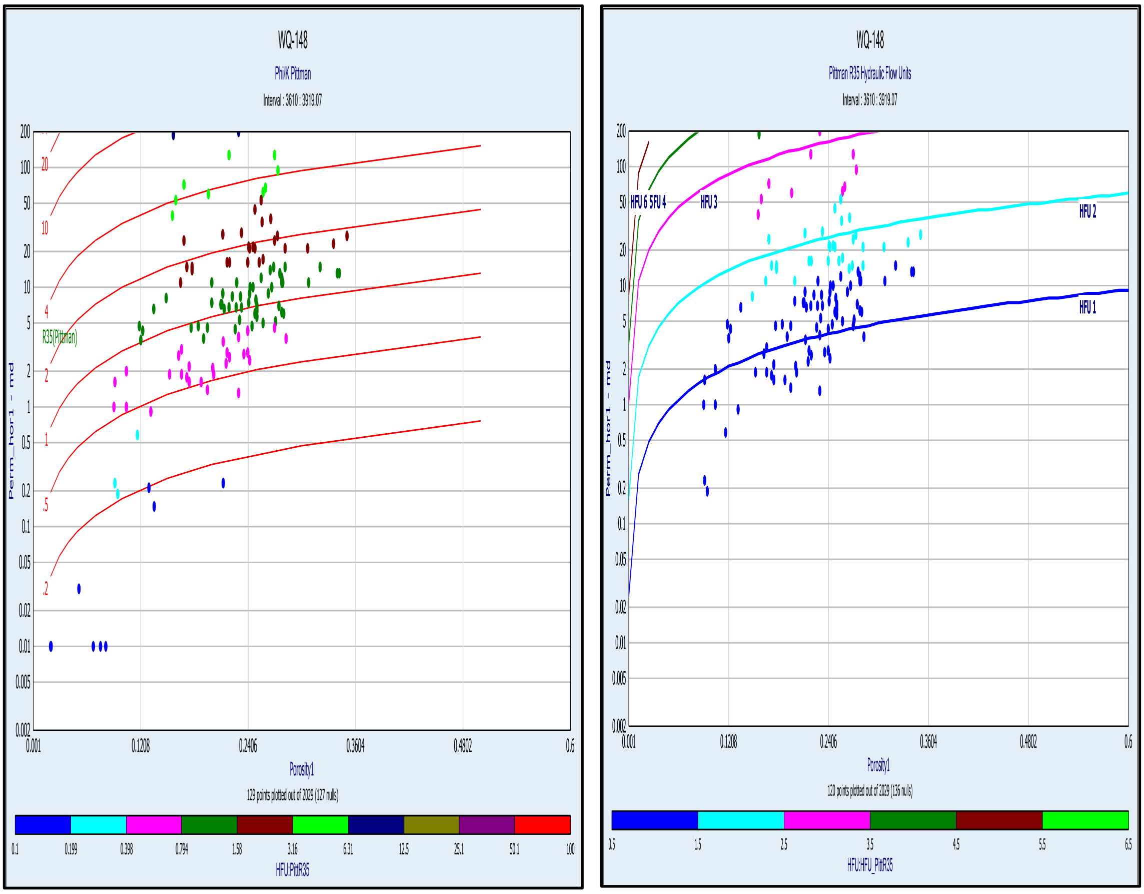

Figure 21- Pittman's plot (r35).

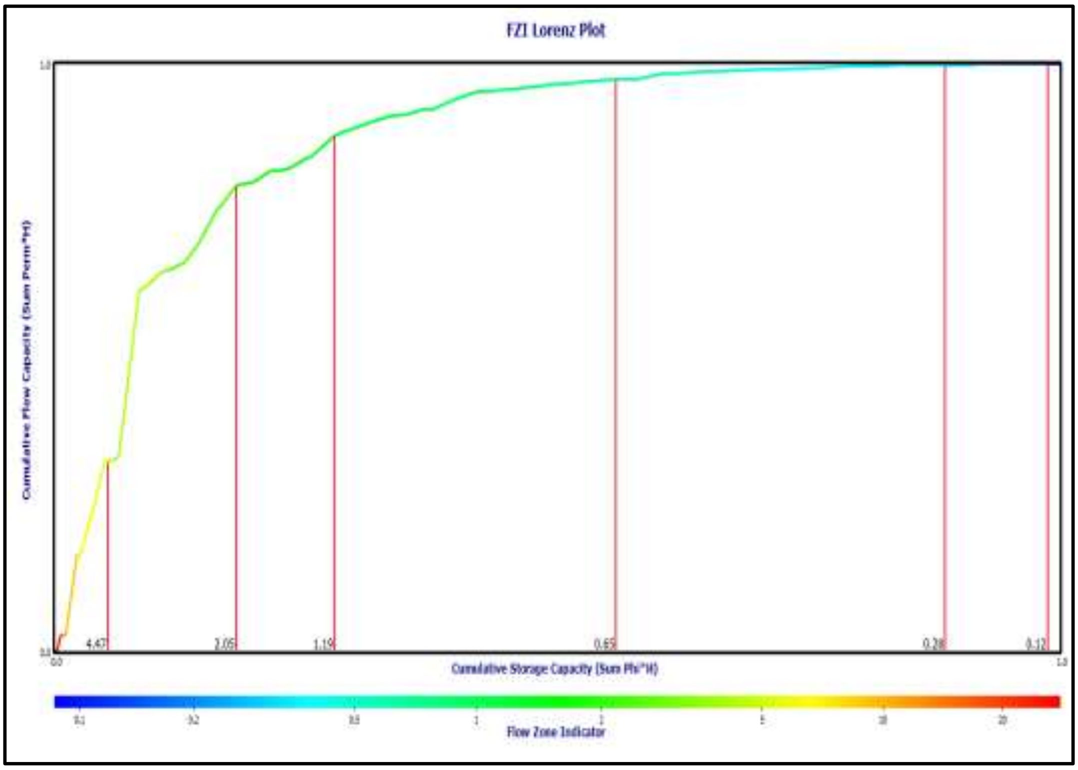

Figure 22- SML plot of the WQ-203.

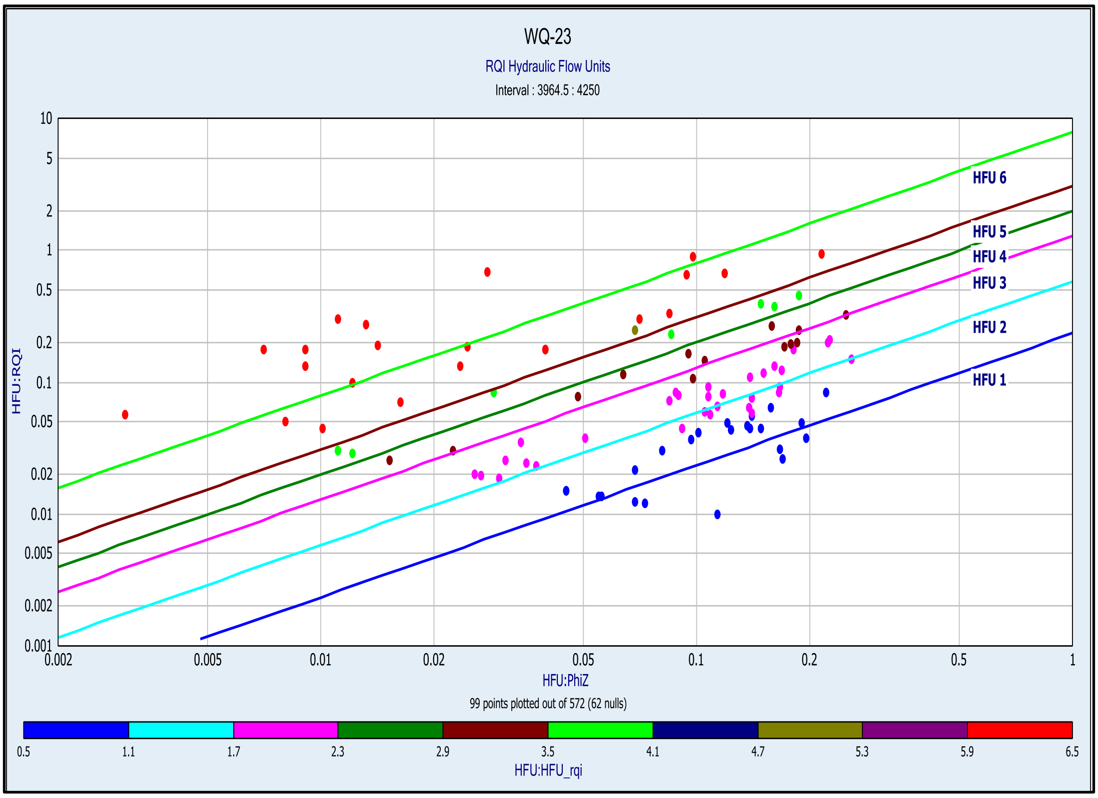

Figure 23- Log-log plot of RQI versus Φz.

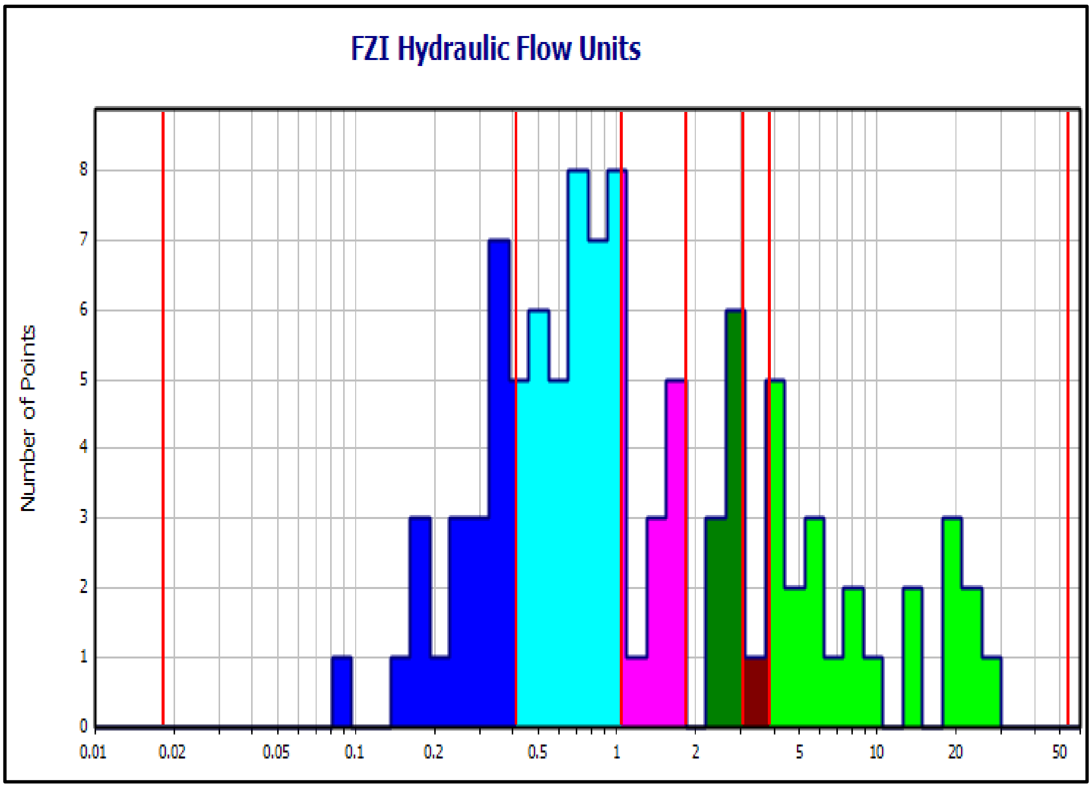

Figure 24- Histogram hydraulic flow units of WQ-23.

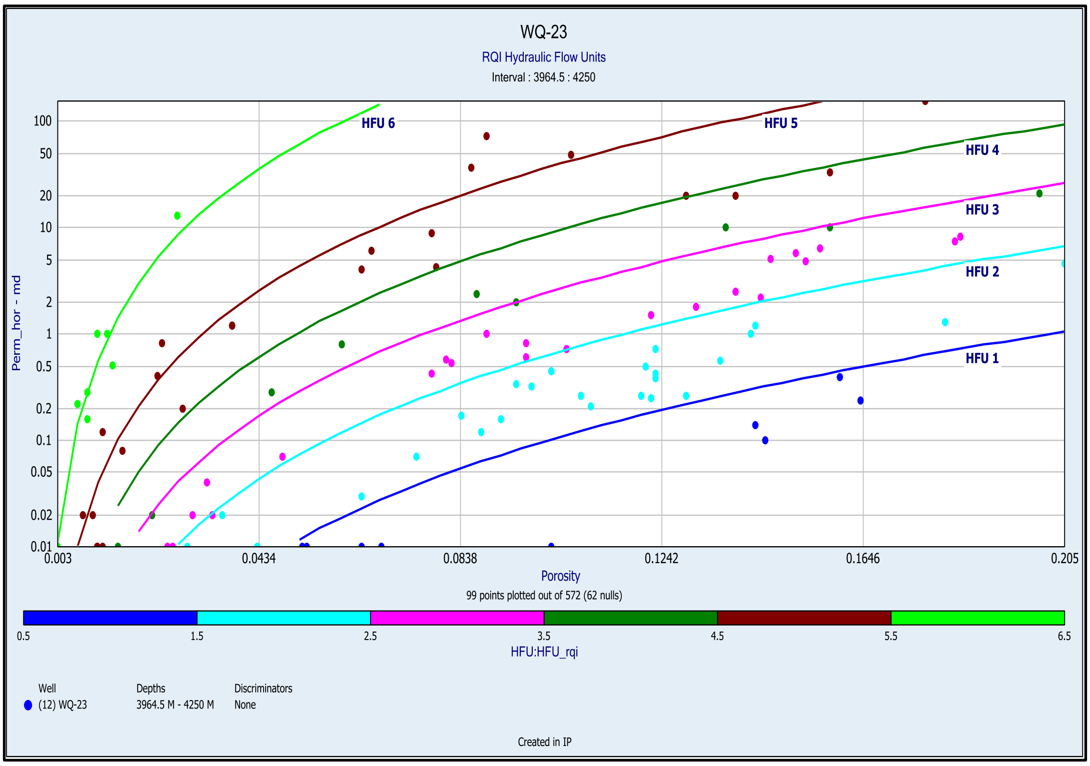

Figure 25- Flow units (Leverett's reservoir quality index).

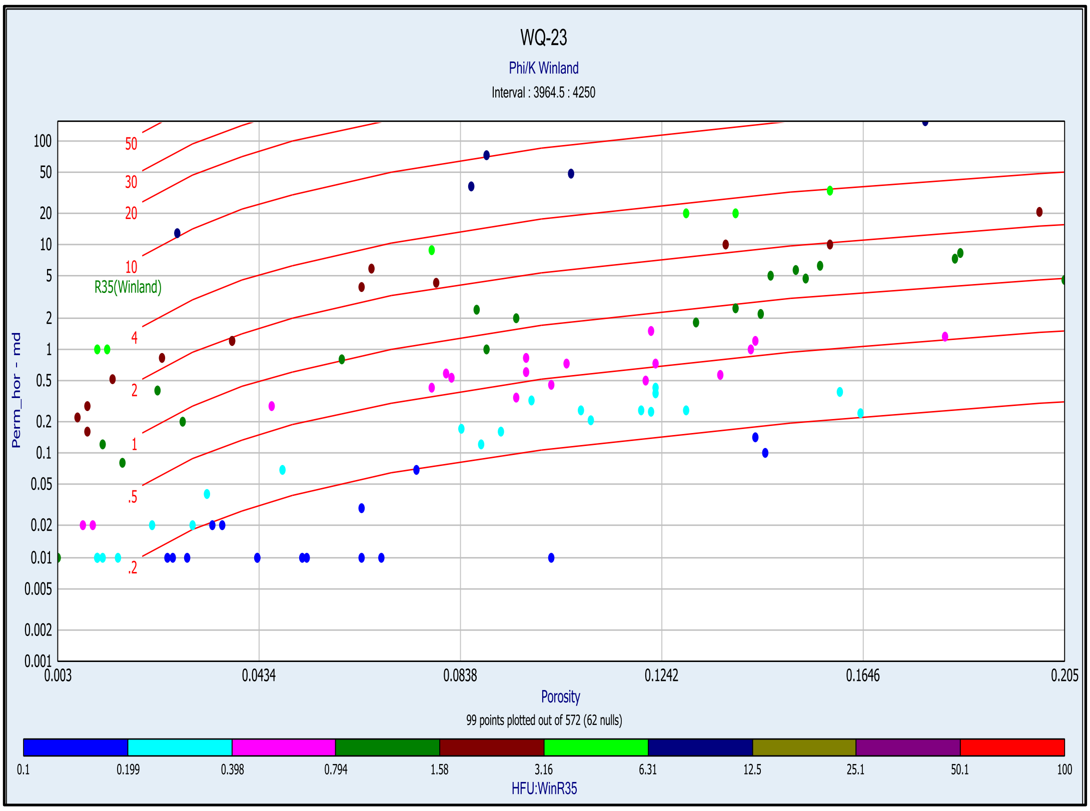

Figure 26- Winland's plot.

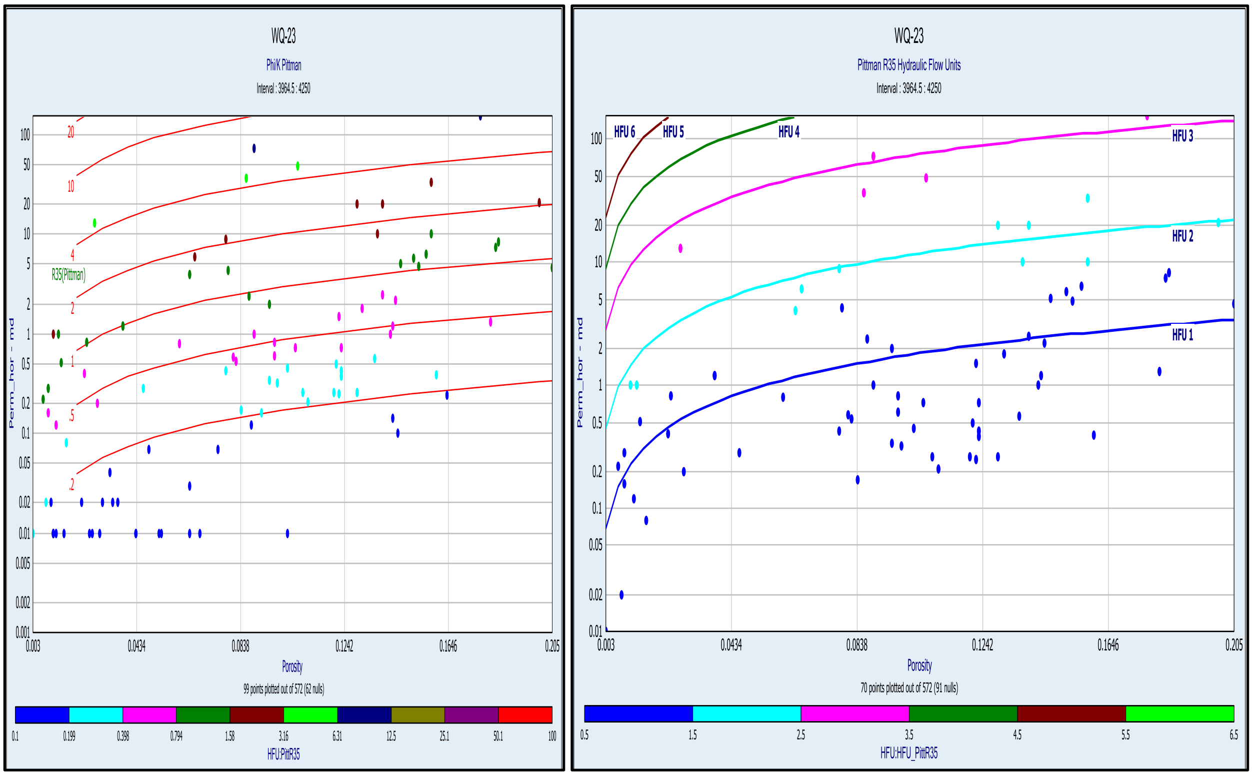

Figure 27- Pittman's plot (r35).

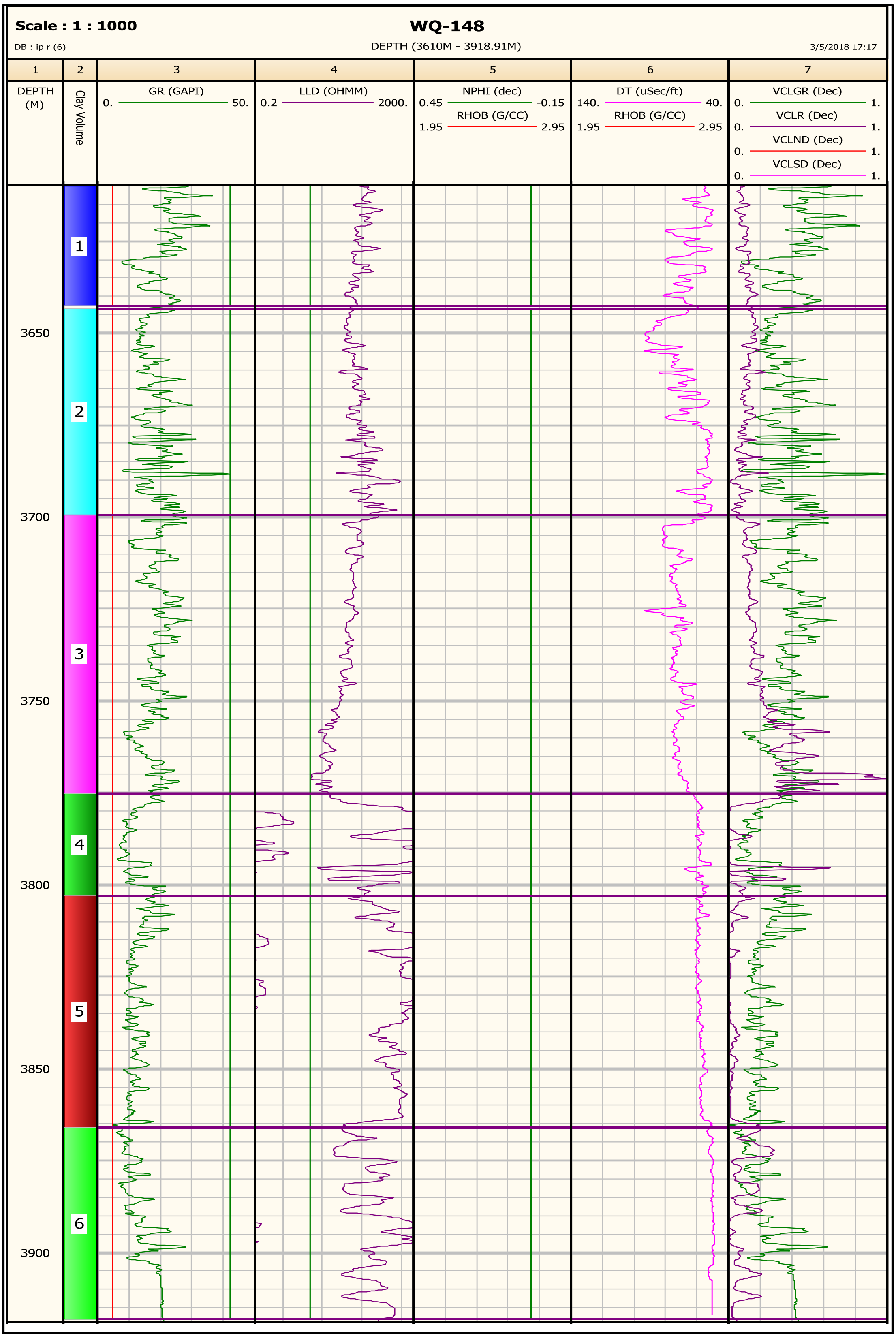

Figure 28- Depth plot of well logs, the distributions of the flow units of WQ-148.

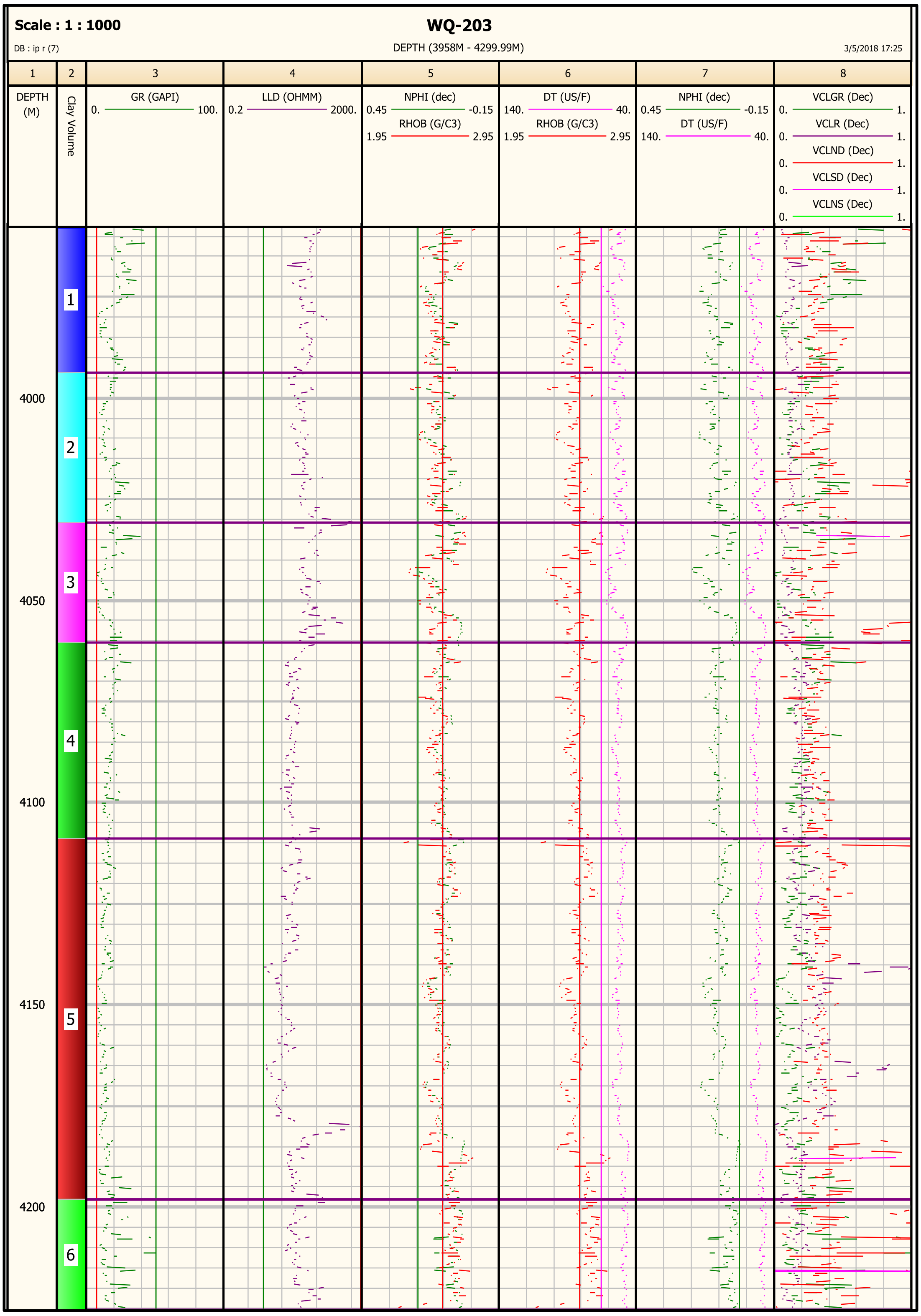

Figure 29- Depth plot of well logs, the distributions of the flow units of WQ-203.

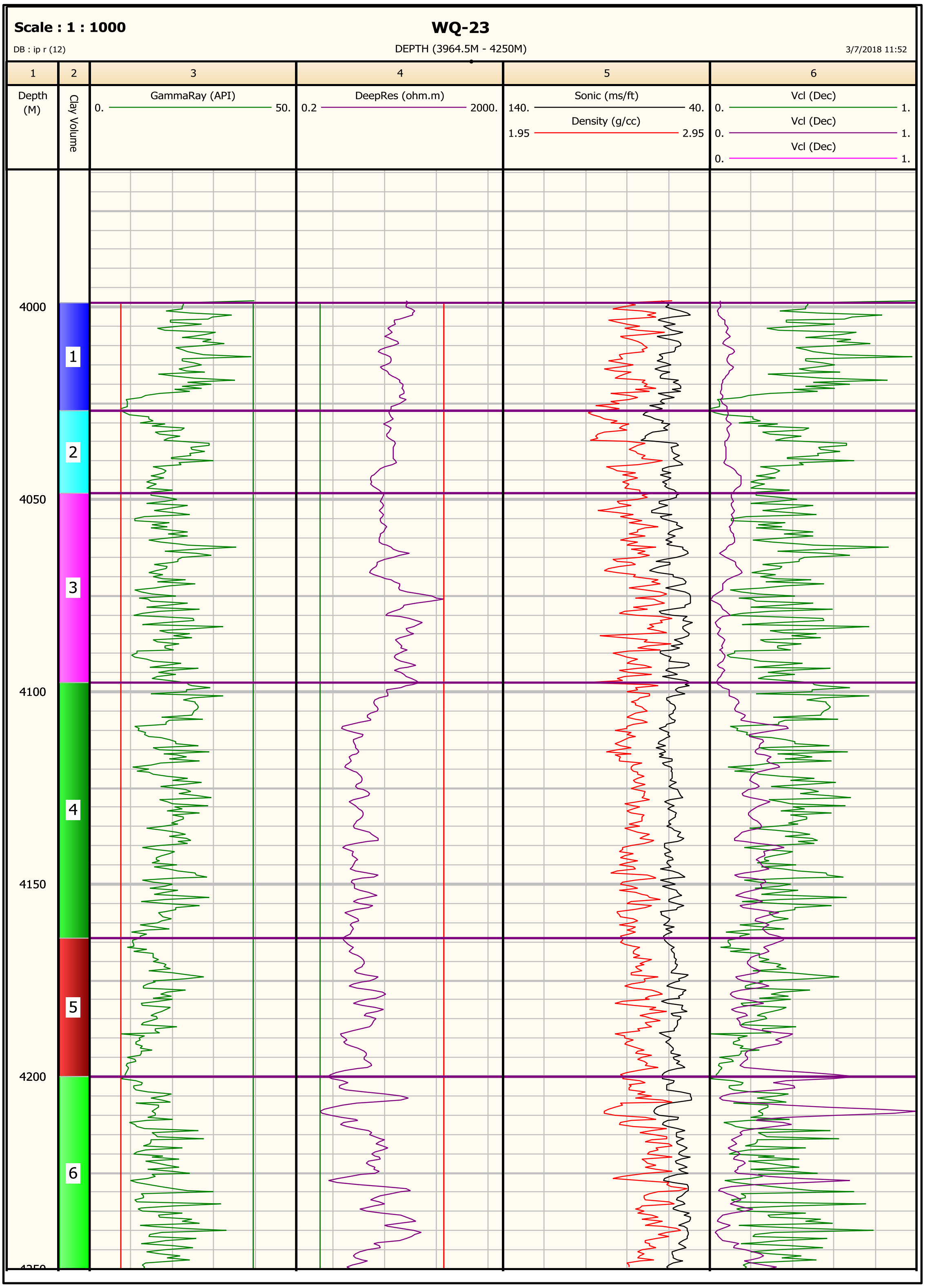

Figure 30- Depth plot of well logs, the distributions of the flow units of WQ-23.

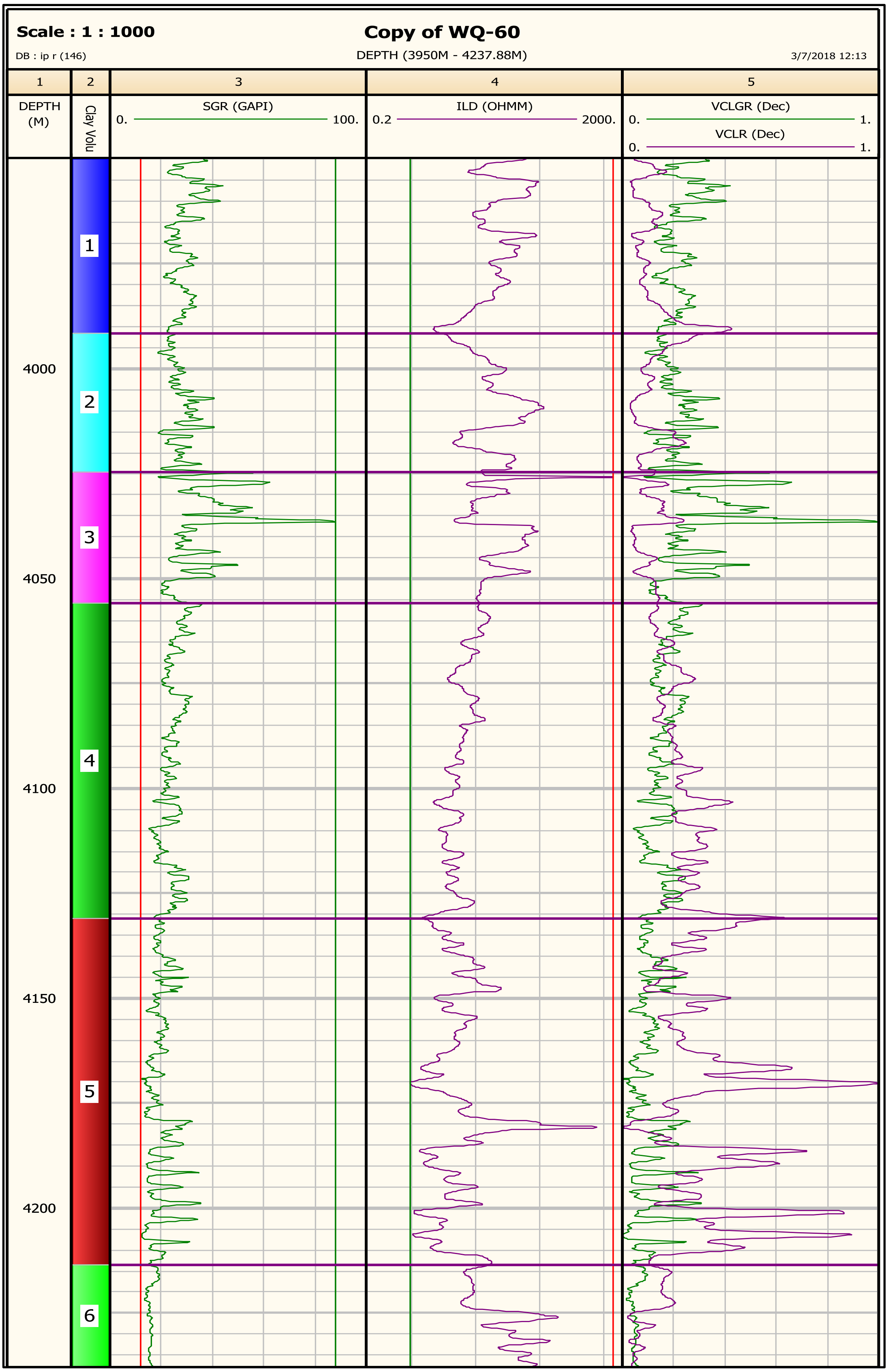

Figure 31- Depth plot of well logs, the distributions of the flow units of WQ-60.

Conclusions

The purpose of this study was to identify flow units for use in reservoir modeling of the Lower Cretaceous West Qurna oil field, South Iraq. Six flow units (FUs) were defined from analyses of porosity and permeability relationships. Data Flow units FU3, FU4 and FU6 have the best reservoir.

Because it possesses large and very large pores as well as medium to good permeability. The behaviors of well logs indicate that these units have very good hydrocarbon quantity in Yamama Formation of the West Qurna oil field.

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