The 2nd International Conf. on Water Resources & Arid Environment (2006)

Aquifers Parameters Estimation Using Well Log and Pumping Test Data, in Arid Regions -Step in Sustainable Development

Osama M. Sallam

Consultant, The High Commission of Makkah Province,Makkah, Saudi Arabia

Abstract

In this Paper an integrated approach to derive aquifer parameters from pumping tests data and well log (Gamma rays measurements) in sandstone is presented. This method is based on matching pumping tests analysis data especially hydraulic conductivity (K) and gamma ray measurements in well log. The linear and nonlinear regressions are then used to develop empirical relationships between pumping tests analysis data and well log data to determine formation parameters as shale ratio and hydraulic conductivity. This information is then fed into groundwater flow model calibration and inverse modeling. Finally, the method was tested using real data from south Egypt. It was concluded that hydraulic conductivity can be accurately predicted at observations wells locations without carrying out any pumping tests.

Introduction

Although the first geophysical log can be traced back to 1869 when Lord Kelvin ran a temperature tool in water well, the schlumberger Brothers together with H.G. Doll developed borehole logging in the 1920's. The history of borehole logging has revolved around meeting the needs of the petroleum industry with little development of specified tools for the groundwater field. Gamma tool measures the natural gamma radiation emitted by the various strata. Because the most common radioactive element is potassium -40, this log is generally regarded as an indicator of clay or shale content. Various theoretical models have been proposed to model the fluid–solid interaction in reservoir rocks for the purposes of lithology prediction and fluid substitution (e.g. Gassmann 1951; Kuster and Toksöz 1974; Brown and Korringa 1975; Han *et al.* 1986; Tao and King 1993 and Gist 1994). However, most of these theories have some drawbacks and can only be applied under certain conditions, and some require specific parameters that are not easily obtainable.

In this paper, it is proposed an alternative that provides a satisfactory prediction for Aquifer parameters. Our approach is based on the calibration of pumping test and well-log data. First, well-log and pumping test data are edited and corrected before they can be used. Second, nonlinear regression is employed to derive shale ratio, and hydraulic conductivity (K). A basic flow chart modified after Jan Yan 2002, describing the above procedure is given in Figure (1). The method requires log data and pumping test data as inputs, and the output is hydraulic conductivity (K), this method has been tested using field data obtained from south Egypt wells.

1. Calibration of Logs Data

In general, the available well-log data include deep and medium induction, spherically focused log, bulk density, interval transit time, gamma-ray, caliper and spontaneous potential log data. The pumping test data derived from the field measurements include drawdown. In order to calibrate well-log and pumping test data, the following steps are necessary.

1.1. Log depth correction

Some well logs exhibit anomalous and possibly incorrect data, so it is important to apply quality control when well-log curves are edited and reconstructs. Logging instrument responses are adversely affected by breakout of wall-rock during drilling, and stick-and-pull as logging tools are winched up the well. Gamma-ray log instrument response, in particular, is affected where the borehole is enlarged and distorted by shale breakout. In addition, there are difficulties in correlating depths among various separate run surveys, (Jan Yan 2002)

1.2. Rebuild log curves

When log data at certain depths show abnormal variations or are lost, a correction is normally done by finding a new relationship between erroneous log data and other logs for porosity (Por), shale content (Vsh) or other log curves (log1, log2…). The new log curves (log*) will then be used to replace the abnormal interval, (Schlumberger 1994), based on the following relationship.

$$\text{Log}^* = f\,(\text{Por}, \text{Vsh}, \text{log1}, \text{log2}) \qquad (1)$$

1.3. Curve normalization*:*

For a multi-well data, it is very common to have different log readings for the same formation or rock types in the same area. A standard formation (normally a shale formation) is defined to compare with the same log data in the same formation, and a normalization method is then used to correct log readings, (Jan Yan 2002)

2. Field Data

2.1. Gamma Ray and Shale ratio

The relationship between shale volume Vsh and gamma-ray log (GR) is determined using a non-linear regression which is similar to porosity equations based on a geostatistical method

$$\Delta GR = \frac{GR - GR_{clay}}{GR_{sand} - GR_{clay}} \qquad (2)$$

where: GR Gamma ray value at certain depth (cps) ,
GR_{sand} maximum Gamma ray value (cps), and
GR_{clay} minimum Gamma ray value (cps)

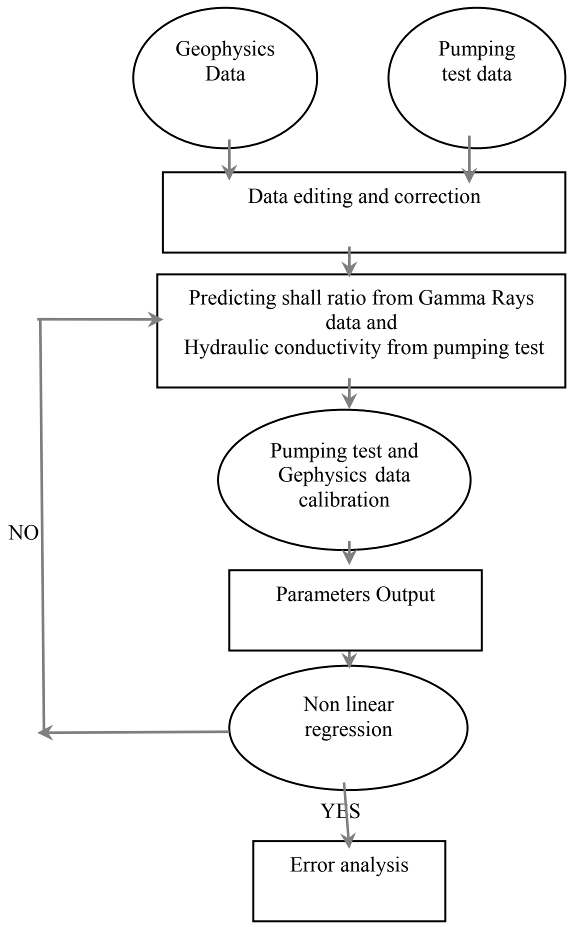


Figure (1) Flow chart for parameter estimation using well log and pumping test data

Figure (2) shows the gamma ray measurements at locations of production wells South Baris 3 and production well 53.

2.2. Pumping Test Data

In South Egypt, there are 40 pumping tests have been done by Research Institute for Groundwater, (RIGW, 2000), representing all areas where hydraulic conductivity (K) values of the main groundwater aquifers had been determined. Table (1) shows Shale ratio and hydraulic conductivity (K) from pumping tests at 29 production wells.

Table (1) Shale ratio and hydraulic conductivity (K) from pumping tests.

Well ID	Shale Ratio	K(m/d) Pumping test	Well ID	Shale Ratio	K(m/d) Pumping test
prd53	0.0954	13.85	prd83	0.1790	5.68
prd51	0.1185	13.00	prd64	0.1802	5.09
prd33	0.1254	9.70	prd49	0.1823	5.2
prd69	0.1259	11.48	prd65	0.1848	5.11
prd25	0.1420	8.78	prd66	0.19	3.61
prd32	0.1486	7.03	prd76	0.1900	4.03
prd73	0.1500	8.33	prd75	0.2000	3.79
prd72	0.1500	7.82	prd10	0.2100	3.96
prd55	0.1599	7.07	farm 2	0.2210	3.10
prd78	0.165	7.42	sb1	0.2222	3.00
prd67	0.17	5.82	prd16	0.2339	2.67
prd71	0.1724	5.74	darb1	0.251	2.00
prd81	0.1730	5.59	darb11	0.2730	1.60
prd65	0.1748	5.11	darb5	0.2800	1.46
sb3	0.3050	1.30			

Estimation of Hydraulic Conductivity (K)

Once hydraulic conductivity (K) is obtained from Pumping test and also shale volume ratio obtained from log data, a nonlinear regression method is employed to estimate the hydraulic conductivity (K) so we can build an equation for hydraulic conductivity (K) prediction. Figure (3) shows shale ratio and hydraulic conductivity (K) relationship. Figure (4) shows shale ratio and estimated hydraulic conductivity (K) values at different depths for production well 53 locations and also figure (5) shows shale ratio and hydraulic conductivity (K) at different depths for production well Sb3 location using an empirical equation. from figures (4, 5) we can note that at production well 53 shale value is low and hydraulic conductivity (K) is high but production well Sb3 shale value is high and hydraulic conductivity (K) is low.

Empirical equation

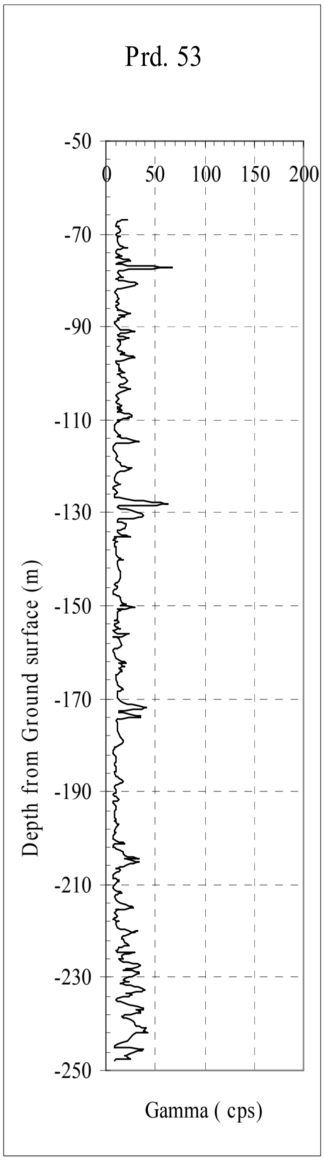
Nonlinear regression was employed to derive the relationship between shale Ratio, hydraulic conductivity (K) as an empirical equation,

$$K = 49.786e^{-12.516\,SHr} \pm \text{error} \quad (3)$$

Where:

K Hydraulic conductivity (m/day), and

SHr Shale Ratio



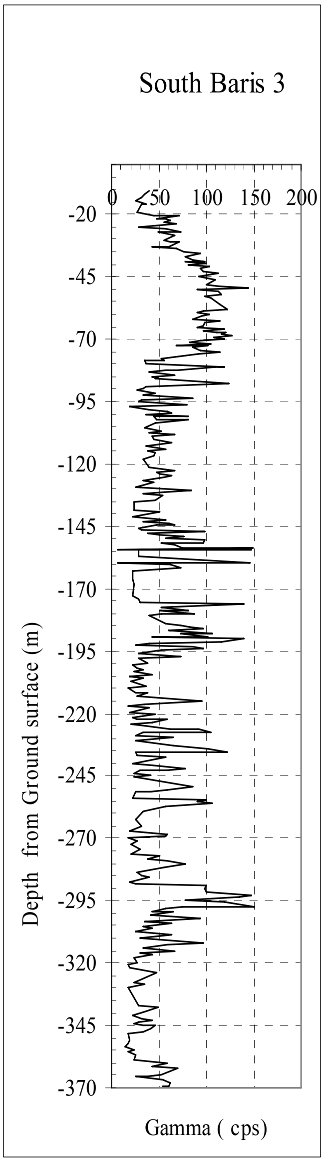


Figure (2) Gamma ray measurements at production wells- South Baris 3 and production well 53.

Emprical Equation verification

In South Egypt –Tushka area there are 11 pumping tests that have been done by Research Institute for Groundwater, (RIGW, 2000), for verification and estimating the errors. Table (2) shows errors in the hydraulic conductivity (K) which has estimated using empirical equation; it is shown that the error is about ±5%

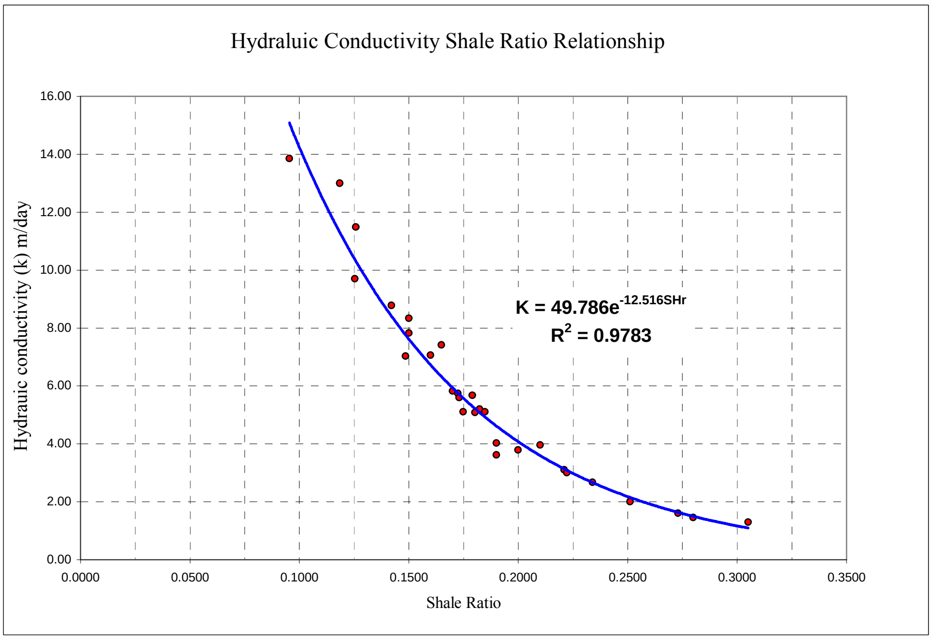


Figure (3) Hydraulic conductivity (K) – shale ratio relationship at south Egypt area

Field Applications

The real well-log data of gamma-rays measurements collected from observation wells at South Egypt especially at Tushka area using the empirical equation (3) shows that hydraulic conductivity (K) can be accurately predicted at observations wells locations and depths without carrying out any pumping tests.

Table (3) shows that hydraulic conductivity (K) estimated at observation wells locations in Tushka area which will be used in groundwater flow modeling. Figure (6) shows hydraulic conductivity (K) at different depths for observation well Ow5 location

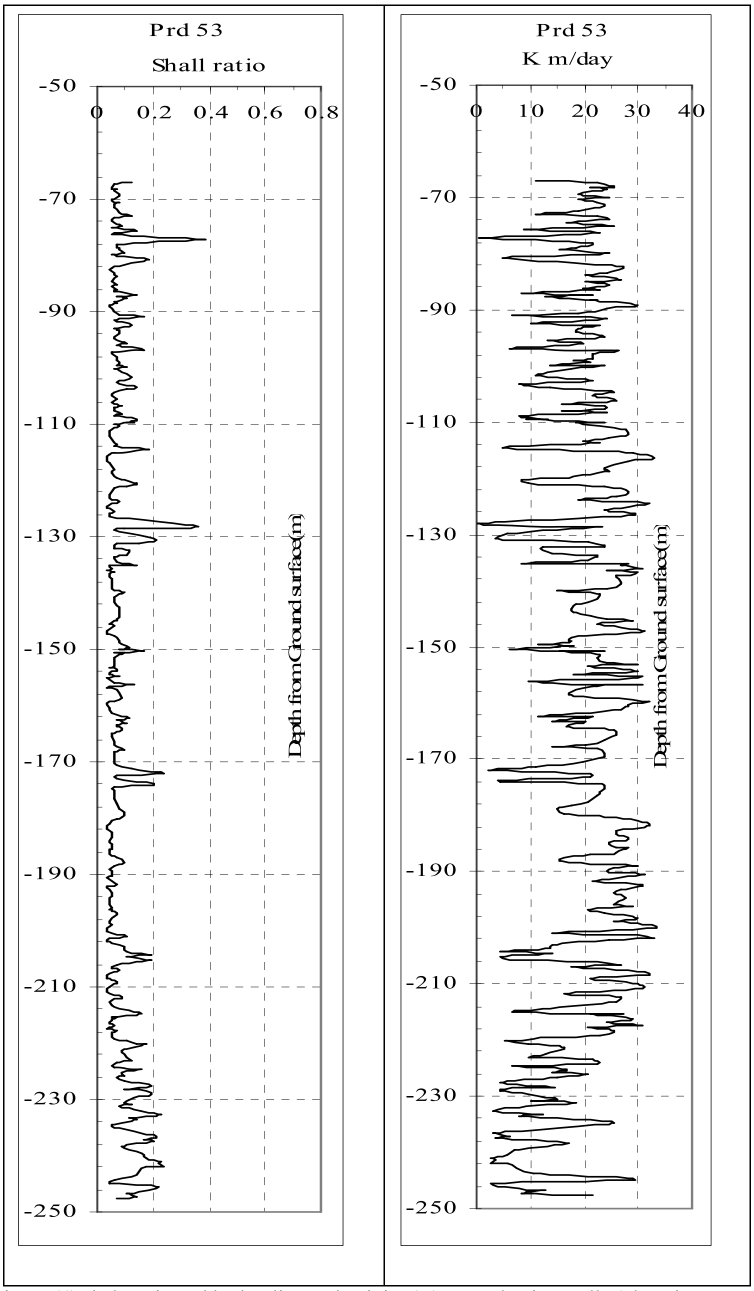


Figure (4) shale ratio and hydraulic conductivity (K) at production well 53 location.

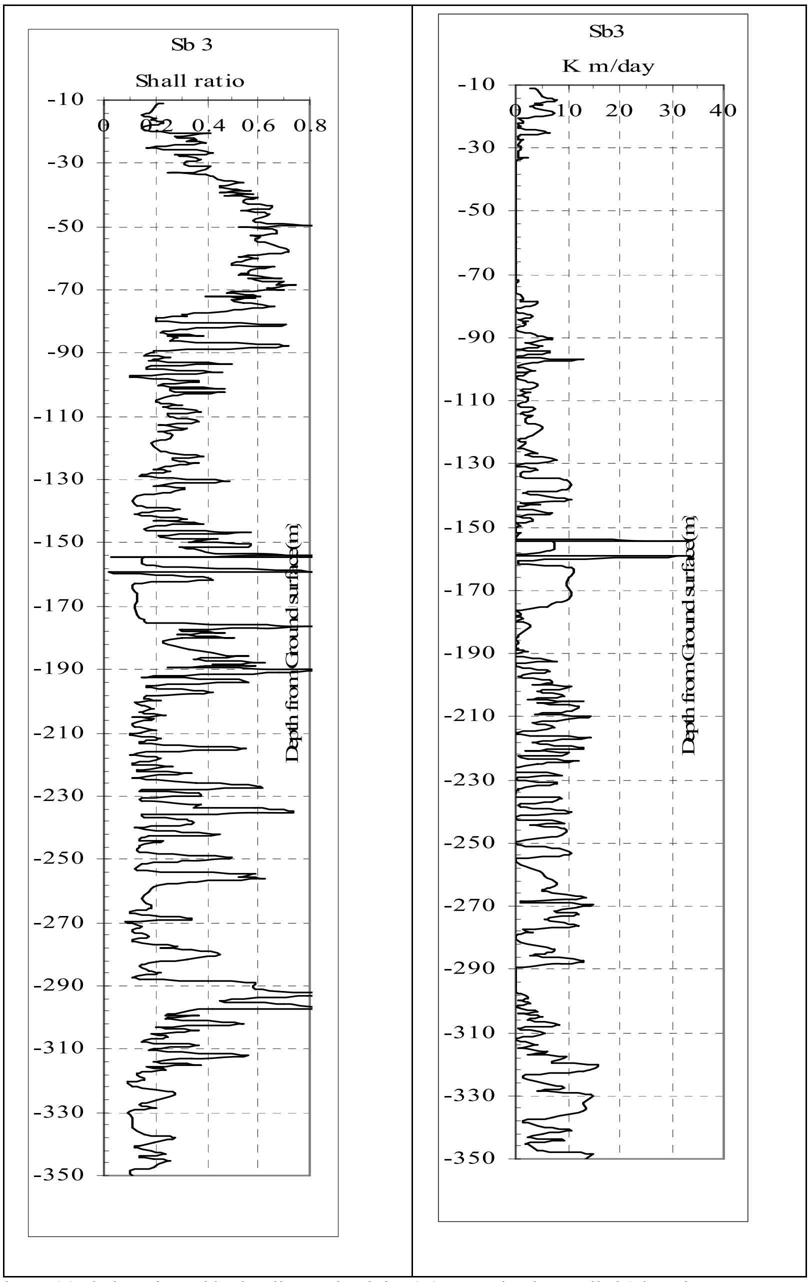


Figure (5) shale ratio and hydraulic conductivity (K) at production well sb3 location

Table (2) Estimated errors in hydraulic conductivity using empirical equation (3),

Well ID	Shale ratio	K (m/d) from Pumping test	K (m/d) from Equation	Error (m/d)	Error%
prd48	0.1100	12.50	12.57	0.0657	0.52%
prd29	0.1380	8.95	8.85	-0.0971	-1.10%
prd82	0.1740	5.30	5.64	0.3378	5.99%
prd10	0.2000	3.96	4.07	0.1136	2.79%
wrc	0.214	3.30	3.42	0.1189	3.48%
darb3	0.2481	2.15	2.23	0.0811	3.64%
sb2	0.2819	1.39	1.46	0.0741	5.08%
prd23	0.152	7.48	7.43	-0.0525	-0.71%
prd64	0.157	7.09	6.98	-0.1086	-1.56%
prd12	0.2034	4.10	3.90	-0.1961	-5.03%
darb5	0.2800	1.46	1.50	0.0367	2.45%

Table (3) Hydraulic conductivity (K) estimation at Observation wells locations

Well ID	N	E	Drilling depth(m)	Shale ratio value	Estimated K (m/day)
Ow 1	22° 46’ 57.1’’	31° 40’ 02.0’’	322	0.2362	2.59
Ow 2	22° 36’ 02.4’’	31° 29’ 49.4’’	332	0.1950	4.34
Ow 3	22° 52’ 11.7’’	31° 45’ 44.6’’	264	0.3048	1.10
Ow 4	22° 38’ 36.4’’	31° 30’ 21.0’’	260	0.1778	5.38
Ow 6	22° 40’ 30.0’’	31° 27’ 51.0’’	330	0.1788	5.31
Ow 7	23° 07’ 47.7’’	31° 24’ 31.5’’	251	0.3213	0.89
Ow 8	22° 49’ 06.6’’	31° 59’ 50.0’’	224	0.2397	2.48
Ow 9	22° 34’ 18.8’’	31° 15’ 34.9’’	315	0.1756	5.53
Ow 10	22° 56’ 53.7’’	31° 18’ 12.5’’	91	0.2669	1.76
Ow 13	22° 28’ 19.0’’	30° 44’ 32.0’’	186	0.3489	0.63
Ow 19	23° 03’ 49.5’’	31° 27’ 55.6’’	309	0.3482	0.64

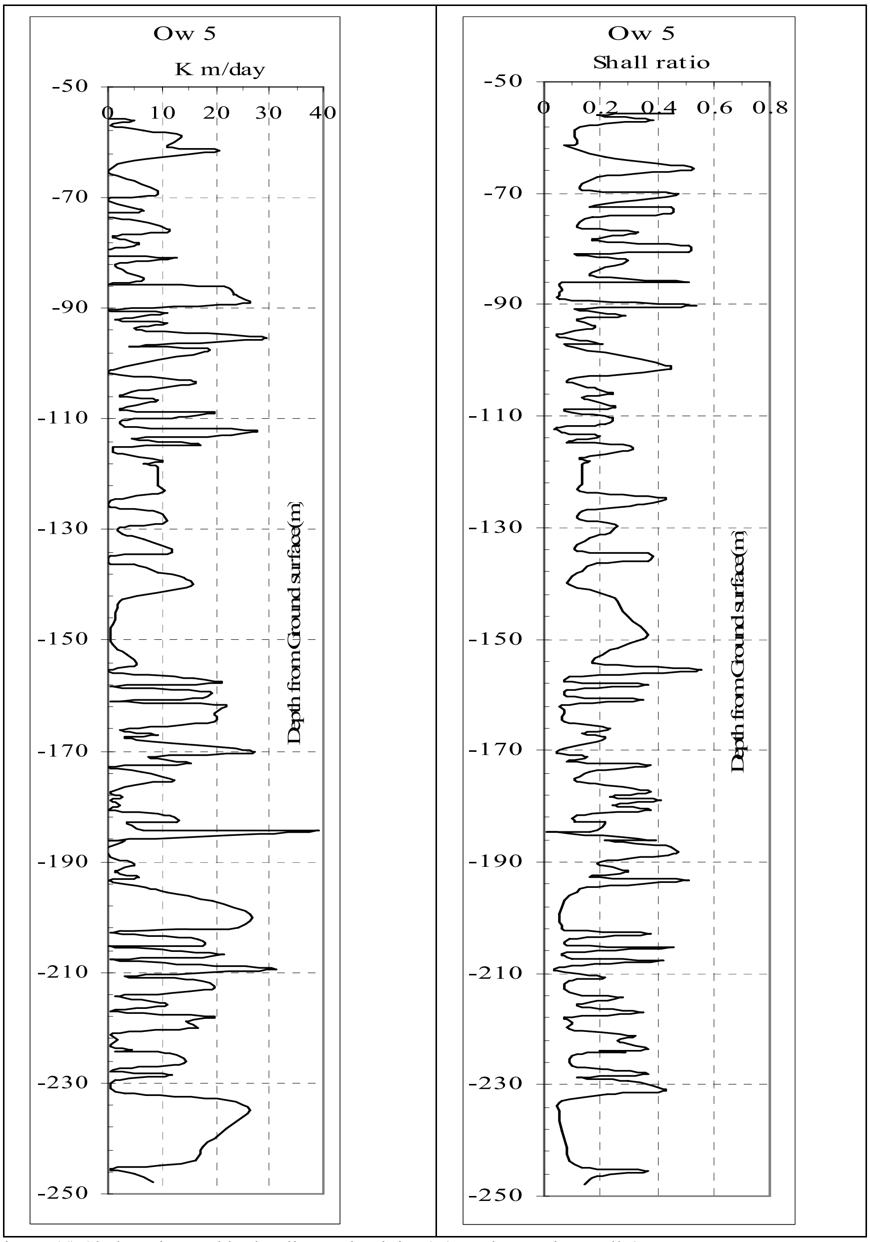


Figure (6) Shale ration and hydraulic conductivity (K) at observation well Ow5

Conclusions

- Nonlinear regression is used to develop empirical relationship between pumping tests data and well log data to determine aquifer parameters. This information is then fed into groundwater flow model calibration and inverse modeling
- Using a similar producer, others groundwater aquifer parameters, such as, transmissivity, and storage coefficient can also be determined

References

Brown, J.S. & Korringa, J. 1975. On the dependence of the elastic properties of a porous rock on the compressibility of the pore fluid. Geophysics, 40, 608–616.

Gassmann, F. 1951. Elasticity of porous rocks. Vierteljahrschrift der Naturforschenden gesellschaft in Zurich, 96, 1–21.

Gist, G.A. 1994. Interpretation of laboratory velocity measurements in partially gas-saturated rocks. Geophysics, 59, 1100–1109.

Han, D.H., Nur, A. & Morgan, D. 1986. Effects of porosity and clay content on wave velocities in sandstones. Geophysics, 51, 2093–2107.

Jun Yan . 2002. ”Reservoir parameters estimation from well log and core data , a case study from the North sea”EAGE/Geological society of London , EAGE/Geological Society of London, Petroleum Geoscience, Vol. 8 2002, pp. 63–69

Kuster & Toksöz, M.N. 1974. Velocity and attenuation of seismic waves in two phase media: part 1: Theoretical formulation. Geophysics, 39, 587–606.

RIGW. 2000 . “Technical reports of production wells in Tushka area “

Schlumberger. 1994. Log interpretation manual and principles, 1. Schlumberger Well Survives, Inc., Houston.

Tao, G. & King, M.S. 1993. Porosity and pore structure from acoustic well-logging data. Geophysical Prospecting, 41, 435–451.

تقدير المعاملات الهيدروليكية لخزانات المياه الجوفية باستخدام تجارب الضخ والرصد الجيوفيزيقى لثقب الحفر فى المناطق الجافة

أسامة محمد احمد سلام

الهيئة العليا لتطوير مكة المكرمة - مكة المكرمة – السعودية

يتناول هذا البحث كيفية تقدير المعاملات الهيدروليكية لخزانات المياه الجوفية و خصوصا معامل الامرارية من قياسات أشعة جاما لاى ثقب حفر وذلك بايجاد العلاقة الرياضية التجريبية بين نسبة الطفلة والتى يتم حسابها من قياسات اشعة جاما فى ثقب الحفر ومعامل الامرارية الذى تم حسابة وتقديره من اختبارت الضخ المستمر لبعض الآبار الانتاجية وقد تم استخدام بيانات حقيقية لآبار انتاجية تم حفرها فى منطقة جنوب مصر لاستباط هذه العلاقة ومن ثم أمكن تطبيقها على قياسات اشعة جاما لبعض آبار المراقبة بنفس المنطقة وأمكن باستخدام المعادلة المستنبطة تقدير معامل الامرارية للخزان الجوفى بمناطق حفر أبار المراقبة التى لايمكن اجراء تجارب ضخ عليها ممايساعد فى معايرة نماذج المحاكاة اثناء تقييم امكانات خزانات المياه الجوفية بالمناطق الجافة حيث يصعب حفر آبار انتاجية واجراء تجارب ضخ وما لذلك ايضا من تكاليف عالية.