INFILTRATION RATES OF SOILS IN SOME LOCATIONS WITHIN ERBIL PLAIN, KURDISTAN REGION, NORTH IRAQ

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ABSTRACT

The present study includes infiltration capacity of Quaternary sediments in some locations at the middle part of Erbil Plain, which covers a total area of about 1670 Km^2. Quaternary sediments cover about 85 % of the study area, which consists mainly of alluvial fans, slope, flood plain, and valley fill sediments. Aeolian sediments and some outcrops of Bai Hassan (ex- Upper Bakhtiari) Formation are also present in northeast, northwest and southeastern parts of the study area. Mukdadiya (ex-Lower Bakhtiari) Formation is also exposed in the northwestern part.

For infiltration tests, seventeen localities are selected in different parts of the study area. These localities were selected according to the texture of the soil and kind of sediments. Depth of infiltration with time is determined for all selected locations.

According to f(t) value, the infiltration capacity of the middle part of Erbil Plain is between Slow – Rapid. The study area is classified in to three zones (A, B and C) based on infiltration results:

Zone A: Is located at the northeastern and southeastern parts of the study area, it is characterized by medium rate of infiltration.

Zone B: Is located at the southern part of the study area, it is characterized by slow to medium rate of infiltration.

Zone C: Is located at the northern, northwestern and southwestern parts of the study area, it is characterized by medium to rapid rate of infiltration.

The infiltration capacity results indicated that all parts, except the southern part, of the study area are considered as a good recharge area for Erbil city, so it is recommended not to use these areas for heavy construction projects to remain as a source of recharge for Erbil city. Whereas, the southern part of the study area is characterized by slow to medium rate of infiltration capacity.

The lithology of the deep wells indicated that the southern part mainly consists of clay with few silt intercalations, where the clay is characterized by high porosity, but low permeability, so the rate of infiltration is low. The other parts of the study area consist of alternation of gravel, sand, silt and clay. Where the gravel, sand and silt are characterized by high porosity and permeability, so the rate of infiltration is high.

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سعة الترشيح في الترب لبعض المواقع فى سهل اربيل، إقليم كردستان، شمال العراق

كلاويز بكر بابير، على محمود سورداشى و كريم محمود حسن

المستخلص

تشمل الدراسة الحالية سعة الترشيح في الترب لبعض المواقع في الجزء الأوسط من سهل أربيل، وتبلغ مساحة منطقة الدراسة تقريباً 1670 كم^2. وحوالي 85% من المنطقة مغطاة بترسبات العصر الرباعي المتكونة من المراوح الغرينية، ترسبات المنحدرات، ترسبات السهل الفيضى والترسبات المالئة للوديان. بالإضافة إلى ترسبات الرياح وبعض مكاشف تكوين باي حسن الموجودة في الجزء الشمال الشرقي والشمال الغربي والجنوب الشرقي من منطقة الدراسة، إضافة إلى تكشفات تكوين المقدادية في الجزء الشمال الغربي أيضاً.

تم اختيار 17 موقعاً في منطقة الدراسة لغرض تحديد سعة الترشيح، وتم تحديد هذه المواقع اعتماداً على نسيج التربة ونوع الرسوبيات وتم تحديد عمق الترشيح مع الوقت لكل المواقع. استخدم جهاز لقياس سعة الترشيح من النوع الدائري المزدوج (Double ring infiltrometer) لقياس سعة الترشيح للترب في المناطق المختارة، وتم اختيار هذه الطريقة لكونها سهلة التطبيق وسريعة التنفيذ ويطبق في المناطق المستوية. ويتكون الجهاز من دائرتين معدنيتين مزدوجتين بسمك 2 ملم وبقطرين مختلفين، الداخلي بقطر 30 سم والخارجي 60 سم، ويغرس الجهاز في التربة بعمق 15 سم ويصب الماء في الدائرة الداخلية ويقاس مستوى الماء بشكل مستمر وبفترات زمنية مختلفة (1، 2، 3، 4، 5، 8، 18، ...... و 300 دقيقة)، وقد استغرق كل فحص حوالي 5 ساعات.

اعتماداً على نتائج تجارب الترشيح، يمكن تقسيم المنطقة إلى ثلاث انطقة (A، B و C).

يمتاز **النطاق A** بمعدل ترشيح متوسط ويقع في الجزء الشمال الشرقي والجنوب الشرقي من منطقة الدراسة.

يمتاز **النطاق B** بمعدل ترشيح واطئ إلى متوسط ويقع في الجزء الجنوبي من منطقة الدراسة.

يمتاز **النطاق C** بمعدل ترشيح متوسط إلى سريع ويقع في الجزء الشمالي والشمال الغربي والجنوب الغربي من منطقة الدراسة.

بينت نتائج سعة الترشيح إن كافة أجزاء منطقة الدراسة، عدا الجزء الجنوبي، تعتبر من مناطق التغذية الجيدة لمدينة أربيل وأطرافها، ولذلك نوصى بعدم استخدام هذه المناطق لمشاريع البناء الضخمة لتبقى مصدراً لتغذية مدينة أربيل، كما آن الجزء الجنوبي من منطقة الدراسة يمتاز بمعدل ترشيح واطئ إلى متوسط.

تبين من صخارية الآبار العميقة المحفورة في المنطقة، بان الجزء الجنوبي من منطقة الدراسة معظمه متكون من الطين. وأن الطين له مسامية عالية ولكن النفاذية تكون واطئة، ولذلك معدل الترشيح يكون واطئاً. أما بقية أجزاء منطقة الدراسة فتتكون من التعاقب بين الحصى، الرمل، الغرين والطين. وان للحصى والرمل والغرين مسامية ونفاذية عالية ولذلك فان معدل الترشيح يكون عالياً.

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INTRODUCTION

The study area covers about 1670 Km^2 within and around Erbil city, which is located northeast of Iraq. It is bounded by UTM grid 3960000, 4014300 in the north and 364000, 43200 in the east (Fig.1). The area is surrounded by some hills, mountains and valleys. Sharabout and Kasnazan hills are in the north and northeastern parts of the study area. In the southeast; Bestana hills exist, while Awana Mountain forms the southwestern boundary. The Dameer Dagh hills bound the study area from the northwest (Fig.2). It is worth to mention that the middle and southern parts of Erbil Plain are mostly covered by Quaternary sediments.

Infiltration capacity is expressed in terms of the depth of water in millimeters that can infiltrate in the soil in a unit of time (one hour) (Small, 1989). Surface infiltration depends on rain fall density, column water pressure, initial soil water content, pore size and continuity, soil matrices potential and vegetation (Halfman, 2005). Among the other factors that affect on the infiltration rate are: Slope surface, size of rain drops, presence of organic matter, frozen surface, porosity and permeability, compaction and temperature.

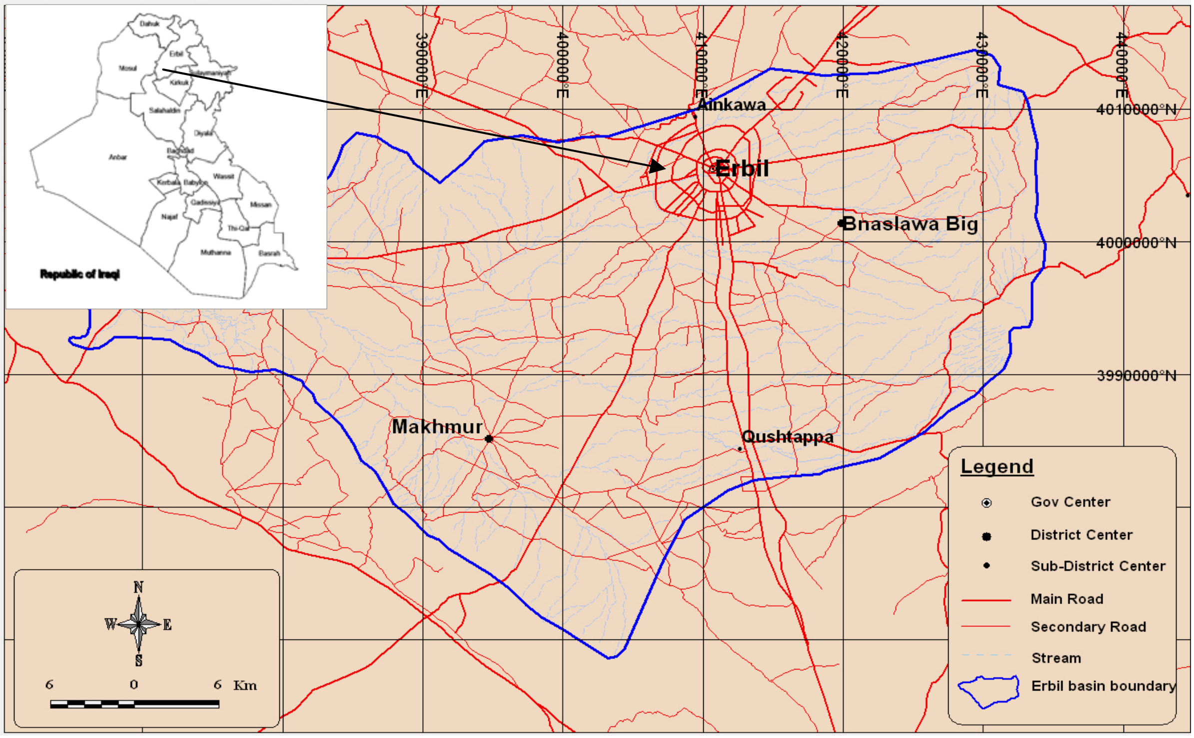

Fig.1: Location map of the middle part of Erbil Plain

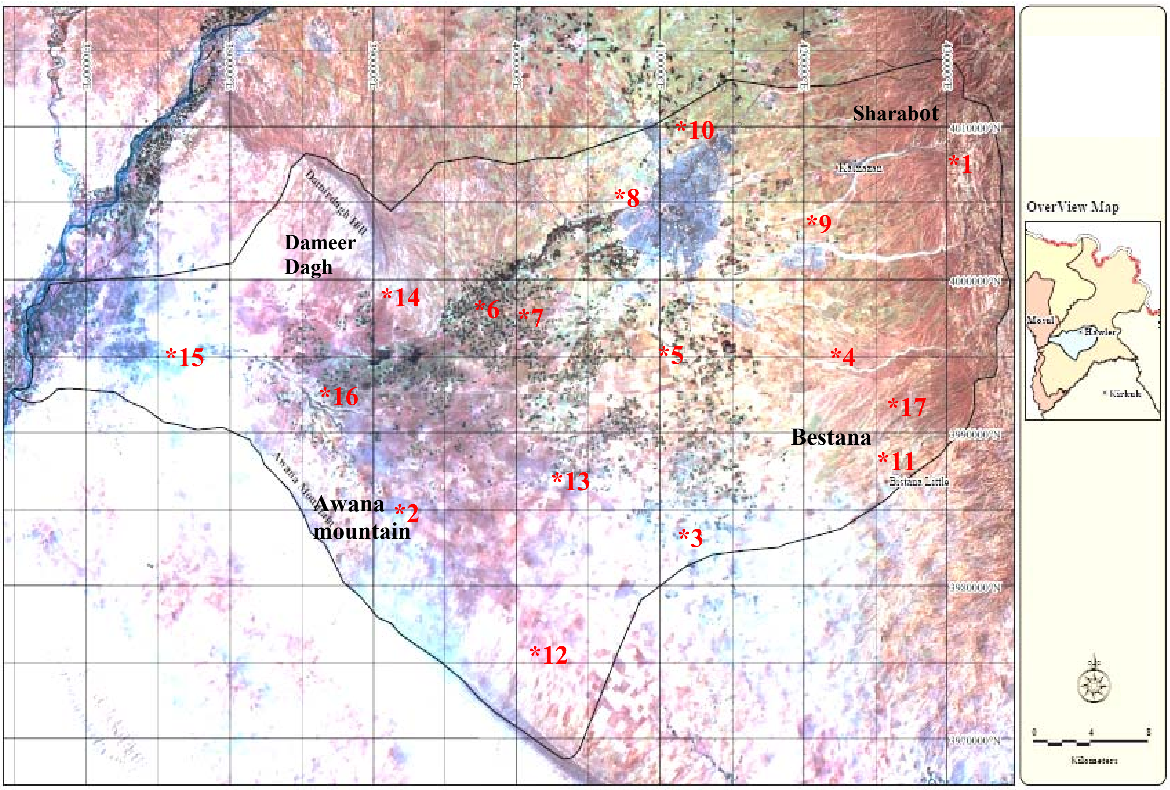

Fig.2: Satellite image map of the middle part of Erbil Plain, showing the location of samples and numbers for infiltration test

REVIOUS STUDIES

Many studies have been carried out in the study area by several authors, some of which dealt with hydrology and geophysical researches, such as:

- Hassan (1981) dealt with hydrological condition of the middle part of Erbil Plain.
- Al Talabany and Aiub (1987) dealt with morphology and hydrology of "Kahareez" in Erbil basin.
- Al-Saigh *et al.* (1989) applied regional gravity and magnetic traverse along the high way from Erbil to Shaqlawa.
- Hamid (1995) carried out a regional gravity traverse between Mosul and Harrir passing through Arbil area.
- Hassan (1998) dealt with urban hydrology of Erbil city.
- Omar (1999) studied the morphometric analysis of some drainage basins in Erbil city.
- Ghaib (2001) carried out geophysical study of the Erbil Plain.
- Stevanoic (2002) studied the infiltration and permeability tests of Erbil Plain.
- Chnaray (2003) studied the hydrogeology and hydrochemistry of Capran sub division.

GEOLOGICAL SETTING

Generally, Erbil Plain is a part of the Low Folded Zone. It is bounded by two main anticlines; Pirmam anticline to the north and Kirkuk structure to the south. According to Buday and Jassim (1987), these two anticlines are separated by a large syncline, which represents the middle part of Erbil Plain, which consists of three main parts: North, Middle and South. The study area represents the Middle Part, which is covered by Quaternary sediments that are accumulated under the effect of weathering and erosion of surrounding elevated area. The Quaternary sediments cover Bai Hassan Formation, which crops out at north and northeastern parts of the study areas. The Bai Hassan Formation consists of molasse sediments, represented by alternation of conglomerate and claystone with subordinate sandstone and siltstone, The Mukdadiya Formation also crops out at the northwestern part of the study area, it consists of cyclic clastic materials fining upwards (Youkhanna and Sissakian, 1986). The contact between the Quaternary sediments and Bai Hassan Formation is almost obscure; due to the large similarity between the lithological units. Ghaib and Aziz (2003) considered that the recent sediments involve more lateral changes than the pre-Quaternary sediments (Bai Hassan Formation). They based the contact between the Quaternary and pre-Quaternary sediments according to geophysical studies, by combination of electrical and gravity measurements.

METHODS OF INFILTRATION MEASURMENTS

Basically, there are three main approaches to make simple, fast and accurate measurements for infiltration behavior, these are: Sprinkler methods, Ring Infiltrometer method and Permeameter methods (Smith *et al*., 2002). Double ring infiltrometer was used for determining infiltration capacity for soils in the study area, because this method is simpler, than the other mentioned methods. This method is primarily designed and tested on horizontal surfaces; however it is suitable for characterization of surface soil hydraulic properties in landscapes with slopes up to 20% (Bodhinayake *et al*., 2004). For performing infiltration tests, seventeen localities were selected in different parts of the study area.

A double ring infiltrometer consists of two iron rings (inner and outer rings) with 2mm thicknesses, 30 and 60 cm diameter and 30 cm height (Gregory *et al*., 2005) (Fig.3). The iron rings are pushed into the soil of a selected locations to a depth of 15 cm. One ring could be used, but it causes more changes on infiltration measurements, due to the lateral movement of

water, which can be controlled, so it is better to use double rings to prevent lateral movement (Chnaray, 2003).

The inner ring must be in the middle of the outer ring. An indicator is placed at the top of the two rings, and then water is added until it reaches the indicator. A ruler is placed in the inner ring to measure the depth of infiltration in millimeter. The measurements in the study area were recorded at different times (1, 2, 3, 4, 5, 8, 18……….300 min), (Table 1), each test took about 5 hour.

The infiltration rate can be calculated by using the following equation:

$$\textbf{Infiltration rate} = \frac{\textbf{Cumulative depth of infiltration}}{\textbf{Time (hour)}}$$ (Smith *et al.*, 2002)

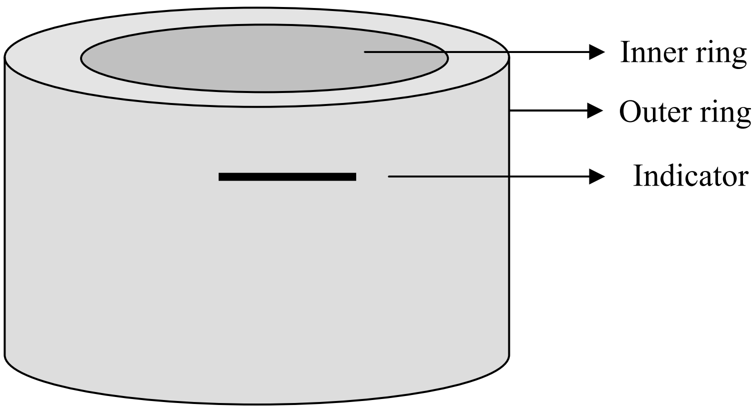

Fig.3: Double ring infiltrometer (30 – 60) cm diameter

RESULTS AND DISCUSSION

Horton, 1940 in Chin (2006) proposed the following equation for describing the infiltration capacity [f(t)].

$$\mathbf{f(t) = f(c) + (fo - fc)\ e^{-kt}}$$

where:

f(t) = infiltration capacity (mm/hour)

f(c) = equilibrium infiltration capacity (mm/hour)

f(o) = initial infiltration capacity (mm/hour)

K= constant (1/hour)

t = total time during infiltration time (hour)

The values of **f(o)**, **f(c)** and **K** in the study area were measured from Statistical Package for Social Science (SPSS) programs and depending on the value of infiltration rate (mm/hour) and time (hour) (Table 2). For example the infiltration capacity f(t) of Bakhcha location is calculated as follows:

$$f(t) = 23 + (81.9 - 23)e^{-3.87/5}$$

$$f(t) = 23.00 \text{ mm/hour}$$

Table 1: Infiltration rate of soil with time in the study area

Time min	Infiltration rate (mm) in the tested areas																
	Grdish	Sadawa	Kurdawa	Sature	Pirdawd	Bakhcha	Mastawa	QushTapa	Bnaslawa	Science College	Jmka	Erbil Park	AinKawa	Kasnazan	Shawes	Birajna	Qush Tapa
1	235.3	154.2	160.32	120.76	60.63	79.41	165.88	73.53	342.35	254.71	196.47	196.47	116.47	111.76	168.24	242.35	337.06
2	221.2	154.2	162.43	120.55	55.76	77.88	170.91	72.12	311.21	240.91	202.73	202.42	116.06	113.64	169.09	228.18	259.09
3	208.11	153.7	160.67	120.45	51.87	74.40	165.80	67.20	281.00	217.40	198.20	193.80	113.60	111.20	163.20	204.60	227.40
4	187.3	152.5	159.25	119.23	46.74	70.15	163.28	63.13	256.27	195.37	195.97	189.10	110.45	108.51	158.36	183.88	211.79
5	174.5	150.25	159.50	119.5	40.98	66.51	160.72	59.64	232.53	172.17	195.42	184.82	109.88	106.27	155.66	170.84	202.65
8	152.8	146.67	156.80	117.3	32.86	53.46	154.06	48.12	172.56	150.60	190.00	159.32	105.79	94.89	119.77	148.12	169.62
10	143.9	140.23	154.55	110.22	27.56	48.38	149.64	43.23	152.51	142.51	182.99	149.76	103.77	93.23	110.06	139.16	156.83
12	137.5	136.3	153.45	115.34	25.54	44.70	146.20	39.65	138.45	137.15	178.60	142.20	102.25	90.75	103.45	133.30	141.95
15	125.6	130.54	151.66	100.55	20.66	42.00	141.56	35.12	118.76	128.72	177.12	133.80	99.92	86.80	96.24	125.16	130.88
20	120.4	122.82	144.98	95.67	18.45	38.74	135.77	30.18	97.33	123.15	174.92	120.06	97.09	81.32	88.32	119.85	119.43
25	115.3	1118	140.56	92.33	17.78	36.35	131.61	27.03	84.03	116.47	172.78	111.49	94.80	77.53	83.05	113.31	112.28
30	103.2	115.4	138.95	90.56	16.87	34.80	128.88	24.98	74.90	108.60	171.40	105.58	93.46	74.96	79.56	105.58	106.04
35	95.88	113.89	135.78	88.76	15.25	33.45	126.48	23.36	68.10	99.83	170.31	101.27	92.28	72.95	76.93	96.91	102.71
40	89.22	111.56	131.50	86.82	13.56	32.20	124.33	22.11	62.89	92.91	169.24	97.74	91.03	71.33	74.77	90.01	99.43
45	83.23	109.60	127.45	84.33	13.00	31.15	122.60	21.09	58.77	87.65	168.37	94.95	90.01	69.99	72.92	84.77	96.69
50	79.12	107.80	122.44	80.52	11.65	30.24	120.98	20.28	55.46	83.45	167.30	92.67	89.20	68.63	71.21	80.58	94.18
55	76.43	105.5	118.54	80.67	11.77	29.29	119.28	19.59	52.51	79.91	165.99	90.50	88.43	67.33	69.60	77.06	91.70
60	73.22	104.97	116.30	78.54	11.45	28.38	117.83	19.03	50.10	77.05	164.43	88.53	87.88	66.27	68.15	74.20	89.54
70	68.11	100.54	114.90	76.65	10.56	26.82	115.32	18.22	45.80	72.31	159.79	84.30	85.42	64.46	65.64	69.76	84.22
80	65.24	95.65	100.76	74.25	10.34	25.60	112.58	17.56	42.61	68.80	156.20	80.97	83.46	62.89	63.58	66.48	80.15
90	62.78	90.50	94.77	70.95	10.33	24.49	109.48	17.01	39.94	65.91	153.04	78.09	81.69	61.41	61.67	63.83	76.74
105	59.57	85.25	91.43	67.45	9.73	23.17	105.35	17.42	37.08	62.18	149.36	75.02	79.70	59.53	59.86	60.28	72.63
120	58.44	83.22	89.75	66.86	9.50	22.12	100.98	17.70	34.75	59.06	146.32	72.64	77.50	57.84	58.40	57.27	69.23
135	56.87	80.73	87.98	66.53	9.50	21.27	96.98	17.91	32.93	56.32	143.72	70.46	75.46	55.94	57.23	54.61	66.78
150	54.83	74.88	80.54	63.99	11.25	20.54	93.28	18.05	31.39	54.00	141.45	68.61	73.56	53.75	56.14	52.45	64.39
180	52.25	70.67	75.70	61.54	11.30	19.33	86.55	18.28	28.79	50.20	137.53	64.51	69.90	46.47	53.45	48.83	60.56
210	49.78	67.80	72.34	59.77	11.50	18.40	80.50	18.44	26.93	47.22	134.61	61.27	66.96	42.83	51.34	45.99	57.79
240	47.93	62.80	68.76	57.87	12.00	17.64	75.45	18.52	25.38	44.86	132.25	58.66	64.06	41.99	49.71	43.76	55.74
300	44.23	57.55	65.56	55.56	11.54	16.51	66.95	18.64	23.01	41.26	128.40	54.02	62.57	40.67	47.76	40.33	52.59

Table 2: Infiltration results for different location in the study area

S. No.	Location	X (UTM)	Y (UTM)	F(t) (mm/h)	F(c) (mm/h)	F(o) (mm/h)	K (1/h)	R^2	Classification of infiltration capacity
1	Bakhcha	432798	4005924	23.00	23	81.9	3.87	0.96	M
2	Mastawa	393291	3989977	76.52	73.85	162.3	0.70	0.96	M – R
3	Qush Tapa	413800	3982613	18.4	18.4	79.9	5.0	0.99	S – M
4	Bnaslawa	420331	4001503	41	41	360	5.7	0.98	M
5	Science College	411698	4000897	60	60	236.37	3.20	0.94	M – R
6	Jmka	396524	3999661	131.68	130	195	0.73	0.96	M – R
7	Erbil Park	407719	4004982	6929	69.29	204.6	2.53	0.97	M – R
8	Ain Kawa	409565	4008992	65.8	64.8	111.84	0.77	0.96	M – R
9	Kasnazan	417386	4004801	48.4	48.4	110.2	1.4	0.95	M
10	Shawes	417730	4010054	60	60	181.7	4.2	0.96	M – R
11	Birajna	428350	3991920	57	57	222.9	29.5	0.95	M
12	Qurshaghlu	403100	3976000	78	78	315.6	6	0.93	M – R
13	Pirdawd	402500	4005450	11.51	11.51	66.20	6.7	0.99	S – M
14	Satur	392100	4004300	60	60	123.37	1.2	0.98	M – R
15	Kurdawa	374200	3995100	60.1	60.1	144.9	0.62	0.99	M – R
16	Sadawa	387650	3997250	60.7	60.7	160.9	0.84	0.98	M – R
17	Grdish	430100	3997600	56	56	220	2.8	0.98	M

Depending on **f(t)** values; Nikolov (1983) classified the infiltration capacity into six types (Table 3).

The coefficient of determination $(R)^2$ is calculated to determine the accuracy of Horton model, which is about (0.93 – 0.99). It means that this model is most accurate. However, the infiltration is important for determination type of texture in the study area; also it is important for determination the coefficient of permeability (**C**).

Table 3: Classification of infiltration capacity (after Nikolov, 1983)

Infiltration capacity f(t)	Type
> 160 mm/hour	Rapid (R)
60 – 160 mm/hour	Moderate – Rapid (M – R)
20 – 60 mm/hour	Moderate (M)
5 – 20 mm/hour	Slow – Moderate (S – M)
1.2 – 5 mm/hour	Slow (S)
< 1.2	Very slow

Table 4: Coefficient of permeability in the tested locations within the study area

Sample No.	Location	Infiltration capacity F(t) (mm/h)	Infiltration type according to Nikolov classification
1	Bakhcha	23.00	Moderate (M)
2	Mastawa	76.52	Moderate – Rapid (M – R)
3	Qush Tapa	18.4	Slow – Moderate (S – M)
4	Bnaslawa	41	Moderate (M)
5	Science College	60	Moderate – Rapid (M – R)
6	Jmka	131.68	Moderate – Rapid (M – R)
7	Erbil Park	69.29	Moderate – Rapid (M – R)
8	Ain Kawa	65.8	Moderate – Rapid (M – R)
9	Kasnazan	48.4	Moderate (M)
10	Shawes	60	Moderate – Rapid (M – R)
11	Birajna	57	Moderate (M)
12	Qurshaghlu	78	Moderate – Rapid (M – R)
13	Pirdawd	11.51	Slow – Moderate (S – M)
14	Satur	60	Moderate – Rapid (M – R)
15	Kurdawa	60.1	Moderate – Rapid (M – R)
16	Sadawa	60.7	Moderate – Rapid (M – R)
17	Grdish	56	Moderate (M)

The coefficient of permeability for the tested locations within the study area is determined as follows:

C= B*V/A*t (Stevanovic, 2002).

where:

C = Coefficient of permeability

B = factor calculated from the value of (t/ tI) according to Fig. (4)

t = total time during the infiltration (min)

tI = time during using half of the water for infiltration

V = the total amount of water which used in infiltration test (m^3)

A = the area of the inner ring which is used in the test (m^2)

For example in Bakhcha location, the above equation functions as follows:

V = volume of the cylinder * height of the water column

Volume of the cylinder = $r^2 * \pi = (0.15)^2 * 3.14 = 0.07065$ (m^3)

t = radius of the inner ring = 15 cm = 0.15 m

Height of the water column = 82.56 mm = 0.08256 m (Table 1)

B = 0.53 (Fig.4)

A = 0.07065

t = 300 min.

$C = 0.53 * 5.828625 * 10^{-3} / 0, 07065*300 = 1.4575*10^{-4}$ (Table 4).

The Coefficient of permeability (**C**) is determined in different locations of the study area (Table 4), which indicates that the north and northwestern parts are characterized by high rate of coefficient of permeability that decreases southwards.

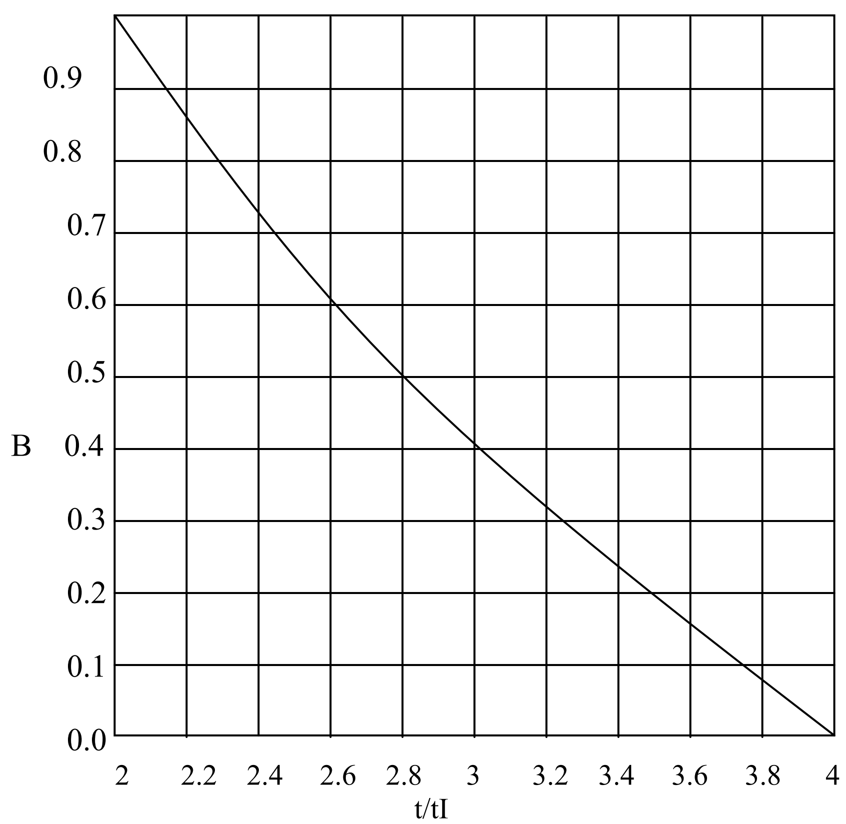

Fig.4: Determination of (**B**) curve from (**t/tI**) for calculating the coefficient of permeability (Chnaray, 2003)

Table 4: Measured values of the Coefficient of permeability in the middle part of Erbil Plain

Location	T	t1	t/t1	B	C (m/sec)
Bakhcha	300	109	2.75	0.53	1.4575×10^{-7}
Mastawa	300	95	3.15	0.34	3.7939×10^{-7}
Qush Tapa	300	152	1.97	–	Equation was not applied
Bnaslawa	300	150	2	1	3.8353×10^{-7}
Science College	300	100	3	0.4	2.7509×10^{-7}
Jmka	300	110	2.72	0.54	11.5552×10^{-7}
Erbil Park	300	110	2.72	0.54	4.8614×10^{-7}
Ainkawa	300	122	2.45	0.68	7.0917×10^{-7}
Kasnazan	300	104	2.88	0.46	3.1181×10^{-7}
Shawes	300	100	2.43	0.72	5.7306×10^{-7}
Birajna	300	100	3.0	0.4	2.6889×10^{-7}
Qurshaghlu	300	110	2.72	0.54	3.6300×10^{-7}
Pirdawd	300	150	2	1	2.1750×10^{-7}
Satur	300	100	3	0.4	4.0638×10^{-7}
Kurdawa	300	108	2.77	0.52	5.7243×10^{-7}
Sadawa	300	94	3.19	0.33	3.5422×10^{-7}
Grdish	300	105	2.85	0.45	3.3082×10^{-7}

CONCLUSIONS

- The application of the infiltration method in the study area indicated that the southern part consists mainly of clayey sediments (flood plain sediments), which have low permeability, so the rate of infiltration is low. The northeastern and southeastern parts of the area are characterized by Medium rate of infiltration, whereas the northwestern and southwestern parts are characterized by Medium to Rapid rate of infiltration.
- The lithology of the study area, as indicated from the deep wells is as follows: The southern part mostly consists of clay with few silt intercalations, where the clay is characterized by high porosity but low permeability, so the rate of infiltration is low. The other parts consist of alternation of gravel, sand, silt and clay. The gravel, sand and silt are characterized by high porosity and permeability, so the rate of infiltration is high.
- The coefficient of permeability is high in the northern, northwestern and western parts of the study area and decreases southwards.

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