



## ***Study the Infiltration and Stability of the Earthfill dams (Proposed Kashkan dam as a Case study)***

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*(Received:9/9/2012 ; Accepted :12/3/2013 )*

### **Abstract**

This paper performed two steps of analysis. The first step used Soil Conservation Service (SCS) method to estimate surface water infiltration rates from the earth fill dams (proposed Kashkan dam north of Duhuk city as a case study). In the second step, a two dimensional finite element seepage analysis using (Seep/w) software was employed to determine seepage rates. The main purpose of constructing Kashkan dam is to store the rainfall water during rainy season and use it during summer season to provide the human requirements of water as well as to performed the agricultural requirements. Mean monthly rainfall data recorded for selected watersheds during the period (1986-2008) was used. The maximum infiltration rate during the depended period asymptotically tends to the value of the saturated permeability. The computed infiltration rates were used as input data for the seepage analysis by assigning the ground surface boundary condition. Finally, positive and negative pore water pressure distributions obtained from the seepage analysis are used as input data to calculate the variations in the factor of safety during the event . It is concluded from that the Kashkan dam is safe against the danger of slope failure due to slippage under the operation heads.

**Key words:** *Earth fill dam, Infiltration rate, Seepage, Seep/w software, Slope stability.*

## تخمين معدلات الترشيح والتسرب من السدود الترابية (سد كشكان المقترح كحالة دراسية)

اعتمدت هذه الدراسة مرحلتين من التحليل . في المرحلة الأولى تم تحديد معدل ترشيح مياه الأمطار خلال السدود الترابية (تم اعتماد سد كشكان المقترح شمال مدينة دهوك كحالة دراسية ) باستخدام طريقة حفظ التربة . Seep/w في المرحلة الثانية تم اعتماد طريقة العناصر المحدودة ثنائية البعد لحساب التسرب باستخدام برنامج ولقد تم استخدام البيانات المطرية كمعدلات شهرية للفترة (١٩٨٦-٢٠٠٨). ووجد إن أقصى معدل للترشيح خلال هذه الفترة كان اقرب إلى قيمة النفاذية المشبعة. قيم معدلات الترشيح المحسوبة استخدمت كمدخلات في تحليل التسرب باعتماد مستوى سطح الأرض كحد شرطي. أخيرا تم استخدام قيم الضغوط الموجبة والسالبة للمياه والمستخرجة من تحليل التسرب كمدخلات في تحليل الاستقرارية وتحديد معامل أمان السد. وتم الاستنتاج بان السد امن ضد فشل الانزلاق .

## **Introduction**

The flow of water in unsaturated soil is a very complicated problem because water flow and moisture content in unsaturated soil may vary both spatially and temporally as a result of time-dependent changes in environmental conditions, such as rainfall and rising water-table, and the storage capacity of soil (Lu and Likos, 2007).

The rate at which water infiltrates, and seeps from a dam is a function of soil moisture retention characteristic, climate ( rainfall characteristics), soil cover( type of vegetation), and degree of saturation in the soil, ( Milczarek, Hammermeister, and Vinson, 2000).

Infiltration and Seepage analyses are an important tool to assess the susceptibility of seepage failure in dams and to study hydraulic conditions for analyzing the stability of dam slopes. Early transient seepage analyses were based on seepage theory for saturated soils, and the determination of the free surface was the key problem, (Chen and Zhang , 2006) .

The objectives of the present study can be divided into two main focuses. Firstly, to determine the infiltration rates from the proposed Kashkan dam site in the north of Iraq using Soil Conservation Survey (SCS) method. Secondly, to estimate the seepage rates through the dam using (Seep/w) software .

Application of SCS method requires that soil survey information be available for the watershed of interest. A soil survey provides the information needed to choose Curve Number (CN) based on soil type, cover, management practice and hydrologic condition, (Ashish et, al, 2003).

The soil investigations carried out by Ministry of Water Resources, General Directorate for Engineering Designs,(GDED, 2006) in the study area show that the top layer is composed of silty clay followed by terrace deposits of silty clay with fine gravel. For this study rainfall data recorded for selected watersheds in Zakho station during the period (1986-2008) was considered. The computed infiltration results obtained from the SCS analysis were used as input data for the seepage analysis using (Seep/w) software,( Geo-slope-international, 2007). This package performs a hydrological-slope stability model as Slope/w to analyze the slope stability.

## **Site description and Soil profile**

The proposed Kashkan dam is situated about 45 km north west of Duhuk city on the Fish Khaboor river, Fig.(1). Both main and coffer dams are designed as earth fill type with central clay core followed by one layer of filter on both sides and supported by sand and gravel shell as shown in Fig. (2). The catchment's area is evaluated about 21km<sup>2</sup>.



Fig. (1) Location of the proposed Kashkan site.

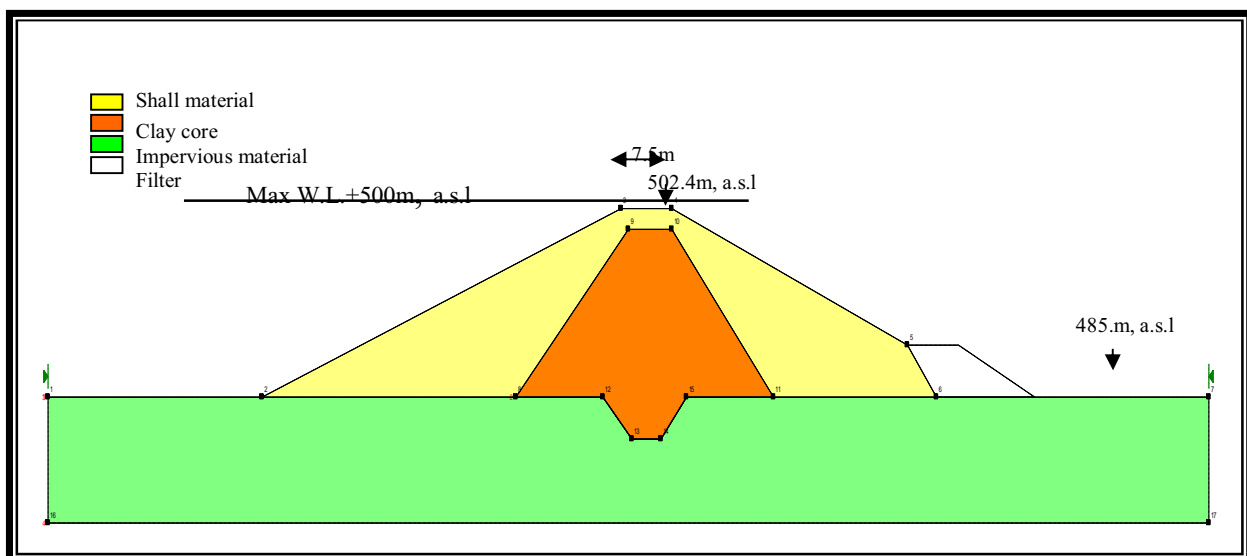


Fig.(2) The cross-section of proposed Kashkan dam(Seep/w software)

The regional topography is relatively flat with elevations ranging from 450 m, a.s.l to 500m, a.s.l. The site is very suitable to construct the dam because of the wide stream with the narrow valley which will lead to store a large volume of water during the rain season, (GDED, 2006). The main purpose of constructing Kashkan dam is to store the rainfall water during rainy season and use it during summer season to provide the human requirements of water as well as to performed the agricultural requirements.

The lithological cross – section in the study area is consists of a series of formations which vary according to the depth. Top layer (1-2m) is composed of silty clay followed by terrace deposits of silty clay with fine gravel at a depth vary between (3 to 4m). The depths more than 4m are composed of gravelly silty clay, sandy clay and sandy silty clay mixed with gravel. Properties of the soil underneath Kashkan earth dam illustrated in table-1, and the investigations carried out by (GDED , 2006). The permeability of upper layer ranges between  $0.26 \times 10^{-4}$  to  $6.05 \times 10^{-4}$  cm/sec, which it is medium and possible to construct a dam with proper engineering safety against piping phenomenon, (GDED , 2006) .

Table (1) Properties of the soil underneath the proposed Kashkan dam(GDED , 2006),.

Depth (m)	Grain size analysis			Specific gravity	Dry density (T/m <sup>3</sup> )	Voids ratio	Permeability (cm/sec)
	Sand%	Silt%	Clay%				
0 – 3	8	61	31	2.71	1.65	0.65	$6.05 \times 10^{-4}$
3 – 6	7	70	23	2.71	1.624	0.60	$0.714 \times 10^{-4}$
6 – 9	6	76	18	2.69	1.66	-	$0.435 \times 10^{-4}$
9 – 12	5	73	22	2.72	-	-	$0.27 \times 10^{-4}$
12 - 15	9	68	23	2.72	-	-	$0.26 \times 10^{-4}$
15 - 18	11	72	17	2.73	-	-	$0.286 \times 10^{-4}$
18 - 21	6	76	18	2.73	-	-	$0.404 \times 10^{-4}$

## Climatic Conditions

The area is characterized by a semi-humid with two well defined seasons, hot-dry Summer and cold-wet Winter. The available records are cover the period (1986-2008), table (2) with monthly total rainfall data in the study area (Zakoh Meteorological Station, (GDED, 2006). The average annual temperature is 23.7<sup>o</sup>c. The maximum monthly average is 40 <sup>o</sup>c in August, while the minimum is 8 <sup>o</sup>c in January. The average value of relative humidity varies from 16% in July to 66% in December, with annual average value reaches to 37% .

Rainfall begins in October and ends in May after which it becomes scarce. The maximum annual rainfall is 139.7 mm occurring in January, while its minimum was recorded during Jun. to Sep. with annual average rainfall of 698.8mm.

The maximum and minimum monthly averages of evaporation are 335.8mm and 46.7mm in July and December, respectively with annual average evaporation of 1981.1mm. There is no recharging source of water passes through the study area, so the precipitation is the main source of water.

Table (2) Monthly average meteorological data at Zakoh station for the period (1986-2008) (GDED , 2006).

Month	Mean temp. °c	Relative humidity%	Wind speed m/sec	Rainfall mm	Evaporation mm
Jan.	8	60	1.9	139.7	59.9
Feb.	13	55	2.4	110.8	80.3
Mar.	16	50	2.2	112.8	95.7
Apr,	20	45	2.2	79.1	114.9
May	27	33	1.9	41.2	195.2
Jun.	34	17	2.7	-	271.8
Jul.	38	16	1.8	-	335.8
Aug.	40	19	2.1	-	320.5
Sep.	34	21	1.6	-	238.4
Oct.	23	40	1.8	22.9	142.5
Nov.	18	38	1.5	76.8	79.4
Des.	13	60	1.6	115.5	46.7
Annual	23.7	37.8	2	698.8	1981.1

### Infiltration rate analysis using SCS method

Numerous models are available for performing simulations related to the movement of water. The rate of infiltration of water is generally the most important parameter required in such models. A great majority of the compiled models are based on widely-accepted concepts of soil physics. Proper use of these models should provide a rational and scientific basis for remedial decision-making related to soil contaminant levels, (Ashish , et al ,2003).

Soil Conservation Service (SCS) model, also known as the Curve Number (CN) method, is one of such models and has been applied in the present study for estimation infiltration rate from the study area (Kashkan dam site). This empirical method is based on correlation parameters affecting infiltration rates such as soil type and surface cover (vegetation cover) as in the following equation, (Ashish , et al ,2003):

$$i = \frac{S^2 r}{(P - I_a - S)^2} \text{----- (1)}$$

and

$$S = \frac{25400}{CN} - 254 \quad \text{-----} (2)$$

Where:  $I$  = infiltration rate (mm/hr) ,  $r$  = rainfall intensity (mm/hr) ,  $S$  = maximum available retention capacity ,  $P$  = total storm precipitation (mm), and  $I_a$  = basin volume equal to the initial abstraction of rainfall.

A common approach is to reduce the value of  $I_a$ , thus relaxing constraint that:

$$I_a = 0.2 S \quad \text{-----}(3)$$

The study area is considered as Pasture land use and medium soil conductivity. From these data the value of Curve Number (CN) is determined using a specified Table taken by United State Department of Agriculture (USDA, 1986) . The value of  $CN$  is found to be 79. So, the recharge capacity ( $S$ ) which is found to be 67.5.

In order to obtain the rainfall intensity, the Intensity – Duration – Frequency Curves for Zakho station were applied according to the Probable Maximum Precipitation Atlas of Iraq (ISSWR, 2000), for a return period of 100 years and 100 minutes duration. The rainfall intensity in area was found to be 3.2 mm/hr.

Values of  $S$ ,  $r$  and mean monthly precipitation ( $P$ ) during the period (1986-2008) were applied in equation (1). The calculated infiltration rates are given in table (3).

Table (3) Summary of infiltration analysis results

Date	Mean monthly precipitation(mm)	Infiltration rate (mm/hr)
Jan.	139.7	2.579
Feb.	110.8	2.499
Mar.	112.8	2.504
Apr.	79.1	2.462
May	41.2	2.320
Oct.	22.9	2.275
Nov.	76.8	2.408
Dec.	115.5	2.512
Sum	698.8	19.56
Mean(during raining periods	87.35	2.445

## Seepage analysis

Seepage flow of water through porous media depends on the soil media, type of flow, properties of liquid and hydraulic gradient. Seepage piping account for approximately 50% of all earth dam failures, so its analysis is important in the assessment of long term stability of slope, (Milczarek, et al, 2000).

The governing equation for water flow through a dam can be obtained by introducing Darcy's law into continuity equation as follows, (Lu and Likos, (2007):

$$\frac{\partial}{\partial x} \left\{ k_x \frac{\partial h}{\partial x} \right\} + \frac{\partial}{\partial y} \left\{ k_y \frac{\partial h}{\partial y} \right\} = - \frac{\partial \theta_w}{\partial t} \quad \text{--- (4)}$$

where  $k_x$  and  $k_y$  are the hydraulic conductivity in the  $x$  and  $y$  directions, respectively;  $h$  is the total head;  $\theta_w$  is the volumetric water content; and  $t$  is the time. The computer program, Seep/w, v.7 (Geo-slope-international, 2007) was used to estimate the seepage rate through the study area. Seep/w software is one of powerful program works based on finite elements technique and it is able to simulate and analyze isometric water distribution through soil and rocks, (Kamanbedast and Shahosseini, 2011)

The proposed dam is divided into a mesh of quadrilateral elements (139\*10), Fig.(3).

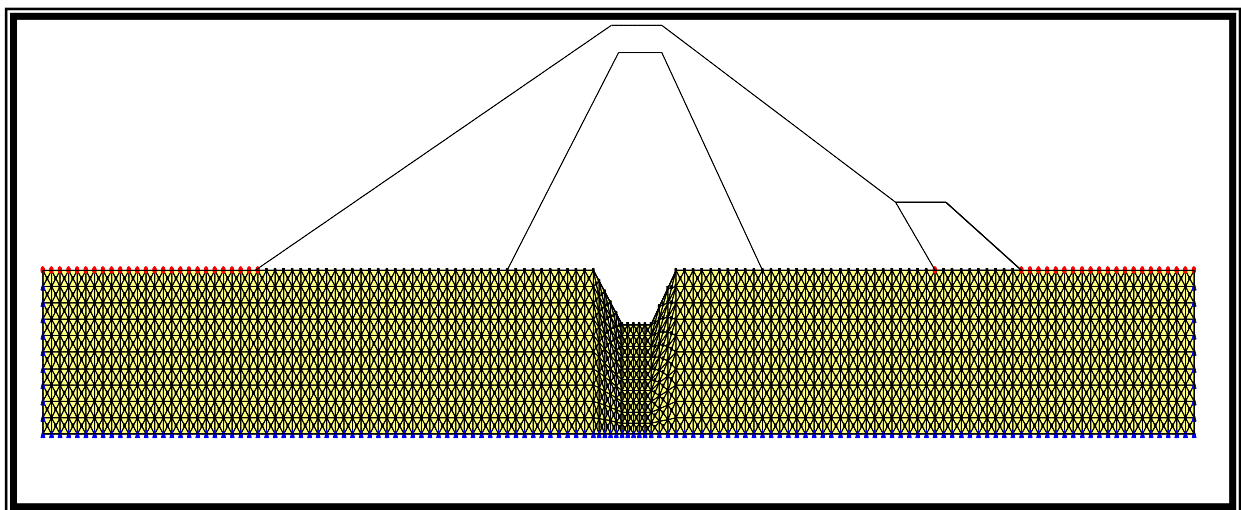


Fig.(3) Mesh of quadrilateral Elements for Area



The results from the infiltration analysis were used as input data for the seepage analysis by assigning the computed infiltration rate as boundary condition to the ground surface nodes. Zero flux conditions were assigned to the left, right and lower boundaries. Figure 4, shows the distribution of steady-state pore-water pressure distribution across the dam site. The output data showing the distributions and locations of the free surface seepage line and the quantity of seepage through the dam, (Fig. 5)

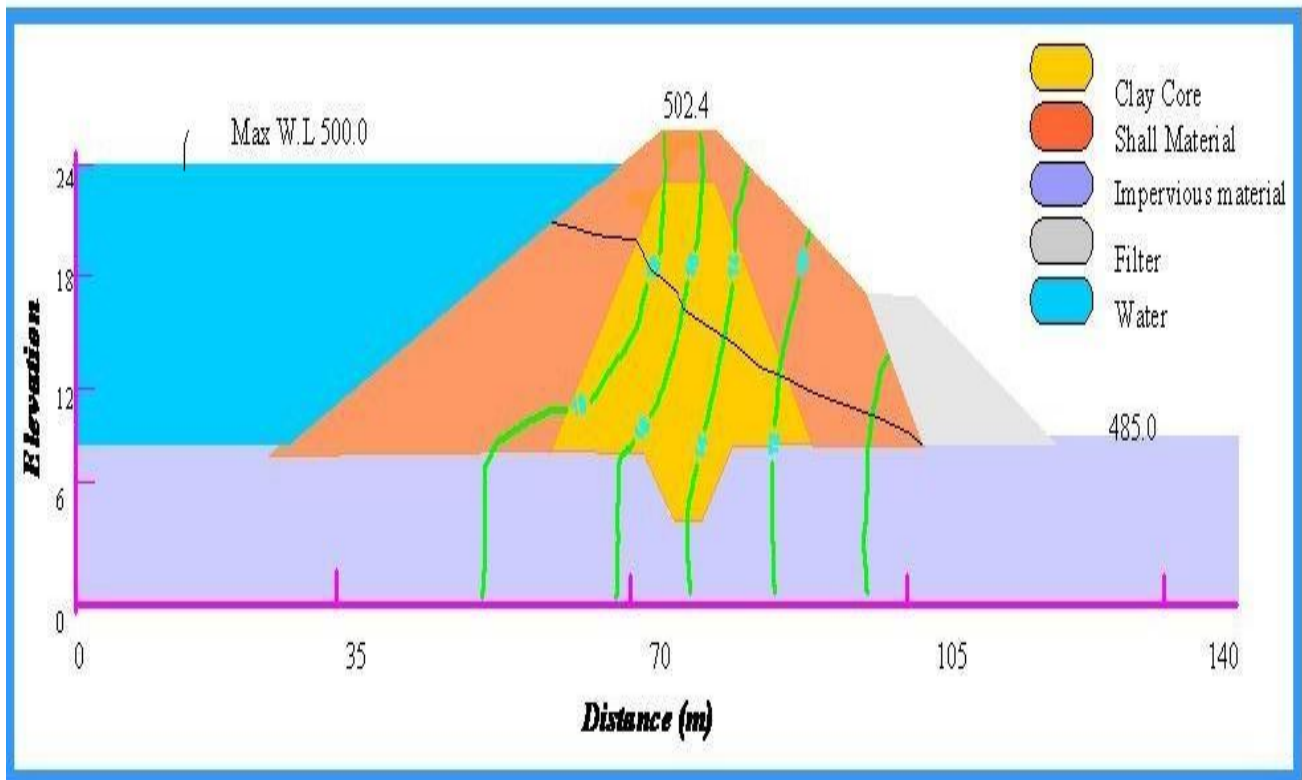


Fig.(4) Total head distribution

### Stability analysis

The positive and negative pore water pressure distributions obtained from the seepage analysis were used as input data in slope stability analysis. The Slope/w, v.7, (Geo-Slope, 2007), was used to determine stability with respect to slide type failures.

The unit weight was updated using the following equation, (Tofani1 V, et.al, 2006):

$$\gamma = \gamma_d + 9.81\theta \quad \text{-----} \quad (5)$$

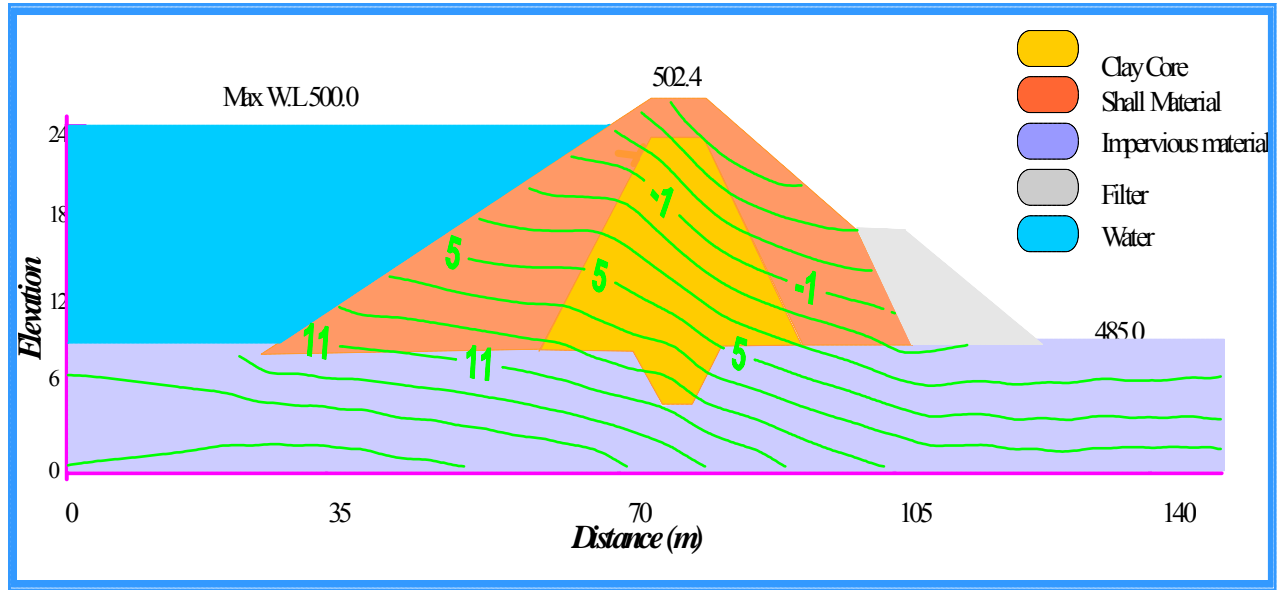


Fig. (5) Seepage through the Dam with phreatic line

where  $\gamma$  is the unit weight of the soil during the time step,  $\gamma_d$  is the unit weight of soil under completely dry conditions, and  $\theta$  is the volumetric water content during the time step, which is estimated from the soil water characteristic curve using the simulated pore water pressure in that time step.

The slope stability of the Kashkan dam is studied using the computer program to determine the minimum factor of safety by Bishop equation, (Noori and Ismaeel, 2010) as:

$$FS = \frac{\sum_{i=1}^n (c' b_i + (w_i - u_i \cdot b_i) \tan \phi') \frac{1}{m_{\alpha i}}}{\sum_{i=1}^n w_i \sin \alpha_i} \quad \text{--- (6)}$$

$$m_{\alpha i} = \cos \alpha_i + \frac{\tan \phi' \sin \alpha_i}{FS} \quad \text{--- (7)}$$

Where

$C'$ = effective soil cohesion,

$L$ = length of the bottom of the slice,

$b$ = width of the slice and equal to  $(L \cos(\alpha))$ ,

$u$ = pore water pressure,

$W$ = weight of the slice,

$\alpha$ =inclination of the bottom of the slice, and

$\phi'$ =effective internal friction angle

According to the properties of materials of the dam, the results showed that the factor of safety ranges between 1.5 and 2.1. Fig. 6 and Fig. 7 show the critical slip surfaces determined at the U/S and D/S of the dam, respectively. The results indicated that the dam is safe against slope failure, (Krahn, 2004).

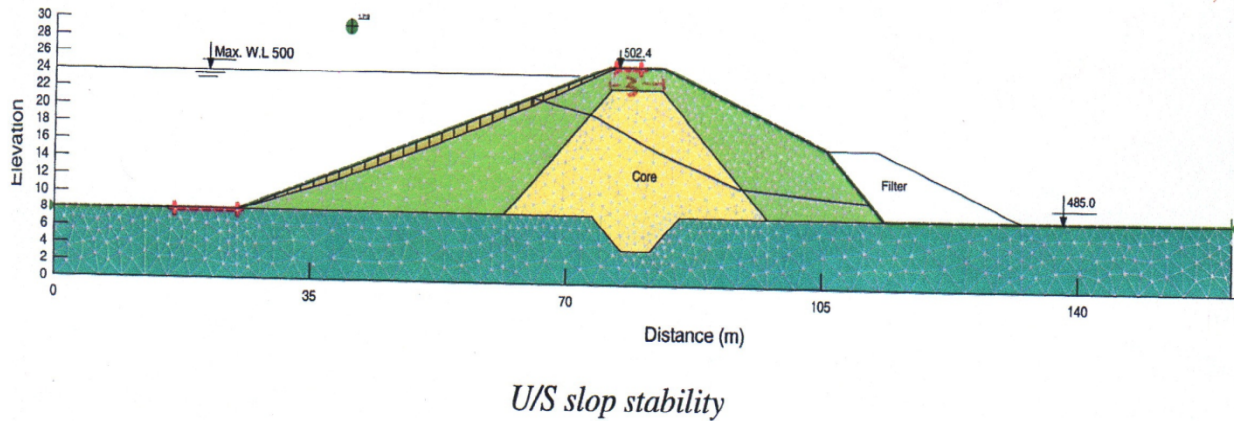


Fig. (6) Location of the critical slip surface in the U/S the Kshkan Dam

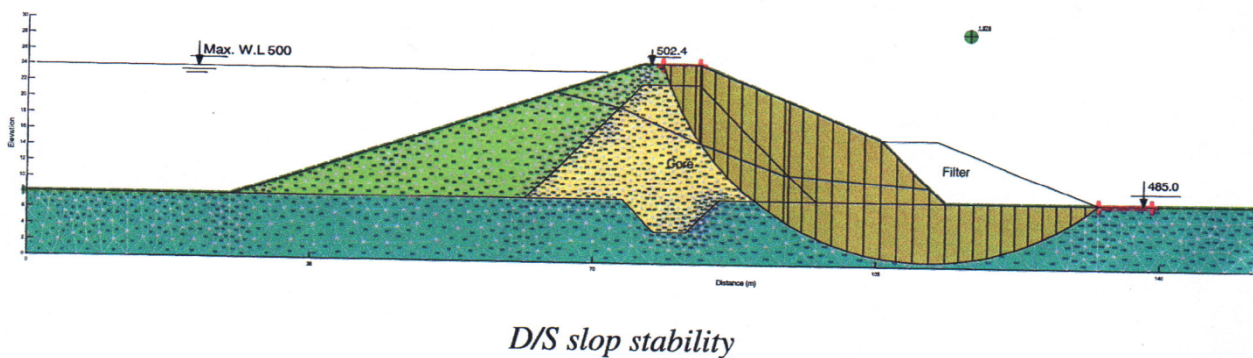


Fig. (7) Location of the critical slip surface in the D/S of the Kshkan Dam

## **Conclusions**

The high intensity rainfall and the stability of dams could be compromised as a result of rainfall infiltration because the effective stress and, hence, the strength of the dam will decrease due to the increase of pore-water pressure caused by excessive rainfall.

Infiltration, Seepage and Stability analyses for an earth fill dam (proposed Kashkan dam, north of Duhuk city) have been performed in this study. Effects of rising water-table and rainfall were shown by the change of pore-water pressure distribution at the crest and shell regions of the dam. The results of this study demonstrate the ability of (SCS) model to provide the information required for the analysis of infiltration rates from the earth fill dam. The Curve Number (CN) estimated from a spatial Table taken by USDA, in combination with observed mean monthly rainfall values predict infiltration rates, as summarized in table (1). The maximum infiltration rate during the depended period asymptotically tends to the value of the saturated permeability. The pore water pressures at each selected time step were then transferred to the stability program which calculated the change in the factor of safety influenced by the changes in pore water pressures. It is concluded from the stability analysis that the Kashkan dam is safe against the danger of slope failure due to slippage under the operation heads.

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