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Mitigation of Flood Wave Disaster Using Channel Improvement

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ABSTRACT:

The research project reported in this paper study the effects of channel improvement on the flood wave that propagates along the main stream. The channel improvement affects different flood criteria such as the total volume of flood, the time to peak discharge, peak discharge, total sediment volume, and peak sediment graph.

The flood event is simulated using the well known hydrological model, WASHMO which uses a finite difference method for modelling unsteady free surface water flow and also simulate rapidly varied flow over common hydraulic structures (Elhanafy 1999). A series of simulations are carried out and compared with previous study on a specified watershed in the Northern coast of Egypt. The positive effects of channel improvement are promising and could be used before the design of any control actions. This indirect method could be used to mitigate the flood disaster effects. This model could be used as a stepping stone for different purposes including cost minimization of protection works, increasing the live span of the water structures along the main stream, minimization of the erosion near the piers of bridges and culverts, and seepage minimization.

Keywords: flood disaster, channel improvement, flood simulation

1. Introduction:

The design of any protection works depends on the flood wave criteria represented in many factors, such as the total volume of flood, the time to peak discharge, peak discharge, total sediment volume, and peak sediment graph. These criteria are the outputs of flood simulation using a hydrological model. Although there are some differences in their values according to which model is used to simulate the flood event, but the inputs still the same for each flood event and for each watershed.

The modification of reservoir release rates, the operation of control structures such as gates, locks, weirs, the diversion of water into canals and floodplain storage facilities (Sanders et al. 2000), the design of detention dams, culvert, and Irish crossing system as protection works and control actions in channel flow systems are highly affected by the flood criteria.

These inputs could be divided into three groups as follows: Topographical data; meteorology data; and soil and surface data. One of the main factors that could be used to mitigate the flood event impact is the improvement of the stream conditions. The research project reported in this paper study the effect of changing the channel conditions on the predicated flood event downstream.

The development of hydrological models has gained a lot of momentum in recent years as their ability to describe the spatial and temporal variation of water flow phenomena has been improved.

These models may be used by researchers and engineers or by commercials authorities to produce commercial hydrological software. But, before these models could be used, their validation is an important point.

However, now that commercial hydrological software has the ability to solve a specified range of engineering problems, the validation material that accompanies them can only ever apply to a subset of these applications.

While academic researchers should compare the hydrological simulations with experimental results in order to test the accuracy of the new model. The users of the software assume that the software produces results that can be relied on. The researchers on the other hand, have to validate the software before using them.

Once the hydrological model is validated, it could be used for several purposes such as the prediction of circulation in estuaries for hazardous spill response (Cheng et al. 1993), the prediction of flood wave propagation in rivers (Steinebach 1998), coastal flow modelling (Copeland 1998), and evaluating the sensitivity of the flood to some control variables (Copeland and Elhanafy2006).

In this paper a well known hydrological model, “WASHMO ”(Watershed Storm Hydrograph- Multiple Option) has been applied on a specified watershed in the Northern coast of Egypt under different conditions of the main stream.

2. The Study Area:

Location :

The study area, Wadi EL-Graola covers an area of about (21km2), Its outlet station lies (20 km) east of Matruh City and it's main channel running through a tourist village as illustrated in Figure [1].

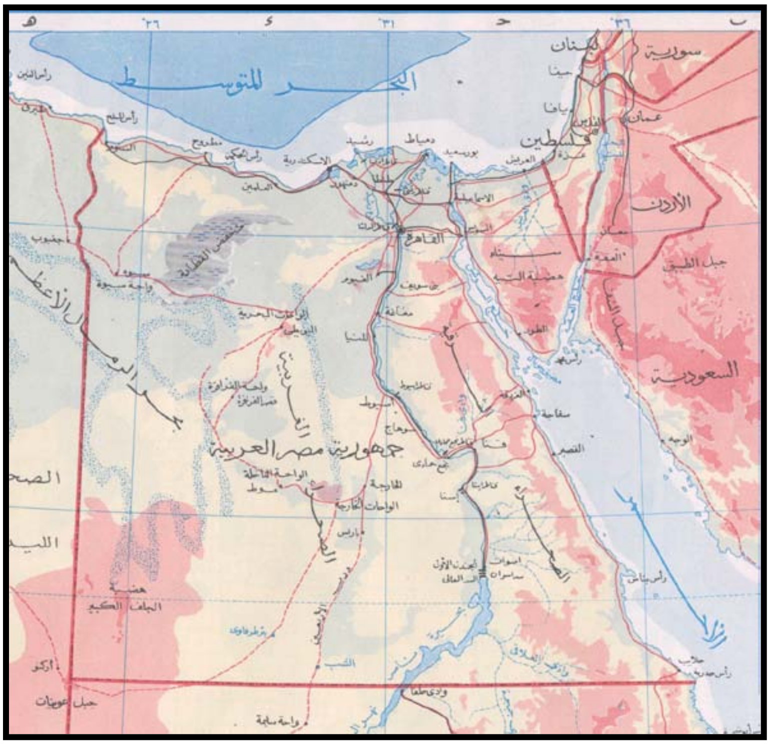


Fig [1] Location of the study area

Geology :

Several geological studies were carried out by many geologists for the northern part of the Western Desert of Egypt.

" Shata, 1972 " studied the region which extend from western part of Nile delta to western part of Matruh. He described these beds in several terms as Pink Oolitic limestone, Pink Pseudo Oolitic or Pink sandy limestone. The record thickness of pink limestone is ranging from few meters to 70 meters (surface & subsurface).

" Scott. W, Prior, 1976" from lithologic data obtained from well bores show the basin to have developed from a pre-middle Jurassic graben into a broad Cretaceous. The basin was uplifted in the Tertiary owing to collision of the African and European crystal plates.

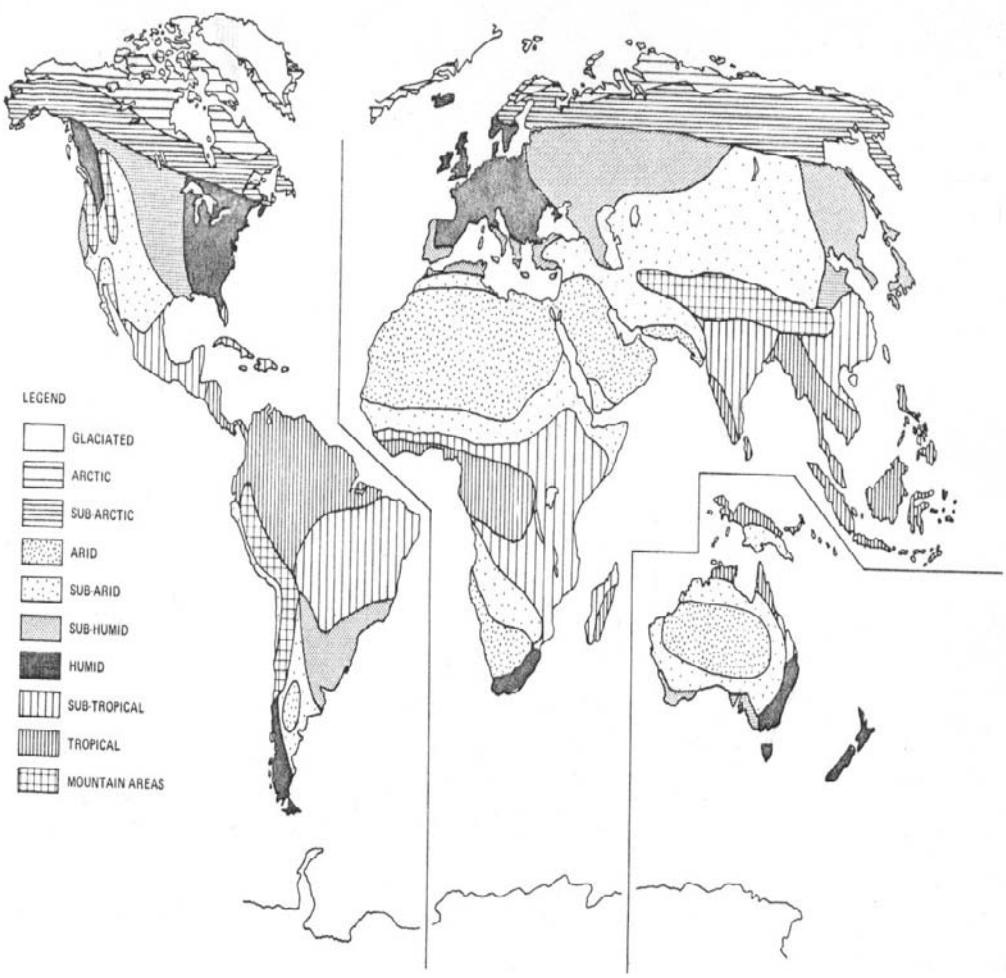
Lower and middle Jurassic rocks have not been reached by drilling in the basin owing to excessive depth, but are thought to consist of terrigenous clastics. A carbonate -shale phase of deposition is known to have followed clastic deposition. Some 10,000 meters of Cenozoic rocks are estimated to lie within the northern part of Matruh basin.

The most prominent fault trend is the NW-SE trend. It is expressed by several closely faults across the basin which control the basin drainage lines (Dewey and others, 1973).

2.3 Climate:

The Western North coast of Egypt is considered as arid region fig.[2], It is characterized by less than 20 inches of annual rainfall but sometimes it exceeds this value. Precipitation is higher in winter months when temperature is relatively low.

In such arid regions the landform are generally more rugged and without significant soil development over rock features. In these regions the lack of both precipitation and vegetation results in slower weathering, but when storms occur they tend to be severe, thereby causing rapid erosion of any materials that may have disintegrated.



Fig[2] The basic climatic zones of the world, including glaciated, arctic, sub-arctic, arid, sub-arid, sub-humid, humid, subtropical, tropical, and undefined mountains areas.

2.4 Topography:

Since little moisture is available for chemical weathering in such arid climates, the limestone present erodes very little. Pure, thick limestone deposits from cap or table rocks as illustrated in Fig.[3].

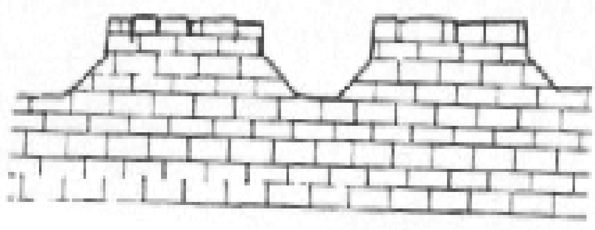


Fig. [3] Table rock.

The maximal elevation is about 176-m (A.S.L.) at about 19.0 Km from the out let station, which reflect the lightness of the slope.

2.5 Drainage pattern:

The surface drainage system is well developed. The pattern is very angular, following jointing alignments in the bedrock, and is medium to fine textured. Major streams are intermittent as illustrated in Fig. [4].

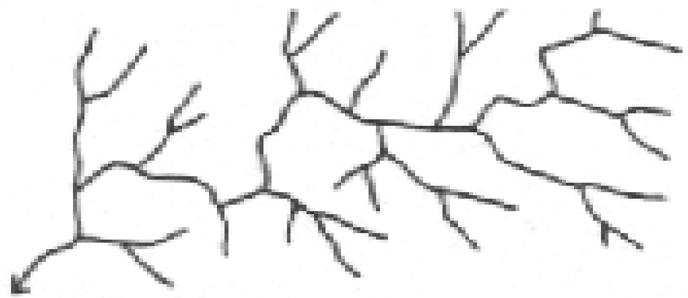


Fig [4] angular dentdritic: medium to fine

3. The Hydrological Model used in the study:

3.1 Introduction

The “WASHMO ”(Watershed Storm Hydrograph- Multiple Option) model was developed at the university of Kentucky, department of agricultural engineering. The model is a modified version of the WASH (Watershed Storm Hydrograph) model (Ward et al., 1979).

Recently, Ward et al, 1980 developed a modified version of WASHMO model. This model basically consists of two intertwined models, one describing the hydrology of the basin and the other describing the associated detachment and transport.

3.2 The hydrological model:

The first model mainly describes a design storm hydrograph. It is capable of simulating the hydrological response of a watershed with only a limited amount of calibrated data such as: rainfall amount, soil conservation service (SCS) curve number, storm duration, and average overland slope, the hydraulic length of the watershed and land use coverage.

3.3 The sediment detachment and transport model:

The process by which soil particles are eroded contains three interrelated phenomena:

i- Detachment.

ii Transport.

iii Deposition.

The USLE " the Universal Soil Loss Equation " (Wishmier and Smith, 1965) or any of the modified version of it is used to determine erosion from an area either for long term period, gross erosion or for storm event.

The USLE " the Universal Soil Loss Equation ":

$$\mathbf{A=RKL_SCP_r}$$

Where:

A is the computed soil loss per unit area (tons/arce).

R is the erosive potential rainfall factor.

K is the soil erodibility factor.

L_s is the slope - length factor.

C is the ground cover factor.

P_r is the reclamation practice factor.

3.4 Model verifications:

The “WASHMO ” model appears to be capable of simulating the hydrological response of watersheds exhibiting a wide range of land use and the ability of the (WASHMO) (WAtershed Storm Hydrograph- Multiple Option) model to predict observed runoff hydrographs was demonstrated in a study with twenty storms on five watersheds ranging from an urban watershed to a steeply sloping forested watershed by Andy ward et. al,(1980).

The model gives fairly good results of the peak discharge for most of the events and for the set of twenty storms as shown in Fig [5].

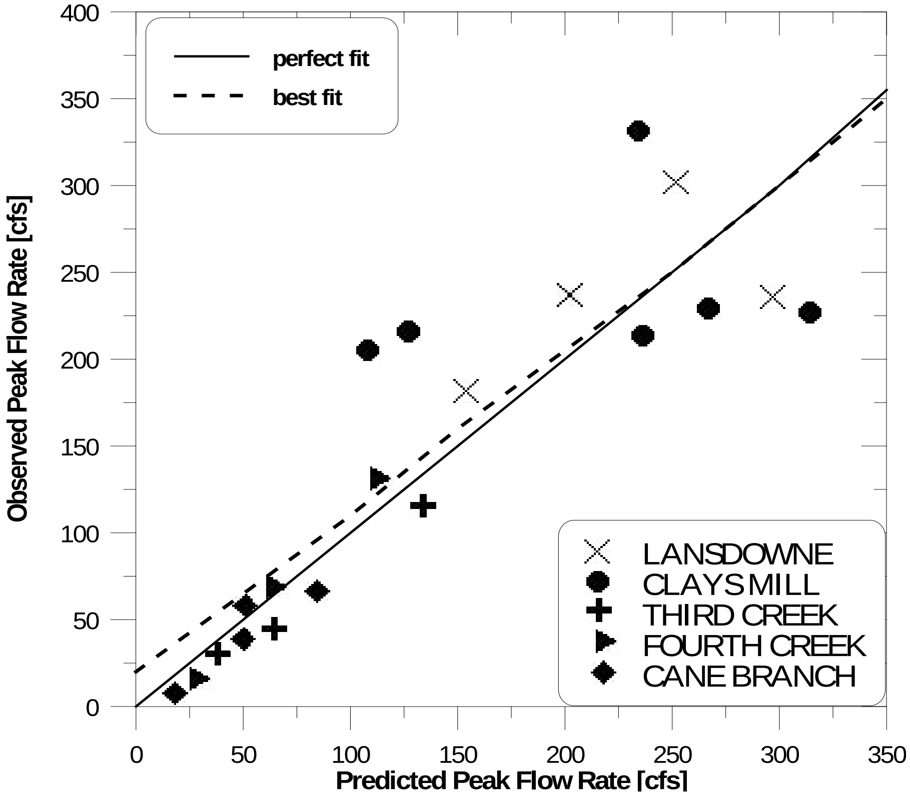


Fig. (5) Observed VS. Predicted Peak Discharges.

4. Hydrological results, and results analysis

Wadi EL-Graola watershed consists mainly of two sub-watersheds as illustrated in Fig. [6] and Fig. [7], Four different cases have been studied in this research under different scenarios for the main streams conditions which are:

Natural stream – Unlined stream – Grasses stream – Concrete lined stream.

The watershed output files have been studied, the hydrographs and sedimentgraphs were plotted as illustrated in Fig.[8] and Fig.[9] respectively.

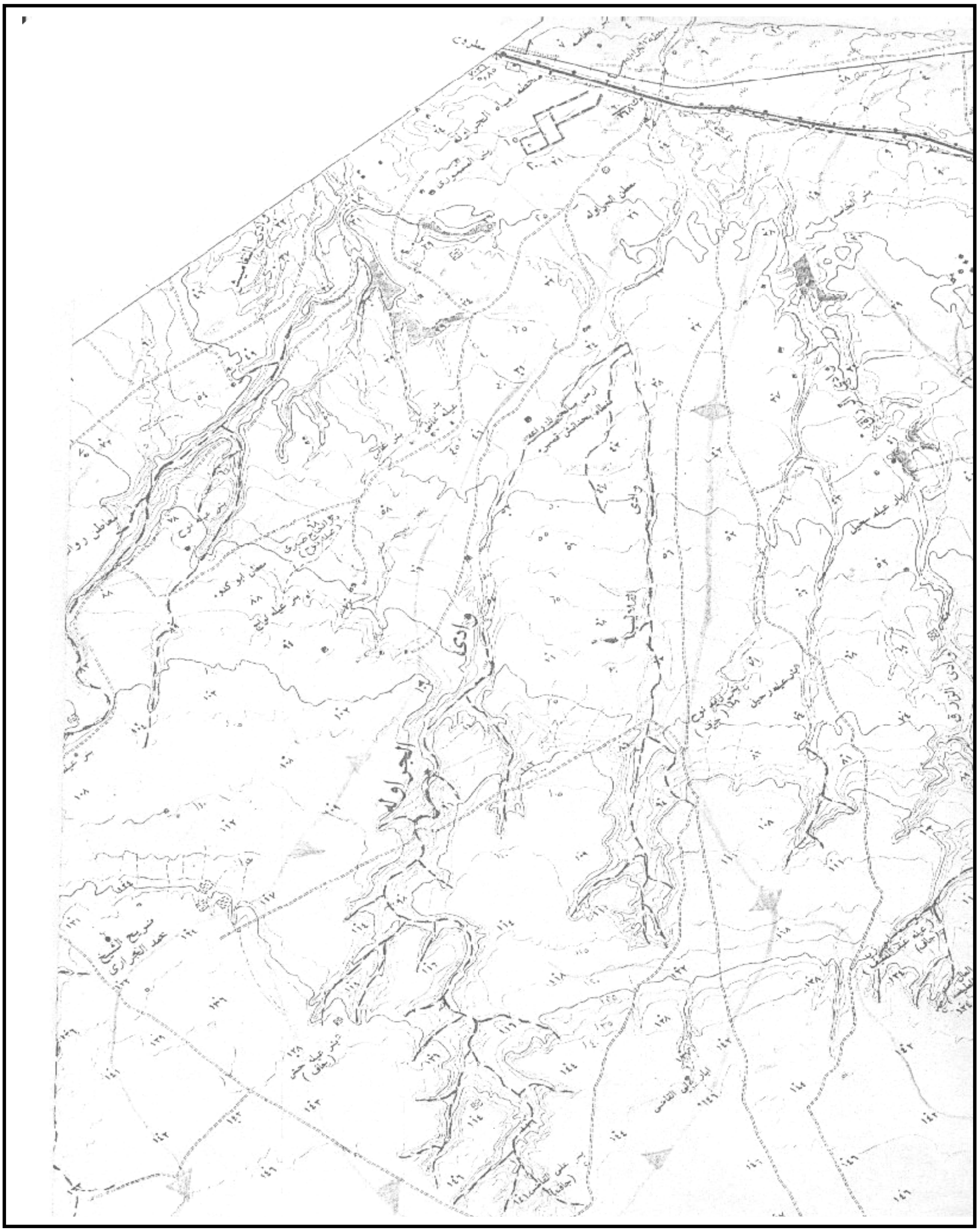
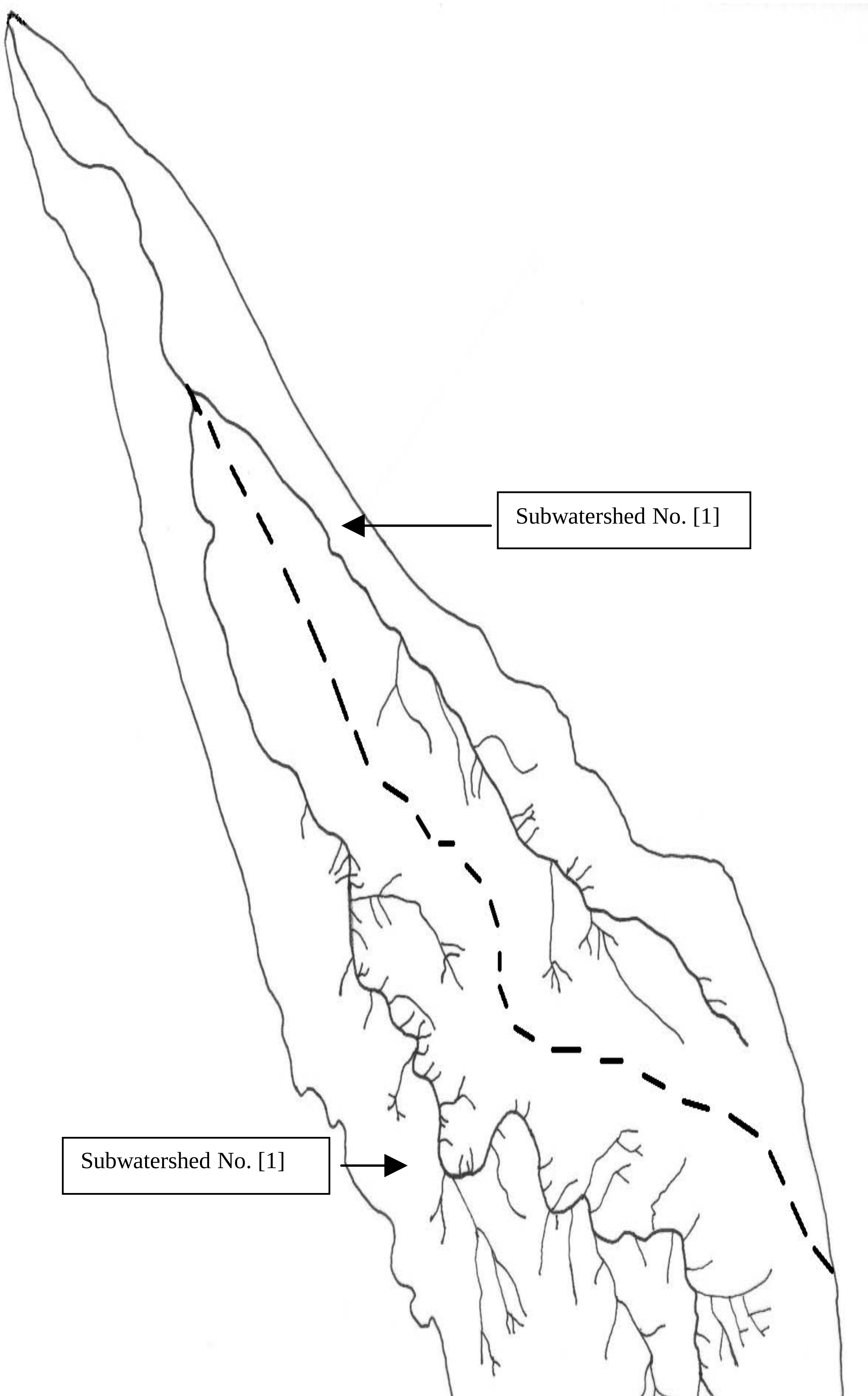


Fig. [6] topographical map of Wadi EL-Graola watershed



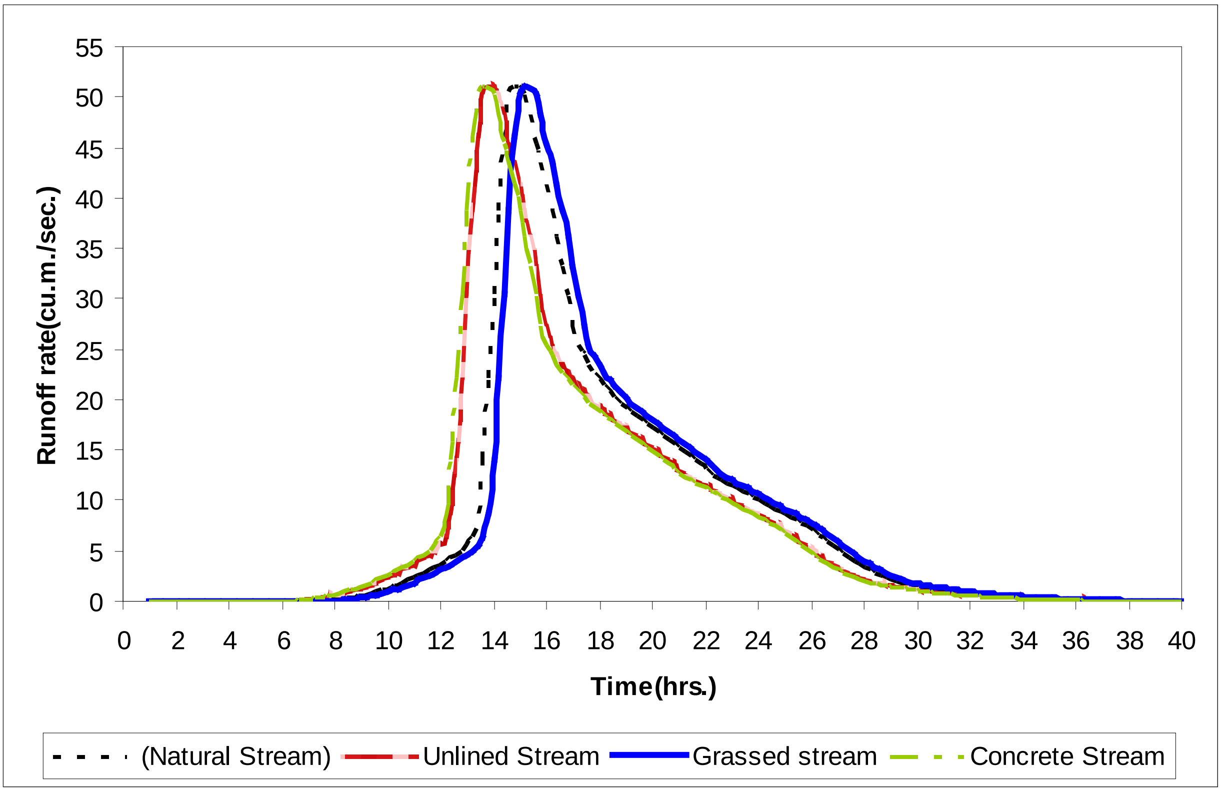


Fig. [7]. Subwatersheds of Wadi EL-Graola watershed.

Fig. [8]. Four Hydrographs for the Four cases.

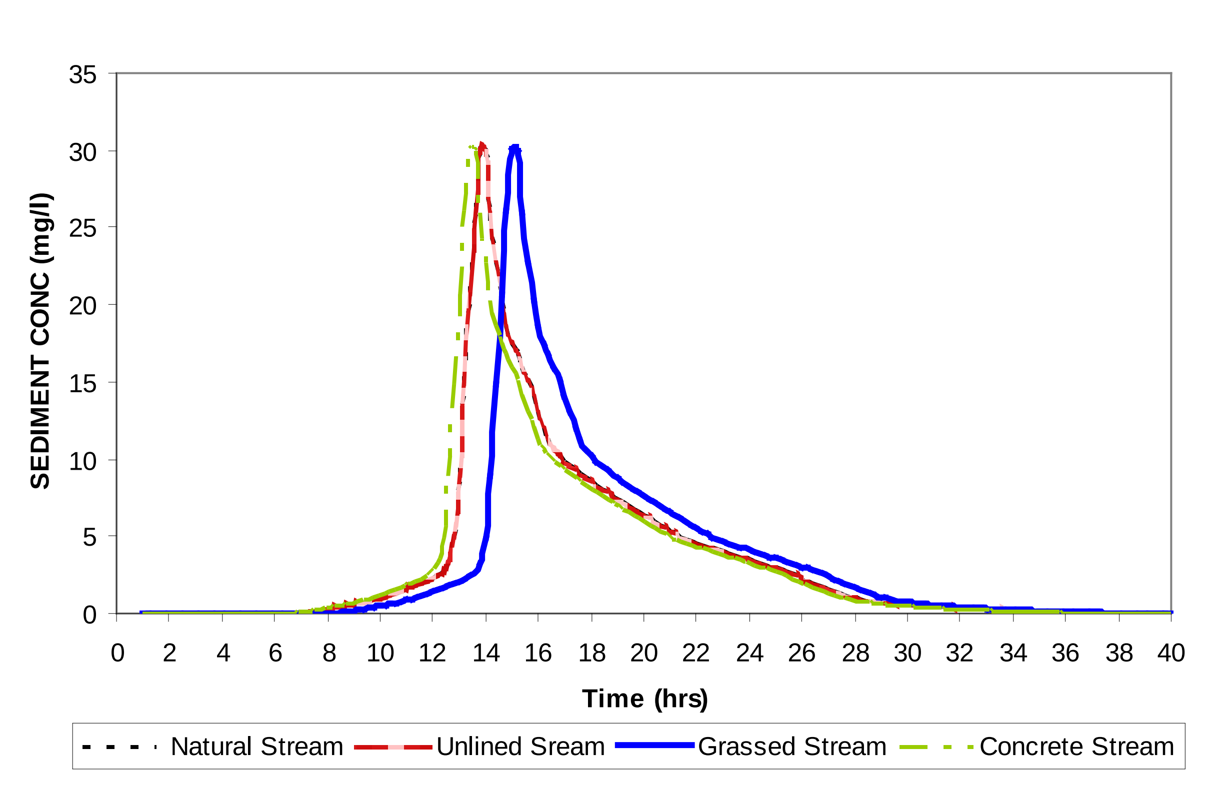


Fig. [9]. Four Sedimentgraph for the Four cases.

Table [1] Hydrological outputs for the four cases

Stream case	**Natural**	**Unlined**	**Grassed**	**Concrete**
Volume Of Runoff (thousands m^3)	1092.63	1092.68	1092.55	1092.69
Peak Runoff Rate (cu. m./sec.)	51.03	51.03	51.03	51.03
Time To Peak Runoff (hr.)	14.70	13.90	15.02	13.5

Table [2] Sediments outputs for the four cases

Stream case	**Natural**	**Unlined**	**Grassed**	**Concrete**
Total Sediment Yield (tonnes)	24502.99	24502.99	24502.99	24502.99
Peak Sediment Concentraiton (mg/l.)	30.07	30.07	30.07	30.07
Time To Peak Sediment concentration (hr.)	14.60	13.8	15.00	13.4

It is clear from Fig [8] and Fig [9] that both the hydrographs and sediementgraphs for the four cases follow the same shape with almost the same peak values. The total volume of flood in the four cases is the same which is bout 1092 thousand cubic meters. For the sediemntgraph the total volume of sediments is 24502 tonnes under the different four cases.

It is obvious from Table [1] and Table [2] that the most effective change is found to be the time to peak for either the hydrograph or the sedimentgraphs. This result is expected since the velocity of the flood wave is highly affected by the boundary conditions. As long as the time to peak discharge increase, the warning time increase which of course will be helpful on warning communities and safe both the properties and people life's downstream. The most delayed case in time is found in the case of grassed stream which is about 1.6 longer than the concrete channel case.

This exactly what the Bedouin people did from a very long time till today. They get used to cultivate the main stream, and as a result they mitigated the flood wave downstream and also they recharged the ground water aquifers with the flood water.

Results at this paper are very encouraging and have demonstrated new ideas for addressing some issues in hydrologic modeling especially stream flow modelling and flood wave propagation.

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