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Analysis of the Runoff Generated due to the 2011 Monsoon Rainfall in Sindh using HEC-HMS

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Abstract: An in depth analysis is carried out for the calculation of runoff generated due to the heavy 2011 monsoon rainfall in the South East of Sindh, which luckily also has a very large manmade drainage system operating in the area namely Left Bank Outfall Drain (LBOD). The large runoff created havoc in the area and rain water remained in many areas for months. The calculation of the runoff is carried out with the help of widely used software Hydrologic Engineering Centre's Hydrologic Modeling System (HEC-HMS). HEC-HMS version 3.5 was used for the purpose. The rainfall data was obtained from the Pakistan Meteorological Department, Government of Pakistan which records rainfall every 24 hours period. The results show very large amount of runoff due to heavy rainfall which looking at the present capacity of LBOD would take months to drain off.

Keywords: Analysis Carried out Calculation Run off Generated Monsoon Rainfall

1. INTRODUCTION

The Development of Irrigation system in Sindh commenced in 1932 with the commissioning of the Sukhur Barrage and continued till (1962). Due to the progressive raising of water table the Kotri Basin drains were built to discharge saline water into the dhands (lakes). Later on studies and ground work continued to expand drainage system to combat the water logging problems subsequently LBOD stage 1 was commissioned in December (1997).

Drainage is an essential requirement in the environment of the Sindh Province, where continued diversion of Indus River water for irrigation and relatively flat topography requires mechanisms to flush the root zone. Before 1932, much of the area in Sindh had water tables below 3.6 m and around 50 years later 75 percent of these areas had water tables less than 1.5 m and 20 percent less than 2.4 m. However the key drainage issues in the project area may be summarized as below:

- Control the ground water table in the areas where it is rising due to the continuous irrigation and seepage from canals
- Decrease the evacuation time in case of heavy rainfall so as to save the standing crops
- Reduction in overflows of storm water from the Main Drains and the Spinal Drain

No significant study has been reported in the area for the calculation of runoff due to heavy rainfall. The object of the present study is thus to calculate the amount of runoff generated due to rainfall using the HEC-HMS software. Many studies have been done like.

2. MATERIALS AND METHODS

Description Of The Study Area

LBOD Stage-1 Project and Badin Area Drainage System are located in the South Eastern part of Sindh and its tail end is close to the Arabian Sea. Geographic coordinates of the area lie between latitudes 24^o 10' and 26^o 40' N and longitudes 68^o 09' and 69^o 26' E in the districts of Benazirabad (Nawabshah), Sanghar, Mirpurkhas and Badin. The area can be defined as semi arid zone. The ground elevation of the region varies from 125 to 10 feet above mean sea level (amsl). The project area is spread to more than 3155 square miles, and the length of complete drainage system is 1565 canal miles (7825 RDs) including 220 canal miles (1098 RDs) of outfall drains.

Climate Of The Study Area

Climate has considerable effect on the hydrology of the area. The most important parameters are precipitation and evaporation. Evaporation depends upon temperature, humidity, air pressure and wind velocity. Precipitation and evaporation have direct influence on water balance in a basin and therefore, they influence both volumes of surface and subsurface runoff.

Global motion of dominating air masses results in the formation of two rather well defined rainy periods in the year, i.e. monsoon rain in summer and winter rainfall. Southwestern monsoons from the Arabian Sea in July to September bring most of the annual rains. The average annual precipitation in the study area is between 150 mm to 200 mm. However, several years may pass without significant rainfall.

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The study area has a hot arid climate, the hottest months being May-June when average maximum temperatures approach 43-46^{o} C. The coolest months are November-February when minimum temperatures average 10 - 8^{o} C. Evaporation rates vary from over 10 mm/day in the summer hottest months to 3 mm/day or even low in the winter.

Meteorological Data Collection

The data obtained from the Meteorological Department Government of Pakistan has been used for the analysis of rainfall-runoff relationship because it is considered the most reliable. However, this data is still lagging in terms of temporal distribution because the measurement is made every day at 8 am, as well as spatial distribution as many areas don't even have a single gauging station. There is no automatic rain gauging arrangement available at any of these stations. It is, therefore not possible to know, the duration of the heaviest rainfall and its actual amount, during a particular storm event.

Analysis of 2011 Monsoon

The phenomenon of global warming and climate change has resulted in both drought and severe flooding situation followed by heavy rainfall, which is a real challenge for engineers and scientists dealing with water resources planning, flood protection works and drought studies. Few events of heavy rainfall during the last decade have been analyzed and special analysis is also done on the monsoon rainfall of 2011.

An in-depth analysis is carried out for the monsoon of 2011 in all the four components of the project. The monsoon path for 2011 shows its entrance in Sindh from the South East corner and the travels in the North West direction. Hence the areas in the South East of the province and specially the left bank of River Indus and the LBOD project areas received the maximum rainfall.

The daily and cumulative rainfall recorded at the three gauging stations of Benazirabad, Mirpurkhas and Badin by the met office during the monsoon of 2011 was analysed. This daily rainfall is recorded at 8:00 am in the morning. A quick look into the monsoon pattern shows that the monsoon rain was divided into two major spells. The first spell started around 10th of August, 2011 and lasted for three to four days whereas the second spell was of a longer duration and started on the 30th of August and went on until the 9th of September in the Benazirabad and Mirpurkhas areas and up to 13th of September in the Badin area. The second spell created major devastation in the area due to the fact that the soil was nearly in a saturated state due to the first spell and that created runoff of much greater magnitude. It was a continuous spell and didn't give any time to the pools of water to get evaporated or get evacuated by the drainage system.

Graphs are also plotted for the individual daily and cumulative rainfall in the component areas and are shown in **(**

Fig. *1* to

Fig. *6*). It can be seen in the graphs that although the rainfall was witnessed in two calendar months but the actual days of the continuous rainfall were between 12 to 16 days in different project component areas. Due to this reason these monsoon rains created an unprecedented destruction / devastation in the area.

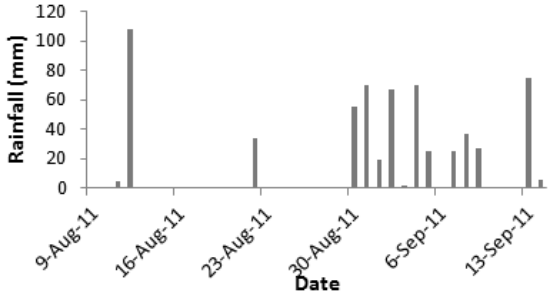

Fig. 1: Daily monsoon 2011 rainfall in Nawabshah.

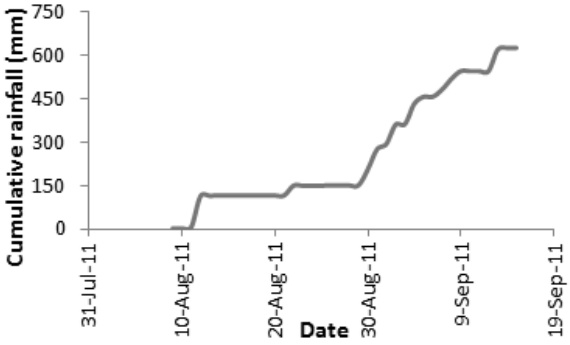

Fig. 2: Daily cumulative monsoon 2011 rainfall in Nawabshah.

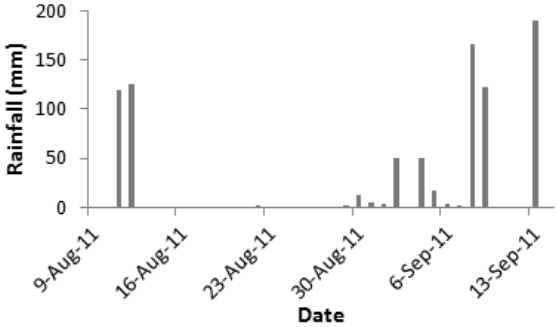

Fig. 3: Daily monsoon 2011 rainfall in Mirpurkhas.

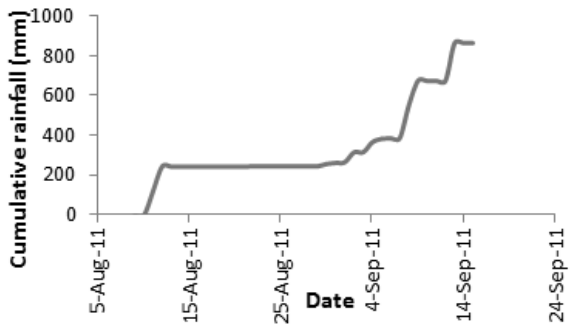

Fig. 4: Daily cumulative monsoon 2011 rainfall in Mirpurkhas.

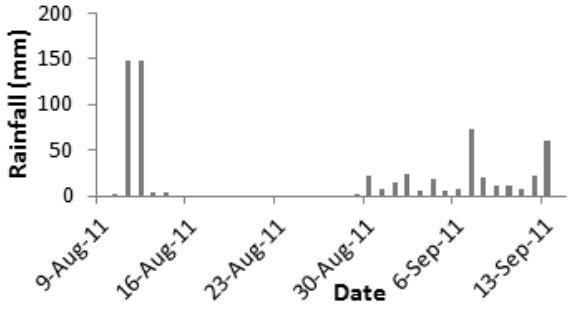

Fig. 5: Daily monsoon 2011 rainfall in Badin.

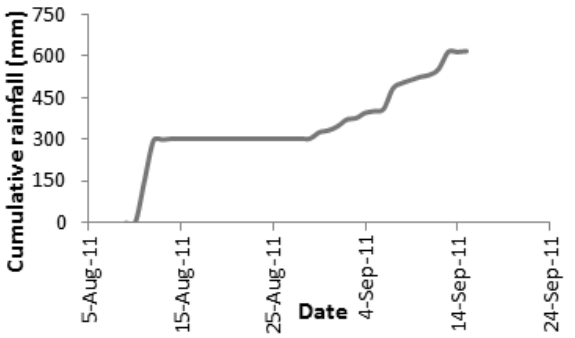

Fig. 6: Daily cumulative monsoon 2011 rainfall in Badin.

3. RESULTS AND DISCUSSION

Computation Of Runoff Volume By Hec-Hms

In the absence of any discharge data at the project site, the flood runoff at the project site has been estimated through rainfall data. For this purpose computer model HEC-HMS has been used. HEC-HMS computes the runoff volume by computing the volume of water that is intercepted, infiltrated, stored, evaporated or transpired and then subtracting all these losses from the precipitation (USACE-HEC, 2010). The program considers that all the land and watershed can be categorized as either directly connected impervious surface or pervious surface. Directly connected impervious surface in the watershed contributes all precipitation as runoff with no major volume losses. The precipitation on the pervious surface on the other hand is subjected to losses. For the present study the SCS curve number (CN) loss model is used to account for the cumulative losses (TR-55, 1986). With this model, the precipitation loss is found for each computation time interval and is subtracted from the total depth for that interval. The remaining depth is referred to as precipitation excess. This depth is considered uniformly distributed over the watershed area, so it represents the volume of runoff.

The total rainfall volume, losses and excess runoff generated during the monsoon (2011) are tabulated in Table 1. It may be noted that due to the fact that there is no gauging station to record rainfall in the Sanghar component, the rainfall for the nearest station i.e. Benazirabad is taken. This is done in line with the previous studies conducted in the project area from time to time.

Table 1: The total volume of rainwater and the runoff thus generated.

Project Component	Area (acres)	Precipitation (mm)	Total volume generated (1000 m^3)	Losses (1000 m^3)	Excess runoff (1000 m^3)	(1000 ac-ft)
Nawabshah	626000	628	1591737	225982	1365755	1107.2
Sanghar	424000	628	1078334	160305	918029	744.3
Mirpurkhas	376000	866	1318204	167922	1150282	932.5
Badin	593496	630	1513981	250798	1263182	1024.1
Total			5502256	805007	4697248	3808.1

The table shows the total volume of nearly 1.59 x 10^9 m^3 of water falling in the Benazirabad area of the project out of which about 0.22 x 10^9 m^3 going as losses in various forms thus generating an excess runoff of nearly 1.1 x 10^9 m^3. Similarly the total volume of water generated as well as the losses and excess runoff are also calculated for other component areas. The total runoff thus generated in the whole project area comes to nearly 4.7 x 10^9 m^3 or 3.8 million ac-ft. This excess runoff got evacuated through the LBOD drainage system working in the area as well as through the old natural drains (dhoras) flowing through these areas.

A small investigation is also carried out to ascertain the number of days required to drain off this generated runoff through the LBOD system alone. The total runoff generated through the monsoon (2011) and the number of days to evacuate it is shown in **(**

Table *2*). The following assumptions are made for the calculations.

catchment area with equal intensity.

2. No allowance is added for the breaches in the irrigation canal system that also contributes in the runoff during heavy rainfall events.
3. The average disposal by the LBOD drainage system is assumed to be:

a. 4,600 cusecs based on the design discharge of LBOD system.

b. 10,000 cusecs based on the calculation on field measurement of discharge.

c. 12,000 cusecs based on the calculation by hydraulic model.

d. 15,000 cusecs based on future improvements in the system.

Table 2: Runoff and number of days required to evacuate it through LBOD.

Runoff	Evacuation time in days			
(1000 ac-ft)	4600 cusecs	10000 cusecs	12000 cusecs	15000 cusecs
3808.1	417	192	160	128

This shows that if LBOD drainage system worked for the evacuation of rain water alone it would have required many months to drain off this huge quantity of water.

It may thus be concluded that the heavy 2011 monsoon rainfall in the South East of Sindh generated very large amount of runoff. It was very fortunate to have a drainage system working in the area which helped a lot in the disposal of this water. Due to the limited capacity of LBOD the rainwater remained in the area for many months.

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