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논문

Computations of Overland Flows and Flood Control Analysis on the Cheat River Basin by HEC-1 Model

HEC-1 컴퓨터 모델에 의한 Cheat강 유역의 지표유출 및 홍수분석

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초 록

본 연구에서는 미국 West Virgini주 동북부에 위치한 Cheat River Basin 일원에 1985. 11월에 발생한 대홍수를 HEC-1 Computer Model로 재현시켰다. 전체 유역을 수문 및 지형 특성에 따라 각 소유역으로 나누어 각소유역에 대해 지표면유출을 계산하였다. 적용된 단위도는 본 유역의 지형 특성을 고려 Snyder's Unit Hydrograph를 이용하였다. Cheat River 전체에 대한 홍수조절 계획이 본 HEC-1 Model에 의해 수립되었으며 제3안의 3개의 중규모 다목적댐 건설이 가장 적절한 계획인 것으로 고찰되었다.

I. Introduction

The subject study evolves from the aftermath of the November 4-5, 1985 catastrophic flood on the Cheat subbasin of the Monongahela River Basin, hereafter referred to as the November flood.

It is recognized that other basins, such as the upper Potomac, also suffered greatly as a result of a common weather system that produced the flooding, Additionally, progression of the flood peak downstream results in substantial damage along the lower Monongahela, at and below the Cheat River confluence.

Motivated by the November flood, the study is to formulate hydrologic model for the establishment of flood control scheme.

Since the upper half of the basin is more mountainous than lower half and has long narrow watershed as shown in ⟨Fig. 1⟩, the Snyder's Synthetic Method of Unit Hydrograph(Viessman et al, 1977) is applied to determine hydropgraphs of the basin above Parsons, while the SCS Method of Unit Hydrograph is used for the area downstream of

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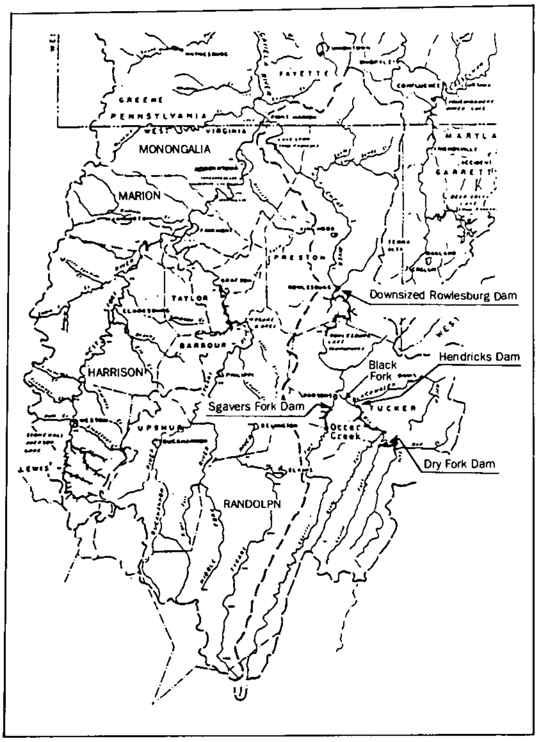
Parsons. Also, the methods are tested by computing the hydrographs at Davis on Blackwater River, Parsons on Shavers Fork and Rockville Big Sandy Creek, and by comparing these to observed hydrographs. It is found that the Snyder Method gives a more accurate fit at Parsons and Davis.



〈Fig. 1〉 Location and vicinity map of the Cheat river basin(Dept. of Natrl. Res. 1973)

The Snyder's Unit Hydrograph, initially, is based on the method developed by Snyder (1938) and expanded by Taylor et al(1952). Dalrymple(1965) relates the Snyder method to the flood peak and precipitation. The U.S. Army Corps. Engineers(1954) compares the SCS and Snyder's Method. There are also a number of versions of the SCS model described in publications(Chow et al, 1982).

According to the study, the installation of three moderately sized dams of option Ⅲ is selected as final plan.

The method that can predict the effectiveness of a given structure design is to conduct a modeling study to test it against historical or hypothetical floods of a sufficitent severity to meet the design requirements. The type of model used in this case is a computer-based hydrological model. In this study the U.S. Army Corps of Engineers HEC-1 watershed hydrology model(Hydro. Engr. Cnt., 1985) is chosen to meet the modeling needs.

The final design options are heavily influenced by the constraints placed on the study by the local citizens of Tucker County and surrounding counties. The constraints required that little or no homes or farms be displaced, hence greatly limiting potential reservoir locations. The town of Parsons and surrounding communities must be heavily protected.

Ⅱ. Basin Description

〈Fig. 1〉 shows the location and surrounding of the Cheat River Basin. The slopes of subbasins and streambed are steeper upstream than downstream of Parsons. The subbasin areas and stream lengths of principal tributaries are shown in 〈Table 1〉.

The Cheat drainage basin is long and narrow, and originate in a north-south direction as shown in 〈Fig. 1〉. Parsons is located at the geometric center of the basin with the total drainage area split evenly· upstream and downstream at the point. The pattern of stream drainage drainage above Parsons is substrantilally different from what is below. The slops are very steep, the soils are shallow and the drainage path to the main tributary channel is short. Red Creek is an exception in terms of shape, but identical in other

〈Table 1〉 Subbasin areas and lengths

Tributaries	Areas (mile²)	Length (miles)	Average Slope(%)
Red Creek	61.4	17.2	1.8
Laurel Fork	60.1	34.1	0.9
Glady Fork	63.4	37.6	0.7
Otter Creek	29.0	13.0	–
Blackwater River	139.1	27.4	1.4
Shavers Fork	213.3	78.1	0.5
Big Sandy Creek	206.9	31.4	–
Main Stem & Othrs	628.5	120.0	

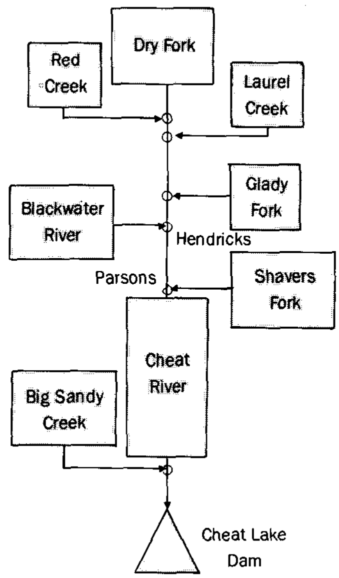
respects. The Blackwater River is the lone exception from this overall description. It drains a high altitude plateau that is dominated by the Canaan Valley, which contains unique hydrologic features in a setting of shallow sloping terrain, with significant area in marsh land. Other portions of Blackwater Basin are also characterized by shallow marshy deainage at high elevation.

Ⅲ. Modeling of the River Basin

HEC-1 is used to simulate the Cheat Basin and the November flood event. The HEC-1 model enabled river discharge versus time to be simulated for the November flood at many points along the tributaries and main channel of the Cheat River where there is insufficient historical data available to decrease the flood to the extent required for a design study. This is accomplished by subdividing the entire drainage basin into many small subareas. The precipitations excess is computed by subtrating infiltration and detention losses based on a soil water infiltration rate function. The rainfall and infiltration are assumed to be uniform over subareas. The resulting rainfall excesses are then routed by the option to the outlet of the subbasin producing a runoff hydrograph.

3.1 Subarea and Stream Network Development

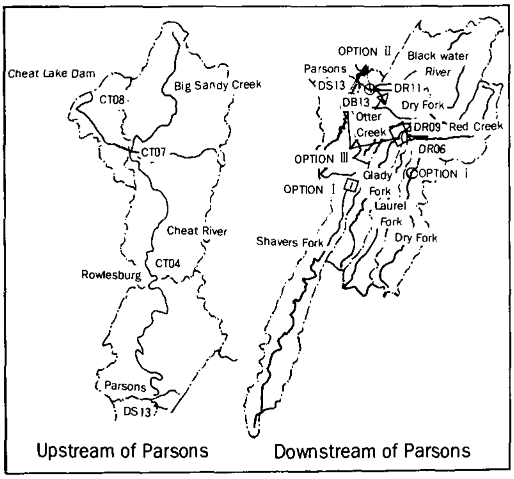
The first important step in fitting the HEC-1 computer model to the Cheat River Basin is to subdivide the entire basin into several small areas, and to select these subareas and stream segments so that they are of sufficient resolution accurately to reproduce the detailed variation of the rainfall-runoff process. A second but no less important factor in there selection is that they should be divided at points along the river channels where a structural design is to be tested, which is influenced by basin characteristics and hydromentological processes. It is assumed in the HEC-1 model that each subarea represents an area of watershed which, on the average, has the same hydraulic /hydrologic properties. The rainfall and other necessary data are determined for each subareas. The



〈Fig. 2〉 Schematic diagram of the basin

model is then capable of computing a separate discharge versus time record for each of these subareas. It then accumulates these flows as it proceeds downstream.

The flow charts of the subareas and their connecting streams of the Cheat Basin are included in ⟨Fig. 2⟩ and ⟨Fig. 3⟩, respectively.

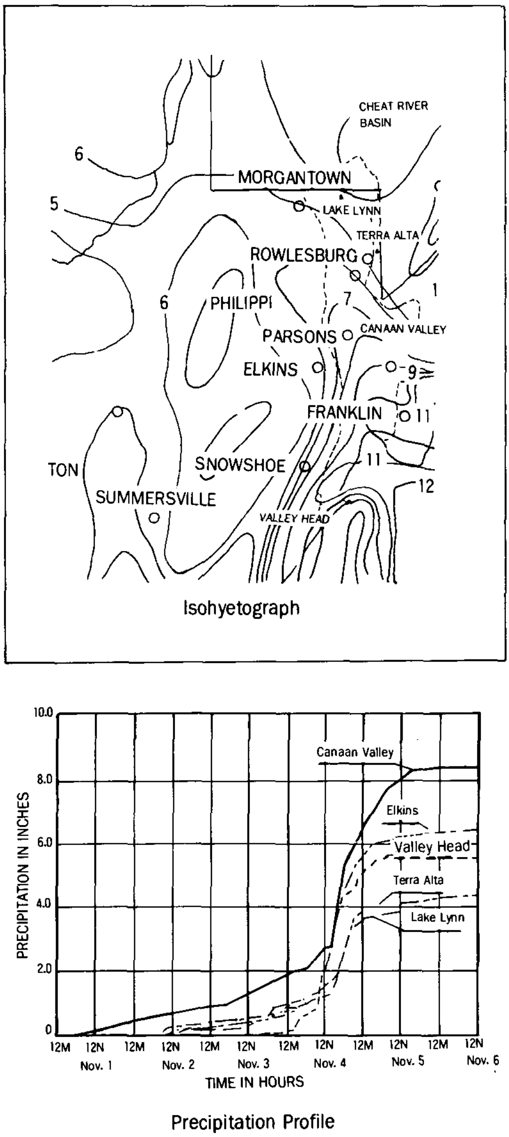


⟨Fig. 3⟩ Plain map for schematic diagram of the basin

3.2 Storm Design Used in the Model

The November 4-5, 1985 flood event is selected for use as the design flood because of its extreme rarity, with a magnitude exceeding the 500-year flood. Actual frequency calculations based on the available historical record yield return periods values much greater than 500-years at many points along the Cheat River. The decision is made not to use these values because of the potential large errors resulting from any computed frequency values exceeding the 500-year flood. Therefore, the decision was made to label this flood simply as on "exceeding the 500-year flood". The peak discharge at the Rowlesburg Dam site exceeds the original Standard Project Flood(SPF) used in the design of the dam. This was another good indication that the November flood was a sufficiently severe test of any proposed structural flood control design.

Having made the decision to utilize the November flood as SPF for this flood control feasibility study, it is useful to examine the precipitaition which lead to the flood. As shown in ⟨Fig. 4⟩, the accumulated rainfall



⟨Fig. 4⟩ Accumulated Rainfall for the Period No-vember 1~6, 1985(SCS Morgantown, 1987) depth for the total storm event is highest in the ridge and valley mountain topography of the upper watershed. The storm is obviously influenced by the elevation of the ridges in the upper reaches of the drainage basin. Although the lines of equal rainfall depth indicate maximum at the 11 inch depth level, it is known that local depths exceeded 14 inches at several points along the ridges on both sides of the West Virginia border. Overall, the depth decreases in the northwest direction, receding to approximately the 4-inch level near the outlet of the watershed at Lake Lynn. This pattern is consistent with many storms that result from moist air from the south meeting cooler dry air from the north. This latter collision is sufficient within itself to produce large depths of rainfall over a short time period. The ridge lines intensify the effect by acting as a lifting mechanism, forcing the moist air to higher levels, resulting in a greater rate of condensation, and hence havier rainfall. Historical rainfall data, averaged over time, reflects the same general distributions as shown in ⟨Fig. 4⟩. Therefore, it appears that the rainfall accumulation pattern resulting in the November flood is consistent with storms that have occurred in the past, and might again occur in the future.

The rainfall records, during the flood period, of 4 stations located in Elkins, Valley Head of Randolph Co., Terra Alta of Preston Co., Lake Lynn of Monongalia Co., respetively, are used to provide rainfall distribution data from which the storm's total precipitation for each subareas can be interpolated. The ⟨Table 2⟩ shows the accumulated precipitation. It should be noted that the rainfall distribution for Canaan Valley in ⟨Fig. 4⟩ is simulated on the basis of discharge records at Davis on the Blackwater River, and the Canaan Valley total precipitation accumulation. The Canaan Valley is too far from other available recording station to apply their distribution records.

⟨Table 2⟩ Rainfall accumulations of recording stations

STATIONS	ACCUMULATIONS (inch)	PERIODS
Elkins	6.49	Nov. 1~6, 1985
Valley Head	5.69	same
Lake Lynn	4.00	same
Terra Alta	4.36	same
Canaan Valley	8.40	same

3.3 Applied Unit Hydrograph

The Snyder's Unit Hydrograph Method (Snyder, 1938 ; Taylor et al 1952) is used for the computation of runoff on each subwatershed above Parsons where the topograph is steeper and mountainous. The Soil Conservation Service(SCS) Method is Applied to the area below Parsons where the slope of the basin is milder.

For the Snyder Method, the two main parameters, T_p and C_p, are input to the model. By assuming the coefficient, C_t, the basin lag, T_p, in hours can be expressed by

$$T_p = C_t(LL_c)^{0.3} \tag{1}$$

where

L = length of main stream from outlet to divide(miles)

L_c = distance from outlet to a point on the stream nearest the centroid of the basin(miles)

C_t = coefficient ; function of basin slope (lower value for steeper slope)

C_p is the coefficient which influences the unit-hydrograph peak, q_p, given by

$$q_p = \frac{640C_pA}{T_p}(cfs) \quad (2)$$

where

A = drainage area(mile²)

C_p = coefficient ; function of basin slope (higher values for steeper slope)

The empirical coefficients, C_t, and C_p, are calibrated on the Blackwater River and Shavers Fork, respectively, and applied to other subbasins according to their similarity and steepness.

The antecedent moisture conditions for each basin are assumed to correspond to full saturation because of the rain which fall for 48-72 hours before the flood. This phenomenon temporarily reduces the basin's ability to absorb the rainfall ; thus higher values of runoff and peak discharge occurred above Parsons. The exponential loss function option is applied to estimate rainfall losses, and the parameters for the option are obtained by employing the optimization option using observed runoff data at Davis on the Blackwater River and rainfall distribution at Canaan Valley. These optimized parameters are then applied to other subareas.

For SCS Unit Hydrograph Method, the lag time, T_L, and SCS curve numbers(SCS, 1974) are input to the model for the computation of peak times, T_p, and peak discharges expressed by

$$T_p = 0.5\Delta t + T_L \quad (3)$$

$$Q_p = \frac{484A}{T_p}(cfs) \quad (4)$$

where

$T_L = 0.6T_c$

T_c = time of concentration(hrs)

Δt = the duration of rainfall(hrs)

A = Drainage area(square miles)

The lag time applied to the subareas are shown in 〈Table 3〉. The SCS curve numbers are calibrated in the Big Sandy Creek on the basis of rainfall and observed discharge, and applied to other subareas according to their cover condition.

〈Table 3〉 Lag times and applied SCS Curve Number on the Cheat river and Big Sandy basin

SUBAREAS	Lag Times(hrs)	SCS Curve No.	REMARKS
CHET 1	3.5	80	Cheat R.
CHET 2	3.4	78	Cheat R.
CHET 3	5.4	74	Cheat R.
CHET 4	3.0	74	Cheat R.
CHET 5	1.5	73	Cheat R.
CHET 6	1.7	73	Cheat R.
CHET 7	2.1	74	Cheat R.
CHET 8	3.8	74	Cheat R.
CHET 9	3.5	77	Cheat R
BGSN 01	9.0	73	Big Sandy
LTSN 01	4.5	73	Big Sandy
BGSN 02	4.0	73	Big Sandy
LTSN 02	5.6	73	Big Sandy
BGSN 03	4.5	73	Big Sandy

The SCS curve numbers applied on the subareas below Parsons are shown in 〈Table 3〉.

3.4 Flood Analysis

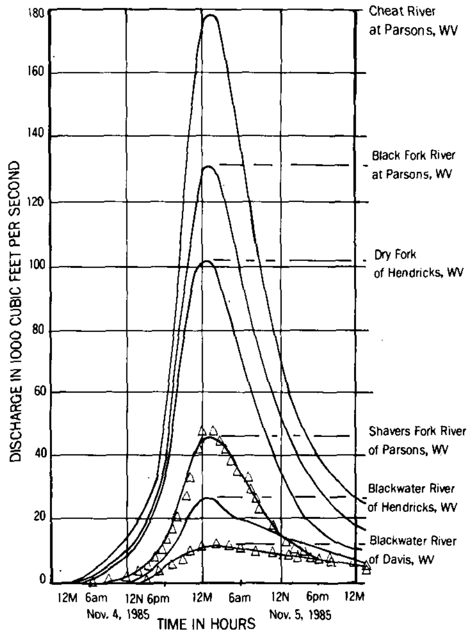
The HEC-1 model requires a large number of parameters to describe the watershed so that it can accurately simulate the discharge along the tributaries and main channel. Where possible these parameters are fine-tuned to match existing records of the November flood. For example, flood records for the Shavers Fork and the Blackwater River are matched with computed hydrographs as explained in previous section. 〈Table 4〉 illustrates the excellent of agreement between the model and the actual flood records on these basins. The Δ's in 〈Fig. 5〉 mark the observed hydrograph on Blackwater River and Shavers Fork. Where flood records are not available, an effort is made to obtain approximate streamflow behavior at the local level by the use of high water marks and the testimony of withness to the rise and fall of the flood wave. All indications are that the simulated flood is an accurate representation of the actual flood event both in terms of discharge record and total volume of runoff.

〈Table 4〉 The comparisons of the computed and observed hydrograph

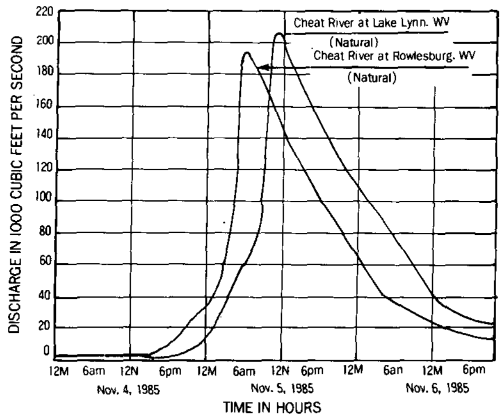
GAGE	CLASS	SUMS (CFS)	MEANS (CFS)	REAKS (CFS)	PEAK TIME(HRS)
Blackwater	Cmptd	310,000	6,000	12,000	26:00
River	Obsvd	312,210	6,244	12,500	26:00
Shavers	Cmptd	752,000	15,000	46,000	25:00
Fork	Obsvd	717,232	14,345	47,833	25:00
Big Sandy	Cmptd	171,000	3,000	7,000	26:00
Creek	Obsvd	161,390	3,228	7,150	26:00

The computed peak discharges of the tributaries are shown in 〈Table 5〉. The flow of Blackwater River, Dry Fork, and Shavers Fork at Parsons, results in a total peak discharge of 176,610cfs.

The town of Parsons is located at the head of the Cheat River, formed at the point by the confluence of the Black Fork and Shavers Fork. The town lies precisely at a natural convergence point of all of the drainage in the upper half of the Cheat Basin. All of the stream and rivers converge at that point, as evidenced by the narrow neck in the overall Cheat drainage basin shape. This natural "funnel" produces a great flooding potential for the town of Parsons and points downstream.



Tributaries above Parsons



At the Lower Half of the Cheat Basin above Parsons

〈Fig. 5〉 Natural streamflows of tributaries

This natural convergence of the drainage in the upper Cheat basin is further enhanced by an apparent equal basin lag time from each of the tributaries discussed above to the convergence point at Parsons. An equal basin lag time for all of the tributaries to the Cheat at Parsons simply means that the individual flood peaks on each of the tributaries tend to arrive at approximately the same time, and therefore are directly additive at Parsons as

〈Table 5〉 The characteristics of hydrograph on tnbutaries and main channel

LOCATION	PEAK DISH.(cfs)	PEAK TIME(hrs.)	BASIN AREAS(mile²)	REMARKS
Blkw. R.	27,000	23:00	139.1	
Dry F.	102,000	24:00	346.6	Excl. Blk F.R.
Blk F.R.	131,000	24:00	500.3	
Shvr. F.	46,000	25:00	213.3	
Cheat River at Parsons	177,000	25:00	713.6	Incl. Shavers F.
Cheat R. at Rowlesburg	196,000	31:00	935.1	
Big Sandy Cr. Rckvl.	7,000	26:00	206.9	
Cheat R. at Lake Lynn	9,000	35:00	1,410.9	

shown in 〈Fig. 5〉. Tributaties above Parsons producing a much more destructive flood than would otherwise be the case. This also appears to be the case for the November flood.

The combined discharge at Parsons is then passed down the Cheat River while accumulating the remaining tributary runoff as it is encountered to the mouth of the Cheat at Point Marion, PA.

The peak discharge at Parsons is increased by 18% as it travels to the mouth of the Cheat River below Lake Lynn, as shown in 〈Fig. 5〉. Therefore in the case of the November flood, 82% of the peak discharge experiencs at the mouth of the Cheat River occurred at Parsons, to which only 50% of the total drainage area contributes.

The conclusions of this portion of the study, supported by the above observations, are that the hydrologic response of the Cheat River Basin to storm rainfall input is strongly dictated by its unusual basin shape and drainage characteristics, and that the severity of this response is strongly biased toward the upper half of the Cheat Basin. The storm rainfall pattern producing the November flood is believed to be representative of the most likely pattern for severe storm events that will in turn produce the worst case floods along the main stem of the Cheat River. These are additional reasons for selecting the November flood as the design event. It may be further concluded that the most effective use of structural flood control measures(i.e. reservoirs) is to place them at or above Parsons to control the tributary flows at the head of the Cheat River. If the headwaters can be substantially controlled, then the probaility of future major floods will be substantially reduced all along the main stem of the cheat River.

Ⅳ. Examination of Sturctural Flood Control Alternatives

In the study, the criterion to control the flood is assumed to be the 10-year frequency flow. These levels are 30,100 cfs on Black Fork and 14,500 cfs on Shavers Fork(U.S. Army Engr. 1965). These flows are safe to the extent that they minimized possible damage to all populated areas by keeping the water surface elevations to levels at/or slightly above bankfull(U.S. Army Engr., 1965 ; Fed. Ins. Am., 1978).

The final three alternatives as shown in 〈Fig. 3〉 involve the use of various sizes and numbers of dams to provide for the temporary storage of flood waters until such time that they can be released slowly and harmlessly.

A careful examination of the upper Cheat Basin configuration and topograph points out the impossibility of using SCS-type small dams to achieve the desired goals. To provide the level of protection deemed necessary, most of the drainage area above Parsons has to be effectively controlled. By use of the HEC-1 model, it is quickly determined that uplands SCS-type small dams would provide insufficient control of drainage area. At least 50% or more of the area must be controlled in order for there to be even a chance of success. The terrain and streambeds are so steep as to require dam size that quickly rises above those limits normally associated with the SCS dams. This latter situation results when an effort is made to move dam into downstream locations where they could jointly control more drainage area. The need for increased dam sizes and a more downstream location precludes involvement of the SCS in providing the major component of flood protection. But this fact does not mean that these structures cannot be used to provide an additional minor level of flood protection in the same fashion as is offered by the local projection projects discussed above. The comination of local protection projects and SCS dams is considered but found to be still far short of providing any real protection against the November flood.

As mentioned above, to be effective in controlling the desighn flood, dams has to be located sufficiently downstream on the tributaries to control a major portion of the drainage area.

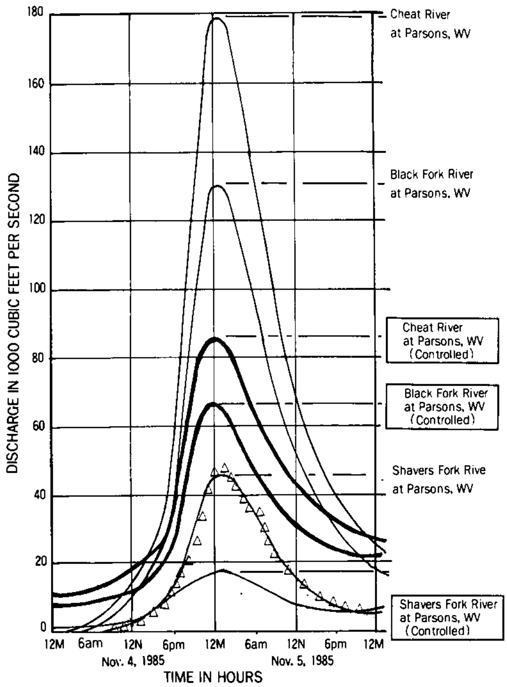
Each of the major tributaries of the Cheat above Parsons is examined for feasible dam sites along their lower reaches, where at least 50% of the drainage area would be controlled. Red Creek, Laurel Fork, and Glady Fork has considerable discharge magnitude and subarea. However, a dam site on Red Creek is not found because the slope is steep with population areas around.

It is realized that full control of Dry Fork and Shavers Fork might be sufficient for the flow of the Blackwater to pass through Parsons and into the Cheat without Significant damage to any populated areas. The watershed model late is shown that this can be accomplished. With blackwater to remain uncontrolled, it is all-important to control the remaining tributaries to the fullest extent possible. This is relatively easy to accomplish on Shavers Fork, while Dry Fork proved to be very difficult. Serveral locations along the lower river channel between Weese and Porterwood on Shavers Fork yields sufficient reservoir storage to reduce peak flows at Parsons to levels the existing channel can easily handle without causing flood damage. In order to maximize efficiency, the most feasible location at the furthest downstream point is chosen. This placed the dam at a point about 1 mile above Porterwood. Locating a single moderately sized dam on the lower Dry Fork is proved to be impossible because of the excessive steepness of the river channel and the narrow valley width. These latter limitations do not permit sufficient reservoir storage to contain the flood without an excessively large dam. The ultimate solution is to locate two dams of moderate size in series, one below the other such that they jointly created enough storage to contain the November flood fully. The most downstream dam is located just upstream of the mouth of the Blackwater River, above the town of Hendricks. The upstream dam is located within a narrow bend in the river at a point just upstream of the mouth of the Glady Fork tributaries. Both of these latter dams are able to work together to contain the November flood on Dry Fork fully. Three main options, which are examined by the HEC-1 computer model to get optimum results above Parsons, are introuduced below.

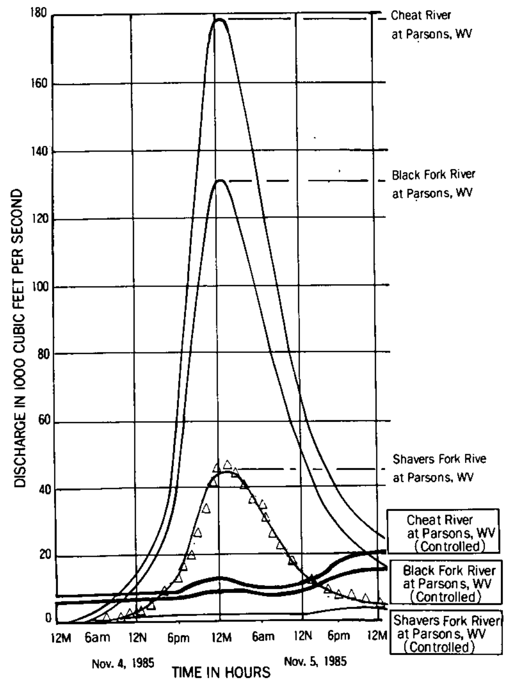
OPTION Ⅰ

This plan involves controlling the design flood by siting two medium sized dams ; one on Dry Fork and other on Shavers Fork. The Dry Fork Dam is sited 0.7 miles below the confluence of Dry Fork and Laurel Fork where the streams have a broad valley with a mild slope upstream. The catchment area of the dam is 222.2 square miles and natural peak flow at this site was 68,937cfs. The computer simulation shows that the dam required would be 200 ft in height with effective storage 23,860ac-ft and 1400 ft in length. However, the remaining controlled peak flow at Parsons is still high at 67,067cfs, as shown in ⟨Fig. 6⟩.

On Shavers Fork, a dam is located near Weese to protect population area downstream, such as Boden and Faulkner. The selected dam site has enough reservoir storage to impound most of the flow from upstream. The catchment area is 136.3 square miles. The maximum dam height is 140 ft with the effective storage 12,020ac-ft. and the maximum length is 1500 ft. long. The controlled peak flow on Shaves Fork and Parsons is 17,877cfs as compared to the natural peak 46,013cfs. Thus the total controlled discharge on Cheat River at Parsons is 84,843cfs. The reduction ratio is 52%, which is short of the ultimate goal of the study, even though other secondary protection measures can be taken. So, it is assumed that a more intensive mitigation plan is necessary to control the November flood.



Option Ⅰ



Option Ⅱ

⟨Fig. 6⟩ Natural versus Controlled Flows in Option Ⅰ and Ⅱ

OPTION Ⅱ

To minimize the flow rate at Parsons, the dam sites are selected at the lowest point possible on both stream, Black Fork and Shavers Fork. A dam sited below Hambleton on the Black Fork River controlled 485.7 mile^2 of the catchment area. The dam is able to reduce the 130,748 cfs natural peak flow to 16,788 cfs on the Black Fork River at Parsons. The maximum height of the dam is 130ft with effective storage 46,400 ac-ft and the maximum length is 1,300ft long. By siting the two dams as described above, the total controlled flow at Parsons is 21, 136cfs as shown in 〈Fig. 6〉. However, the Option Ⅱ is rejected promptly because of conflict with populated areas, and the valuable properties that would be flooded by the proposed dam.

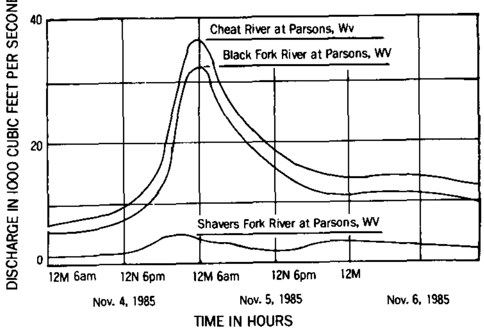
OPTION Ⅲ

As explained in a previous part of the this article, complete control of the flow on the Dry Fork is absolutely necessary since suitable dam sites is not existed on the Blackwater River. Adding one more dam, named Hendricks Dam, to Option I is planned, locating it 1 mile upstream of Blackwater River mouth. The Hendricks Dam could improve the adverse stream runoffs from Glady Fork and Otter Creek which are released downstream without any regulation and thus made the peak flow rate at Parsons too high in Option Ⅰ. The population areas such as Hendricks and Hambleton, to be flooded in Option Ⅱ, would also be protected from the floods. Even though the reservoir site has steep slopes and a narrow valley, enough storage is provided to impound the desired amount of funoff, 38,632cfs, from the Dry Fork Dam, Glady Fork subbasins, and Otter Creek Subbasin. The Hendricks Dam is 210ft. in height with effective storage 34, 555 ac-ft and 1,500 ft in length. Using this medium sized dam, the peak flow rate on Black Fork at Persons is reduced to 32,721 cfs ; 75% reduction ; about 10 years frequency flow.

The Shavers Fork Dam in Option Ⅱ is moved one mile upstream to avoid populated areas in Porterwood, and to avoid flooding route #219.

The controlled flow rate on Shavers Fork at Parsons is 4,428cfs. Thus, the total controlled flow at Parsons is 36,929 cfs as compared to the natural flow of 176,610 cfs. 〈Fig. 7〉 describes the controlled flow of streams above Parsons.

The protection afforded to Parsons and surrounding communities from a flood comparable to the November flood is proved to be complete using the three moderately sized dams specified in Option Ⅲ. While strong protection is also provided to the other Cheat River communities downstream, the lack of control of the Blackwater River could conceivably produce sufficient additive flows to local inflows to raise the flood peak enough to cause minor problems well downstream. This latter possibility would not appear to be a



〈Fig. 7〉 Controlled flows in Option Ⅲ

problems with the November flood event, but might arise in similar future flood levels that have a different rainfall distribution.

V. Conclusions

From the present investigation, the following conclusions have been made :

-The computer model to analyze the November floods of Cheat River Basin is completed by HEC-1 model.

-Because of basin's charateristics the Snyder's Unit Hydrograph is applied on the upstream of Parsons while SCS method is used for the lower half of the basin.

-The reusults computed by the Snyder's Unit Hydrograph are matched remarkably well with those of the observed hydrographs on the upstream of Parsons. This results are illustrating the Snyder's method is suitable in the areas of steeper slopes and highlands.

-According to the analysis, the final proposed plan to mitigate Cheat River Basin flood hazard consists of the use of the three moderately sized dams of Option Ⅲ.

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