SUPPLEMENT TO TECHNICAL NOTE 1

PSEUDO-CALIBRATION OF A RUNOFF MODEL

BY ADJUSTING UNIT HYDROGRAPHS

INTRODUCTION

This supplement to the Montana Dam Safety Program's *Technical Note 1, Determination of the Inflow Design Flood for High Hazard Dams in Montana*, provides short, practical guidance for conducting a pseudo-calibration of a rainfall-runoff model by adjusting the parameters of a basin's unit hydrograph. Pseudo-calibration refers to the adjustment of a rainfall-runoff model to create a synthetic runoff hydrograph that reasonably matches the characteristics or peak flow of a hydrograph "obtained independently from the rainfall-runoff model, such as the 100- and 500-year flood magnitudes. For example, adjusting model parameters based on comparing model results with the 100-year and 500-year flood magnitude estimates computed using the USGS regional regression equations" (Technical Note 1). This supplement assumes the user is familiar with common hydrologic terminology and has some experience in conducting hydrologic analyses for dam safety purposes in Montana.

DESCRIPTION

As described in Technical Note 1, the unit hydrograph parameters that can be adjusted in a rainfall-runoff model (in this case we will use an example of a model developed by *HEC-HMS (Hydrologic Model System – US Army Corps of Engineers)* are T_c (time of concentration) and R (basin-storage coefficient) when using the Clark Unit Hydrograph method, and t_p (Snyder's standard lag time) and q_p (peak of the dimensionless unit hydrograph for the Dimensionless Unit Hydrograph Method. These parameters are estimated using the equations given in Table 4 of *USGS Water-Supply Paper (WSP) 2420, Procedures for Estimating Unit Hydrographs for Large Floods at Ungaged Sites in Montana*. Technical Note 1 warns that these parameters may be utilized to pseudo-calibrate the model but should remain within one standard deviation of the estimated value. This is good guidance, but it can become a complicated process to determine the standard deviation of the parameter values as computed by the methods of *WSP 2420*. The measure of error for the parameter regression equations in Table 4 of *WSP 2420* is based on standard error (logarithm base 10), which is different than standard deviation of the regression data. To compute standard deviation from standard error can be a complicated process. Instead, for the purpose of this supplement, it is recommended that adjusted parameter values should be compared to the range of the same parameters for the sample basins used in the analysis for *WSP 2420* (found in Table 2 of *WSP 2420*) to verify they are reasonable for the basin location and size.

For the unit hydrograph parameters from *WSP 2420*, the common variable that is used to compute the parameters is basin area (in square miles). So, adjusting the basin area for pseudo-calibration will in turn adjust the parameters for both methods of unit hydrograph development (Clark method and dimensionless unit hydrograph). These parameters are adjusted in the following examples. No other basin characteristics were modified in the examples.

EXAMPLE FOR ADJUSTING CLARK METHOD PARAMETERS

To demonstrate the effects of adjusting the unit hydrograph parameters, an example will be used with a HEC-HMS model for an unnamed drainage basin in south-central Montana. The basin characteristics using Clark Method parameters are shown in Table 1. The goal of the analysis is to pseudo-calibrate the model to obtain a peak discharge for a 500-year runoff event close to 389 cubic feet per second (cfs), which was the average peak discharge for the 500-year flood obtained using the USGS StreamStats® analysis tool and USGS regression equations for ungaged basins in this region. (Note that this does not follow the recommended pseudo-calibration process in Technical Note 1, which suggests that a peak discharge value for a basin used for dam safety purposes should be higher than the upper envelope value for peak flow values in this region. The values in this example are for demonstration purposes only.) The rainfall depth for this event was developed using methods for a 500-year return period storm from *USGS Water-Resources Investigations Report (WRIR) 97-4004, Regional Analysis of Annual Precipitation Maxima in Montana*. The storm hyetograph was developed using methods in *USGS Water-Resources Investigations Report (WRIR) 98-4100, Characteristics of Extreme Storms in Montana and Methods for Constructing Synthetic Storm Hyetographs*.

TABLE 1. EXAMPLE INITIAL BASIN CHARACTERISTICS USING CLARK METHOD PARAMETERS.

Parameter	Initial Value	Parameter	Initial Value
Drainage Area	5.1 square miles	Clark's T_c[3]	0.86 hours
Average CN[1]	54.3	Clark's R[3]	4.81 hours
Initial Abstraction[2]	1.681 inches	Constant Baseflow	0.1 cfs
Impervious area[1]	0.8% of total basin		

Notes:

1. The Natural Resources Conservation Service (NRCS) Curve Number (CN) was initially determined by a weighted-average calculation of CN over the basin based on hydrologic soil groups identified in the *USDA NRCS Web Soil Survey*. The same web program estimated the percentage of impervious area in the basin. Curve numbers are estimated using *Chapter 9, Hydrologic Soil-Cover Complexes, of the NRCS National Engineering Handbook, Part 630, Hydrology*.
2. Initial abstraction (I_a) is the amount of rainfall infiltration at the beginning of the rainfall event and is determined by the NRCS equation $I_a = 0.2(1000/CN – 10)$.
3. Clark unit hydrograph parameters T_c and R were calculated using methods in *WSP 2420*.
4. Baseflow was estimated. No stream gage data was available for this basin. The estimated baseflow has little to no effect on the storm runoff determined by the model.

The resultant peak flow from the basin using the initial basin parameters was 283.4 cfs, significantly lower than the target 389 cfs. The peak of 283.4 cfs occurred 35 hours after the start of the storm and produced 473.1 acre-feet of direct runoff volume. Table 2 provides the results of adjusting the Clark unit hydrograph parameters T_c and R. In the adjustment process, both T_c and R are dependent on the independent variable of basin area. Therefore, basin area was adjusted (with accompanying adjustments to T_c and R) until the peak discharge approached the target of 389 cfs. The initial trial provides the results mentioned above. For Trial 1, it was found that the peak discharge increased as basin area was decreased. The basin area was lowered until it reached 1.0 square mile and the analysis was stopped there because it was now much smaller than the basins used in the analysis of *WSP 2420* and was likely producing results that are not reliable for the methods to determine T_c and R. With a drainage area of 1.0 square mile, T_c was 0.30 hour, R was 2.90 hour, peak discharge was 319.6 cfs (lower than the target of 389 cfs), and volume of runoff was 476.1. The take-away for the example is that peak discharge tends to increase with shorter times of concentration and smaller storage coefficients, which makes sense in the context of how the parameters affect runoff.

TABLE 2. RESULTS OF EXAMPLE HEC-HMS ROUTINGS WITH ADJUSTED CLARK METHOD PARAMETERS.

Trial	Area (sq mi)	T_c (hr)	R (hr)	Q_{peak} (cfs)	Time of Peak (hr)	Runoff Volume (ac-ft)
Initial	5.1	0.86	4.81	283.4	35	473.1
1	1.0	0.30	2.90	319.6	34	476.1

EXAMPLE FOR ADJUSTING DIMENSIONSLESS UNIT HYDROGRAPH METHOD PARAMETERS

The same HEC-HMS model and unnamed drainage basin in south-central Montana used in the example for the Clark Unit Hydrograph Method is also used in the following example for the Dimensionless Unit Hydrograph example. The basin characteristics using the Dimensionless Unit Hydrograph Method parameters are shown in Table 3. Runoff loss parameters are the same as in Table 1.

TABLE 3. EXAMPLE INITIAL BASIN CHARACTERISTICS USING DIMENSIONLESS UNIT HYDROGRAPH METHOD PARAMETERS.

Parameter	Initial Value	Parameter	Initial Value
Drainage Area	5.1 square miles	Snyder's lag time, t_p[1]	1.01 hours
Average CN	54.3	Peak of dimensionless unit hydrograph, q_p[1]	8.52
Initial Abstraction	1.681 inches	Unit hydrograph duration[1]	10 minutes
Impervious area	0.8% of total basin	Constant Baseflow	0.1 cfs

Notes:

1. Dimensionless unit hydrograph parameters t_p, q_p and duration were calculated using methods in *WSP 2420*.

The resultant peak flow from the basin using the initial basin parameters was 1676.5 cfs, much higher than the target 389 cfs. The peak of 1676.5 cfs occurred 27 hours after the start of the storm and produced 1847.3 acre-feet of direct runoff volume. Table 4 provides the results of adjusting the dimensionless unit hydrograph parameters. The parameters t_p and q_p are calculated by the regression equations from *WSP 2420* which use basin area as the independent variable. By adjusting basin area, the other dependent parameters are changed. The initial trial provides the results mentioned above. For Trial 1, the basin area was adjusted to 3.9 square miles, which in turn reduced the unit hydrograph duration from 10 to 5 minutes, changed the Snyder's lag time from 1.01 to 0.87 hours, and the dimensionless peak of the unit hydrograph from 8.52 to 8.30. The resultant peak discharge from the basin was dramatically reduced from 1676.5 to 405.9 cfs, which is a little higher than the target peak of 389 cfs, but reasonably close. The direct runoff volume was also significantly reduced from 1847.3 to 500 acre-feet.

TABLE 4. RESULTS OF EXAMPLE HEC-HMS ROUTINGS WITH ADJUSTED DIMENSIONLESS UH METHOD PARAMETERS.

Trial	Area (sq mi)	UH Duration (minutes)	t_p (hr)	q_p (unitless)	Q_{peak} (cfs)	Time of Peak (hr)	Runoff Volume (ac-ft)
Initial	5.1	10	1.01	8.52	1676.5	27	1847.3
1	3.9	5	0.87	8.30	405.9	28	500.0

CONSIDERATIONS AND CAUTIONS

If the unit hydrograph parameters are the only basin characteristics adjusted in a pseudo-calibration of a drainage basin, attention needs to be made to the appropriateness of the parameters for the basin analyzed. If the parameters are estimated using *WSP 2420*, they also need to be within the limitations of *WSP 2420*.