DETERMINATION OF EFFECTS ON CHANNEL MODIFICATIONS ON FLOW CHARACTERISTICS

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INTRODUCTION

Channel improvement and modification have been major features of the Mississippi River and Tributaries Flood Control Project since its inception in 1928. Channel improvement has proven to be successful in agricultural areas where the major flood problem has been the drainage of local rainfall from the area. However, this type of flood relief has limited application and can only be used where an adequate outlet exists.

In recent years, the Corps of Engineers has felt a need to reevaluate the benefits and effects of channelization.

This paper will present a method of analyzing the channel modification. The methodology presented in this paper uses techniques available to the practicing engineer and can easily be applied to similar problems.

Big Colewa Creek is a tributary to the Boeuf River. The lower reach is known as Big Creek and its upper reach is known as Colewa Creek. The stream flows in a southerly course along the western edge of Macon Ridge and serves as the major drainage outlet for the area between Bayou Macon to the east and Boeuf River to the west.

Big and Colewa Creek has a drainage area of some 550 square miles that lies between the general latitude of Winnsboro, Louisiana, on the south and Oak Grove, Louisiana, on the north. It has an average width of less than 10 miles and a length of 60 miles.

The U. S. Army Corps of Engineers has had two previous flood control projects on Big and Colewa Creeks. The first project was completed about 1952. The project was a channel designed to carry 1-year frequency below the damage elevation. The second modification was a channel designed to carry 2-year frequency flow that was completed in 1976. The second modification only included the first 35 miles of Big and Colewa Creeks. The purpose of this study is to re-evaluate the Big and Colewa Creek channel improvement on flows in the lower Boeuf River. To determine the effects of channel improvement of an area, the following parameters must be evaluated. The existing hydrology of the area and the existing channel hydraulics must be carefully studied to determine how the proposed improvements will function. The Big and Colewa Creek study was broken into three phases to accomplish these goals. The phases were Existing Hydrology, Existing and Proposed Channel Hydraulics, and Future Hydrology and Hydraulics of the Tributaries. The third phase has not been completed at this time and will not be discussed in this paper.

EXISTING HYDROLOGY

To evaluate the existing hydrology there were two approaches available to the authors, unit hydrograph or event modeling, and the continuous modeling approach or, as more commonly called, a watershed model. Due to available data, the unit hydrograph approach was used. The Hydraulics Branch, Vicksburg District, has for many years kept records of observed storms in the study area for the purpose of giving guidance for the different parameters used in the Snyder Unit Hydrograph Computations. The parameters that gave the best reproduction of the observed runoff for the Big and Colewa Creek tributaries are shown in Table 1. The process used to arrive at these parameters is discussed in the calibration section of this paper.

EXISTING AND PROPOSED CHANNEL HYDRAULICS

To determine the effects of channel modifications, inflows to the channel must be routed through the channel. If possible, these inflows should be independent of conditions in the channel. In reality, this is almost always impossible to do except in extremely large systems that have little or no uncontrolled intervening flow. In this study, the tributaries drain directly into the channel and thus the channel has some backwater effect on the tributaries' outflow. It is felt, however, that this effect is very insignificant in the overall study and is partially corrected in the hydrology for each tributary.

There are two classes of routing techniques available to use in stream flow routing, the Hydrologic and the Hydraulic. Examples of the Hydrologic Routing Technique are as follows:

1. Muskigum
2. Modified Puls
3. Straddle - Stagger
4. Working R&D

Examples of Hydraulic Routing Techniques are as follows:

1. Kinematic Wave Models
2. Diffusion Wave Models
3. Dynamic Wave Models

The Hydraulic Routing Technique is a numerical approximation of the Saint Venant Equations. These equations contain two independent variables, distance and time, and two dependent variables, water surface elevation and velocity.

Saint Venant Equations:

Continuity: $\frac{\partial h}{\partial t} + \frac{\partial I}{B} \quad \frac{\partial (AV)}{\partial x} - \frac{q}{B} = 0$

Momentum:

$$\frac{\partial V}{\partial t} + V \frac{\partial V}{\partial x} + g \frac{h}{\partial x} \frac{qV}{A} + \frac{gn^2 V V}{a.21R4/3} = 0$$

where

- h = water-surface elevation above mean sea level
- t = rate of change with respect to time
- B = width of water surface
- A = cross-sectional flow area
- V = mean flow velocity
- x = rate of change with respect to distance
- q = lateral inflow per unit distance along the channel per unit time
- g = acceleration due to gravity
- n = Manning's resistance coefficient
- R = hydraulic radius

The Saint Venant equations cannot be solved analytically in problems of engineering interest; therefore, most engineers have used approximate solution techniques in solving the governing equations. Two techniques have been used to approximate these solutions. They are the Finite Difference Approach and the Finite Element Method. Since the Finite Element Method has been and still is basically confined to specialized model situations where considerable amounts of research are done, it was not considered for this study.

The Hydrological Routing Techniques predict only the effect of channel storage on the shape and movement of a flood wave. In the Big and Colewa Study Channel, control parameters (friction, inertia, etc.) would also have to be considered; therefore, one of the Hydraulic Routings was needed. A technique that would solve the complete Saint Venant Equations was used. It was felt that because of small channel slope the pressure and inertia terms of the Saint Venant equations would be important in the study; this ruled out the use of Kinematic Wave Model. The amount of computer time needed to use either the Diffusion Model or the Dynamic Wave Model is almost the same, which led to the use of the Dynamic Wave Model.

There are three methods available for solving the complete Saint Venant Equations, which are used in a Dynamic Wave Model. They are the Method of Characteristics, Explicit Finite Difference Techniques, and the Implicit Finite Difference Techniques. Each technique has its own unique problems in its application. The major problem encountered with the Method of Characteristics is the need to interpolate to get solutions at specific points since locations in space and time solution are obtained at intersections of characteristic lines which depend on the flow. The major disadvantage of applying Explicit Finite Difference Model is the use of small time steps to retain numerical stability. The Implicit Finite Difference Model available can be applied without any of the above disadvantages. The problems and disadvantages associated with using an Implicit Finite Difference Technique are mainly mathematical, and are as follows: a large system of simultaneous equations at each time step must be solved and special arrangements for supercritical flow must be made.

Examples of Explicit and Implicit Finite Difference Models are as follows:

EXPLICIT

1. "Gradually Varied Unsteady Flow Profiles." HEC[2].
2. SØCHMJ - a special purpose version of the above program, developed by WES for the Ohio-Cumberland-Tennessee-Mississippi River System.[3]
3. RIBCO - applicable to sewer systems with limited cross-section shape, Seattle District.[4]
4. "Delta Hydrodynamics Operation Model" - State of California, analysis of tidal flows in the Sacramento-San Joaquin Delta system.[5]

IMPLICIT

1. DWOPER - ("Dynamic Wave/Operational"). Developed by Dr. Fread of the National Weather Service.[6]

The authors chose to use the computer program "DWOPER" developed by Danny Fread of the National Weather Service.

Input in the computer program consisted of:

1. Channel Geometry: Expressed in terms of conveyance and storage.
2. Manning's "n" value for different elevations.
3. Lateral Inflow: Inflow from each tributary.
4. Upstream Boundary: For this study a stage hydrograph was used.
5. Downstream Boundary: For this study a stage hydrograph was used.
6. Computation Time Step: For the purpose of this study, both .5 hour and 1-hour time steps were used.

To determine the effects of channel improvement on Big and Colewa Creeks, three different channel geometries were used. First, the channel as it existed prior to 1973 was used. Next, the channel with the lower half enlarged was used. The last channel geometry used consisted of the channel enlarged from the mouth of the head.

CALIBRATION OF THE MODEL

The model was calibrated to the November 1970 storm. This storm was used because of uniform rainfall over much of the Big and Colewa Creek drainage area, and there was no backwater effect from the Boeuf or Ouachita Rivers.

The goal of this calibration effort was to reproduce three parameters, recorded stage, total storm volume, and discharge. The latter two were derived from an average rating curve.

During the calibration, the geometric data was not varied while "n" value and the Snyder unit graphs parameters were varied. Since the "n" value can affect stage, discharge, and travel time of the flood wave, and the tributary inflow can also affect discharge and timing of the flood wave, steps were taken to keep all parameters in close proximity to observed and computed data similar to basins in the area. It was .035 to .055 depending on the stage. From existing data available it was felt that the following ranges of Snyder's unit hydrograph-640CP, 340-350; CT, 5.9, 6.2 - infiltration rates would vary depending on the antecedent conditions from .05 in/hr to .2 in/hr. The final Snyder coefficient used for each tributary is shown on Table 1. After these coefficients were obtained they were used on 15 different storms to determine the runoff from each tributary to be used in the Routing Model. The coefficients used in all the storms were not changed because the study was interested only in relative difference in outflow at the mouth of Big and Colewa Creek. To reproduce the observed runoff of each storm would have been very time consuming and was beyond the scope of the study.

The Manning "n" value used in the final calibration varied as expected from .035 with flows well below the top bank to .065 for higher flows that were above the top bank. The large "n" value in part is due to the weighting of Manning's "n" value in between the overbank and channel conveyance areas. The overbank "n" value was held constant at .13.

The only other parameter varied during the calibration was the time step. The time that was first selected was 2 hours. This proved to have some numerical problems; therefore, the time interval was reduced to one hour. A one-half time step worked very well except in a few cases where the initial time steps would not converse. In these cases, a .5-hour time step proved sufficient. Sensitivity tests were run to determine the difference between the 1-hour and .5-hour time steps. They showed after the first few time steps there was no difference between the two time intervals.

RESULTS AND RECOMMENDATIONS

Fifteen different storms were applied to the calibrated math model on Big and Colewa Creek. Twelve of these storms were observed events, the three remaining events were the 1 year, 5 year, and 10 year synthetic twenty-four hour rainfall.

The results show an increase in peak flows with each successive increase of channel improvement. The results also show a decrease in stage for these discharges on the upper end of Big and Colewa Creek if the channel is completely improved. The lower end of Big and Colewa Creek does not show this decrease in stage for the flood events. This is due to stages on the lower end of Big and Colewa Creek being subject to backwater conditions. Based on preliminary results obtained from unsteady flow routings, peak flows would be increased from 10-30% if the remaining channel is increased. The amount of increase is dependent on a number of variables which include rainfall patterns, antecendent conditions, downstream conditions and amount of channel improvement. During the calibration of the model it was discovered that tributary topography and land use had more of an effect on the flood wave than did the drainage area of a particular tributary in relationship to the total Big and Colewa drainage area.

The model did not reflect a stage change at the downstream boundary associated with the increased flows at the downstream boundary flow because the downstream boundary was input as stage hydrograph.

The model is being modified to allow for the use of a tailwater rating curve as a downstream boundary. This will allow the model to be used to predict stage changes in the lower end of the model limits. However, caution should always be used if the downstream boundary is a point of interest.

The studies demonstrated that the one-dimensional unsteady flow equation can be used to predict the change inflow characteristics resulting from channel modifications. It is felt the present model setup can accurately be used in bracketing the effects of channel improvement on Big and Colewa Creek.

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TABLE 1

STREAM	RIVER MILE	L (MI)	LAC (MI)	2X CT	1.25X 640CP	TP/5.5 (H.R.)	QPR (CFS)	BASIN A. (SQ MI)	INT A. (SQ MI)	TOTAL AREA
Little Colewa Bayou	72.64	9.5	6.9	12.4	425	3.95	711.0	20.5	25.0	45.5
Little Hurricane	68.40	5.5	3.5	11.8	435	2.61	163.6	4.2	2.7	6.9
Rising Slough	67.95	5.6	2.7	11.8	437.5	2.42	153.1	5.7	0.3	6.0
Hurricane Creek	63.89	10.9	6.9	12.2	435	4.05	645.0	33.3	8.0	41.3
Bear Skin Bayou	59.40	8.4	4.5	11.8	437.5	3.19	274.2	7.3	6.6	13.9
Little Colewa Bayou	45.54	13.9	5.9	12.0	435	4.09	769.9	20.0	29.6	49.6
Little Creek - A	43.75	14.0	9.5	12.0	435	4.81	328.76	22.4	2.4	24.8
Little Creek - B	38.27	8.1	5.7	12.2	435	3.50	436.3	15.2	9.1	24.3
Cypress Creek	35.85	18.7	9.6	12.2	437.5	5.26	464.6	34.4	3.6	38.0
Cow Bayou	29.68	13.8	6.7	12.0	437.5	4.24	437.8	14.8	20.3	35.1
Hurricane Bayou	21.53	6.2	3.0	12.0	437.5	2.62	467.0	6.6	13.1	19.7
Bee Bayou	20.42	14.1	6.1	12.2	426	4.22	628.8	41.4	1.3	42.7
Pine B. - Turkey Creek	13.52	31.6	14.6	12.8	422	7.33	923.9	96.9	11.3	107.9
Pine Flat Slough	10.72	5.7	2.7	12.0	437	2.48	187.4	5.1	2.4	7.5
Mound Bayou	9.37	6.1	2.7	11.8	437	2.49	117.1	4.5	0.2	4.7
Little Creek - C	8.78	23.3	11.2	12.4	425	5.98	556.9	49.2	3.9	53.1
Un-Named	4.78	7.5	4.9	12.2	436	3.27	560.9	9.6	19.6	29.2
Un-Named	89.3	15.55	9.6	12.4	425					70.5
Daves Bayou	51.2	11.29	5.80	12.2	431					36.5
Muddy Bayou	47.8	20.49	11.27	12.4	426					57.4
Total Basin #18	---	58.4	45.0	13.2	413.0					164.4
Cross Bayou	43.1	3.58	2.16	12	435					14.3
Goose Creek	38.5	6.39	2.11	12	435					14.7
Upper Eagle Creek	35.4	2.16	1.28	11.8	437					4.7
Bayou Morengo	33.9	5.06	2.48	12	437					11.4