JUDY'S BRANCH, ILLINOIS REHABILITATION PLAN

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Abstract: Judy's Branch is a tributary to Cahokia Canal, which is located near Glen Carbon, Illinois, (Madison County) and across the Mississippi River from St. Louis, Missouri. Cahokia Canal drains into Horseshoe Lake through an overflow feature at Horseshoe Lake State Park. The Judy's Branch watershed area is 8.64 sq mi and the total stream length of the project encompasses approximately 14.5 mi. The East St. Louis and Vicinity, Illinois Flood Protection Project was authorized through Congressional actions in 1965 and in 1974. The project authorization was again modified by the Water Resources Development Act of 2000. Section 304 of this Act states: "*The project for flood protection, East Saint Louis and vicinity, Illinois (East Side levee and sanitary district) authorized by section 204 of the Flood Control Act of 1965 (79 Stat. 1082), is modified to include ecosystem restoration as a project purpose*." The principal goal of the presently authorized project is to identify potential improvements that will enhance habitat quality and sustainability while also providing incidental ecosystem services, such as flood-damage reduction. This paper summarizes a report that provides a stream-rehabilitation plan for Judy's Branch to address goals of sediment reduction, stream stability improvement, and use as a demonstration and teaching vehicle by agencies and other interested parties.

INTRODUCTION

Judy's Branch is a tributary to Cahokia Canal, which is located near Glen Carbon, Illinois, (Madison County) and across the Mississippi River from St. Louis, Missouri. Cahokia Canal drains into Horseshoe Lake through an overflow feature at Horseshoe Lake State Park. The Judy's Branch watershed area is 8.64 sq mi and the total stream length of the project encompasses approximately 14.5 mi.

In 1801, Samuel Judy (Tschudi) acquired a 100-acre property along the bluff line and was instrumental in establishing the agriculture of the watershed. The history of Judy's Branch takes another step as the railroad and coal mining become established in the early 1880s, when channelization of the stream allowed low gradient routes for railways to climb from the valley to the general level of the Illinois prairie. The former rail routes now provide the right-of-way for bike trails (Cedeck et al. 1992). These early channelizations of Judy's Branch and Judy's Creek, along with the significant quantities of crushed rock used in maintaining the railroads, have significantly influenced the morphology and ecology of the streams. Also, land-use change in the Judy's Branch watershed, from existing rural and agricultural to suburban development, is presently pressuring channel and watershed stability.

This paper provides a stream-rehabilitation plan for Judy's Branch that will address goals of sediment reduction, improve stream stability, and will be used as a demonstration and teaching vehicle for the U.S. Army Corps of Engineers (USACE), Illinois Department of Natural Resources personnel, and other interested parties. A specific sediment-reduction goal is to reduce sediment yield by 70%.

The original report was authorized under contract with the USACE. Dr. David Biedenharn was the primary technical contact at the USACE Engineer Research and Development Center (ERDC) for this contract. Ms. Deborah Roush was the Project Manager for the Ecosystem Restoration Project for the USACE St. Louis District.

BACKGROUND

The East St. Louis and Vicinity, Illinois Flood Protection Project was authorized through Congressional actions in 1965 and in 1974. The project authorization was again modified by the Water Resources Development Act of 2000. The principal goal of the presently authorized project is to identify potential improvements that will enhance habitat quality and sustainability while also providing incidental ecosystem services, such as flood-damage reduction. Two choices that are included in a range of alternatives for controlling sediment delivery to downstream wetlands are: (1) excavate a large basin to retain sediment, or (2) control the sediment sources upstream. A large sediment basin would require continuing maintenance to excavate the accumulating sediment and would require a disposal site. Control of the upstream sediment sources provides the opportunity to enhance instream aquatic and riparian habitat, and reduces the dependence on long-term maintenance. In addition, as the watershed urbanizes, larger flood peaks will exacerbate channel instability.

AVAILABLE DATA

In preparations for the analysis and design of Judy's Branch and related bluff line streams, Federal, State, and local agencies have developed valuable data and related analyses. Several of these studies are briefly reviewed in the following paragraphs.

The Illinois Office of Water Resources (IOWR) conducted a survey of Judy's Branch and tributaries, and provided the initial calibrated HEC-RAS model with roughness coefficients. This HEC-RAS model has served as the basis for the analysis of Judy's Branch. Straub (2004) collected sediment data at three Judy's Branch gages to determine the amount of suspended sediment being delivered from the Route 157 gage (8.33 sq mi) and two subwatersheds (0.23 and 0.40 sq mi) during the period of October 2000 to September 2003. The undeveloped subwatershed drainage area is 0.40 sq mi, and the urban subwatershed drainage area is 0.23 sq mi. The average suspended sediment yield from the two subwatersheds was reported to be 851 tons/sq mi/yr, and the suspended sediment yield at the downstream Route 157 gage was reported to be 2,188 tons/sq mi/yr. Straub (2004) emphasized that sediment yield concentration increases in the downstream, which can be caused by increasing rates of channel erosion and channel failure. He attributed the increase in these sources to greater flow rates caused by urbanization.

Thorne et al. (1997) defined bank erosion as being comprised of detachment, entrainment, and removal of bank material as individual grains, i.e., grain-by-grain removal and transport. He also defined bank failure as the collapse of larger blocks of the bank in mass, generally in response to geotechnical instability processes. Straub et al. (2006) evaluated the geotechnical bank stability along Judy's Branch, and found three primary scenarios of alluvial bank materials: (1) alluvial clayey silt over glacial till, (2) alluvial clayey silt over glacial till with trees, and (3) alluvial clayey silt over glacial till with a sand lense at the interface between the clayey silt and the glacial till.

Straub et al. (2006) reported that the alluvial soil deposits consist primarily of consolidated medium to soft clayey silts. Glacial till regularly outcrops at the toe of the bank, sometimes extending up to mid-bank. They found that till strength varied depending on the amount of time the material had been exposed, and that the degree of weathering may be assessed by the height of the till on the bank. This suggests that the greater the degree of bank incision, the weaker the toe material (glacial till), which can have severe consequences for bank instability.

Bank failure during the recession limb of large-flow events and following prolonged periods of precipitation has been observed by many. Simon et al. (1999) assessed five reasons for this observation:

1. Partial withdrawal of lateral support and confinement by the receding water level after the event;
2. Increase in driving forces due to the saturation and increase in unit of the bank materials;
3. Infiltration of water reduces negative pore water pressure;
4. Generation of positive pore water pressure; and
5. Erosion of bank toe material that steepens the bank and removes previously failed material.

Providing storm-water detention in the basin can reduce the magnitude of the peak flow for a given precipitation event, and can reduce the rate of change of the falling limb of the hydrograph. Both of these result in greater bank stability.

Geotechnical modeling by Straub et al. (2006) indicated that saturated bank materials for bank heights in excess of 10 to 12 ft and at bank angle in excess of 60 to 70 degrees may be unstable. Numerous assumptions must be made in any attempt at estimating bank characteristics over a watershed. However, these computations together with field observations indicate that banks in excess of 10 to 12 ft are likely to be susceptible to geotechnical failure as the degree of saturation increases and as the bank angle approaches 60 to 70 degrees, which may be caused by toe scour. Figure 1 shows bank angle and bank heights for survey cross sections on Judy's Branch. Bank angles and heights for locations greater that 70 degrees and 12 ft, respectively, are shown in the box. The lack of a significant number of cross sections that exceed 12 ft in height and a bank angle of 70 degrees suggests that these characteristics describe a bank failure threshold condition.

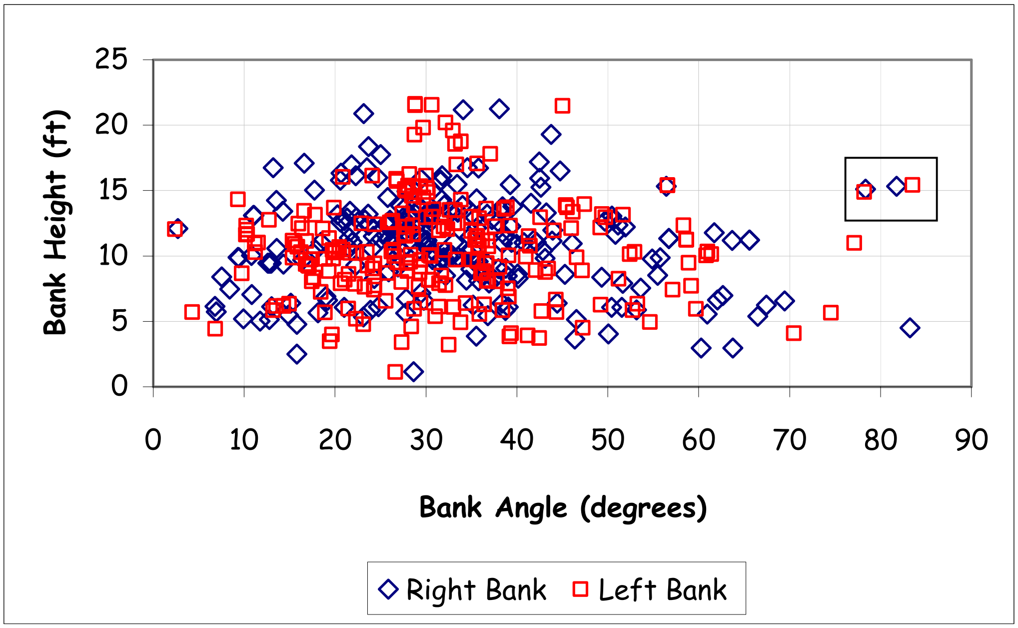

Figure 1 Bank angle and bank heights for surveyed cross sections along Judy's Branch. Only two cross sections (in box) exceed Straub et al. (2006) criteria for instability, which may indicate that most of the banks that exceed their criteria have already failed.

DESIGN PROCEDURES

Together with the original HEC-RAS provided by IOWR, several computer models were used in this design and analysis:

- HEC-RAS (Hydrologic Engineering Center - River Analysis System),
- HEC-HMS (Hydrologic Modeling System), and
- SIAM (Sediment Impact Analysis Model).

HEC-RAS was used to perform steady flow and unsteady flow calculations to estimate reduced discharge caused by planned dry sediment detention basins and to calculate hydraulic parameters. HEC-HMS was used to obtain the flow hydrographs used as the boundary conditions of the HEC-RAS unsteady flow analysis. SIAM is a newly developed program created at Colorado State University (CSU) in cooperation with ERDC that has been incorporated into RAS by HEC, and a version is expected to be available during the coming year. The SIAM model synthesizes quantitative geomorphic information for a watershed, including locations, magnitudes, and composition of watershed sediment sources; magnitudes and durations of discharges comprising the hydrologic regime; hydraulic performance of the stream network; and sediment transport characteristics of the channels. Model output provides sediment budgets, balances, and energy-transport relationships on a reach basis (Mooney 2003). Therefore, SIAM can be used to determine whether the reach will aggrade or degrade, and to predict the sediment yield in each reach.

The SIAM model represents a watershed as a series of linked sediment reaches dividing a channel network into segments at significant changes in bed composition, hydrology, hydraulics, sediment transport, or sediment sources. Sections upstream and downstream of a tributary junction must belong to separate reaches. The selection of sediment reaches determines the resolution of the model. Longer reach lengths can smooth small imbalances while shorter reach lengths amplify local effects. The network of the Judy's Branch model consists of 48 sediment reaches with a maximum of three levels of tributaries. Sediment reaches were created at tributary junctions and at points of significant change in hydrology.

In each SIAM sediment reach, the program keeps track of all the component sources to and transport from the sediment reach. A critical data set from the SIAM model is the *local sediment balance* for each reach, which is the sum of the wash material sediment supply plus the bed material sediment supply, minus the wash load and bed material load transported out of the reach. The wash material size is defined by the user based on field data as the D_{10} of the sediment found on the bed, and bed material is defined as sediment larger than the wash material.

If the local sediment balance for a reach equals zero, the reach is in balance and the reach has reached continuity. A negative local balance means the reach is degrading and a positive local balance means the reach is aggrading. For Judy's Branch, our goals are to achieve a zero local balance for each sediment reach and to reduce sediment yield.

The design procedure used in this rehabilitation design is as follows:

Step 1: Estimate the discharge from each potential site of dry sediment detention basins, using the unsteady flow analysis of HEC-RAS.
Step 2: Establish the flow-duration records including 50- and 100-yr discharges using the data measured at Route 157 gaging station and HEC-WMS.
Step 3: Estimate the sediment yield from the watershed using the sediment concentration data measured at Route 157 gaging station.
Step 4: Estimate the local sediment sources for the SIAM model input from the surface erosion and bank erosion data.
Step 5: Calibrate the local sediment sources using the estimated sediment yield (Step 3).
Step 6: Set a goal for the local sediment sources for each scenario.
Step 7: Design the drop structures and check if the local balance of each reach is within an acceptable tolerance after running the SIAM model.
Step 8: If the local balances of some sediment reaches are out of tolerance range, adjust the design of the drop structures of those reaches, and repeat Step 7 until the acceptable result is obtained.

Grade Control Design: Perhaps the simplest form of a grade control structure consists of dumping rock across the channel to form a hard point. These structures are often referred to as rock sills or bed sills. These types of structures are generally most effective in small-stream applications and where the drop heights are generally less than about 2 to 3 ft. A series of rock sills, each creating a head loss of about 2 ft, was used successfully on the Gering Drain in Nebraska (Stufft 1965). Whitaker and Jäggi (1986) report on design concepts for stabilizing the streambed with a series of rock sills. Abt and Johnson (1991), Newberry and Gaboury (1993), Robinson et al. (1998), and EM 1110-2-1601 (USACE 1994 revisions on 1991 version) provide guidance for sizing stone for these structures.

Among many kinds of drop structures, the drop structures referred to as *Newbury riffles* (Newbury and Gaboury 1993) were modified and chosen for this design. The structures proposed for Judy's Branch were designed using the following criteria:

1. The crest stone is to be constructed of quarry stone (approximately 3 ft x 3 ft x 2 ft) with the approximate center of the structure at the crest elevation specified. The remainder of the crest stone should be constructed to form a shallow V-shape with 0.5 to 1.0 ft of relief. The bed for the crest should be excavated to firm material.
2. The crest should be keyed into both banks using a riprap-filled trench, which extends to the greater of the top bank elevation or the 2-yr flood. A desirable slope for the key trench is 1 vertical on 3 horizontal. A gravel blanket should be placed in the key trench and over the riprap if sandy material or piping of groundwater is observed.
3. Upstream and downstream of the crest is filled using riprap sized in accordance with EM 1110-2-1601 (USACE 1994 revisions on 1991 version). Upstream slope is 1 on 4, and downstream slope is 1 on 20.
4. Spacing of structures along the stream was based on an approximate height of 3 ft for each structure, spaced to provide the downstream crest elevation at or above the toe of the downstream face of the upstream structure.

Drop structures can be used to stabilize the channel and to reduce the bank erosion by decreasing the bank elevation. Therefore, grade control was planned for all of the reaches except tributaries in this design.

RESULTS

These initial four scenarios were analyzed:

1. Scenario with Existing Condition
2. Scenario with 21 Sediment Basins
3. Scenario with Sediment Basins and Vegetative Buffer Strips (VBS)
4. Scenario with Sediment Basins, VBS, and Drop Structures

At public meetings in Collinsville and Carbondale, Illinois, on 4 August 2004, the results of analyses of four initial scenarios were presented. These discussions lead to two additional scenarios that were analyzed. The discussion at those meetings included the consideration of the relatively rapid change in land use from agricultural to residential use. In addition, in previous field investigations the use of storm-water detention basins in the developing residential subdivisions had been noted. Therefore, two scenarios were developed that eliminated all or most of the Natural Resources Conservation Service (NRCS) proposed sediment basins:

5. Scenario with Drop Structures, No Sediment Basins, and No VBS
6. Scenario with Drop Structures, 6 Sediment Basins, and No VBS

Analyses indicated that in Scenario 6, channel stability was achieved with a balance of sediment supply and sediment transport, and that the sediment yield at the Route 157 gaging station is about 31% of the estimated sediment yield of 27,000 tons/yr, a reduction of an average of 69%.

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