Prepared in cooperation with the City of Grain Valley, Missouri

Hydraulic Analyses of Sni-A-Bar Creek and Selected Tributaries at Grain Valley, Jackson County, Missouri

Scientific Investigations Report 2008–5051

Hydraulic Analyses of Sni-A-Bar Creek and Selected Tributaries at Grain Valley, Jackson County, Missouri

By Paul H. Rydlund, Jr., William Otero-Benítez, and David C. Heimann

Prepared in cooperation with the City of Grain Valley, Missouri

Scientific Investigations Report 2008–5051

**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: <http://www.usgs.gov/pubprod>
Telephone: 1-888-ASK-USGS

For more information on the USGS--the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: <http://www.usgs.gov>
Telephone: 1-888-ASK-USGS

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted materials contained within this report.

Suggested citation:
Rydlund, P.H., Jr., Otero-Benítez, W. and Heimann, D.C., 2008, Hydraulic analyses of Sni-A-Bar Creek and selected tributaries at Grain Valley, Jackson County, Missouri: U.S. Geological Survey Scientific Investigations Report 2008–5051, 57 p. plus films.

Contents

Abstract	1
Introduction.....	1
Purpose and Scope	1
Description of Study Area	4
Methods.....	4
Development of One-Dimensional Models.....	4
Cross Sections and Extent of Models	4
Cross-Section Attributes	7
Topographic Information	7
HEC-RAS Model Boundary Conditions.....	11
Bridges and Culverts.....	19
HEC-RAS Model Calibration.....	19
Development of the Two-Dimensional Model.....	20
FESWMS Model Calibration	23
Sources of Errors in HEC-RAS and FESWMS Models.....	25
Hydraulic Analyses of Sni-A-Bar Creek (HEC-RAS Results)	25
Hydraulic Analyses of Sni-A-Bar Creek (FESWMS Results).....	26
Hydraulic Analyses of Sni-A-Bar Creek Tributaries.....	37
Hydraulic Structures Performance.....	37
Flood Plain Determination	37
Summary.....	56
References Cited.....	56

Figures

1–8. Maps showing—	
1. Location of Sni-A-Bar Creek Basin within Jackson County, Missouri	2
2. Location of Sni-A-Bar Creek main tributaries Blue Branch, Yennie Avenue Drain, and Swiney Branch	3
3. Cross-section locations of a one-dimensional step-backwater model along Sni-A-Bar Creek, Grain Valley, Missouri.....	5
4. Study area for the one-dimensional models	6
5. Cross-section locations of the one-dimensional model along Blue Branch, Grain Valley, Missouri	8
6. Cross-section locations of the one-dimensional model along Blue Branch Tributary, Grain Valley, Missouri	10
7. Cross-section locations of the one-dimensional model along Yennie Avenue Drain, Grain Valley, Missouri	12
8. Cross-section locations of the one-dimensional model above the long culvert on Yennie Avenue Drain culvert overflow, Grain Valley, Missouri	14

9–12.	Maps showing—	
9.	Cross-section locations of the one-dimensional model of the reach upstream from the long culvert (B-800) on Yennie Avenue Drain, Grain Valley, Missouri	15
10.	Cross-section locations of the one-dimensional model of Swiney Branch, Grain Valley, Missouri	16
11.	Cross-section locations of the one-dimensional model of Swiney Branch Tributary, Grain Valley, Missouri	18
12.	Location of high-water marks from the June 3, 2005, flood along Sni-A-Bar Creek, Grain Valley, Missouri.....	22
13.	Diagram showing the computational mesh [full model reach and focus reach (inset)] used in the two-dimensional model of Sni-A-Bar Creek, Grain Valley, Missouri.....	24
14.	Graph showing simulated water-surface elevation profiles along Sni-A-Bar Creek, Grain Valley, Missouri	27
15.	Maps showing water-surface elevations of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, Grain Valley, Missouri, simulated using a two-dimensional model.....	28
16.	Graphs showing water-surface elevation profiles through bridges along Sni-A-Bar Creek, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval floods simulated using a two-dimensional model.....	32
17–19.	Maps showing—	
17.	Water depths of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.....	33
18.	Water velocities of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, simulated using a two-dimensional model.....	38
19.	Water velocity magnitude and direction of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model	42
20.	Graphs showing water-surface elevation profiles of <i>A</i> , Blue Branch, <i>B</i> , Blue Branch Tributary, <i>C</i> , Yennie Avenue Drain, <i>D</i> , Swiney Branch, and <i>E</i> , Swiney Branch Tributary, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval events simulated using a one-dimensional model.....	46
21–23.	Maps showing—	
21.	Simulated flood plain for the 100-year recurrence interval flood along Blue Branch and Blue Branch Tributary, Grain Valley, Missouri.....	50
22.	Simulated flood plain for the 100-year recurrence interval flood along Yennie Avenue Drain, Grain Valley, Missouri.....	52
23.	Simulated flood plain for the 100-year recurrence interval flood along Swiney Branch and Swiney Branch Tributary, Grain Valley, Missouri.....	54

Tables

1. Length of stream and number of cross sections used in one-dimensional models of Sni-A-Bar Creek and tributaries	4
2. Roughness coefficients used in the one-dimensional models of Sni-A-Bar Creek, Blue Branch, Yennie Avenue Drain, and Swiney Branch	7
3. Downstream water-surface elevations defined for the one-dimensional models of Sni-A-Bar Creek, Blue Branch, Yennie Avenue Drain, and Swiney Branch.....	11
5. Discharges used in Blue Branch one-dimensional model	11
4. Discharges used in the Sni-A-Bar Creek one-dimensional model	11
6. Discharges used in the Blue Branch Tributary one-dimensional model.....	14
7. Discharges used in the Yennie Avenue Drain downstream one-dimensional model	15
8. Discharges used in the Yennie Avenue Drain culvert overflow one-dimensional model	19
9. Discharges used in the Yennie Avenue Drain upstream reach one-dimensional model	19
10. Discharges used in the Swiney Branch one-dimensional model	20
11. Discharges used in the Swiney Branch Tributary model.....	20
12. Description of the hydraulic structures included in the Sni-A-Bar Creek and tributary one-dimensional models	21
13. Measured water-surface elevations along Sni-A-Bar Creek for the flood of June 2005, and simulated water-surface elevations from the one-dimensional model	23
14. Roughness and eddy viscosity coefficients used in the two-dimensional model.....	23
15. Boundary conditions used in the Sni-A-Bar Creek two-dimensional model.....	23
16. Summary statistics for simulated and observed water-surface elevations used in the two-dimensional model calibration	25
17. High-water mark and simulated water-surface elevations including and excluding contracted openings along Sni-A-Bar Creek for the flood of June 3, 2005	26
18. Water-surface elevations with and without wastewater treatment plant impoundment at the junction of Swiney Branch and Sni-A-Bar Creek.....	27
19. Summary statistics for 10-, 50-, 100-, and 500-year recurrence intervals for Sni-A-Bar Creek simulated using the two-dimensional model.....	37
20. Summary of the performance of hydraulic structures in Blue Branch, Yennie Avenue Drain, and Swiney Branch one-dimensional simulations.	49

FILMS

1. Flow trace of the Sni-A-Bar Creek focus reach for the simulated 10-year recurrence interval flood
2. Flow trace of the Sni-A-Bar Creek focus reach for the simulated 50-year recurrence interval flood
3. Flow trace of the Sni-A-Bar Creek focus reach for the simulated 100-year recurrence interval flood
4. Flow trace of the Sni-A-Bar Creek focus reach for the simulated 500-year recurrence interval flood
5. Flow trace of the Sni-A-Bar Creek full model reach for the simulated 10-year recurrence interval flood
6. Flow trace of the Sni-A-Bar Creek full model reach for the simulated 50-year recurrence interval flood
7. Flow trace of the Sni-A-Bar Creek full model reach for the simulated 100-year recurrence interval flood
8. Flow trace of the Sni-A-Bar Creek full model reach for the simulated 500-year recurrence interval flood

Conversion Factors and Datums

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
Area		
acre	4,047	square meter (m ²)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km ²)
square foot (ft ²)	0.09290	square meter (m ²)
square mile (mi ²)	259.0	hectare (ha)
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
cubic foot (ft ³)	0.02832	cubic meter (m ³)
acre-foot (acre-ft)	1,233	cubic meter (m ³)
Flow rate		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)
Slope		
foot per mile (ft/mi)	0.18939	meter per kilometer (m/km)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Hydraulic Analyses of Sni-A-Bar Creek and Selected Tributaries at Grain Valley, Jackson County, Missouri

By Paul H. Rydlund, Jr., William Otero-Benítez, and David C. Heimann

Abstract

A study was done by the U.S. Geological Survey, in cooperation with the city of Grain Valley, Jackson County, Missouri, to simulate the hydraulic characteristics of Sni-A-Bar Creek and selected tributaries within the corporate limits. The 10-, 50-, 100-, and 500-year recurrence interval stream-flows were simulated to determine potential backwater effects on the Sni-A-Bar Creek main stem and to delineate flood-plain boundaries on the tributaries.

The water-surface profiles through the bridge structures within the model area indicated that backwater effects from the constrictions were not substantial. The water-surface profile of Sni-A-Bar Creek generated from the one- and two-dimensional models indicated that the Gateway Western Railroad structure provided the greatest amount of contraction of flow within the modeled area. The results at the location of the upstream face of the railroad structure indicated a change in water-surface elevation from 0.2 to 0.8 foot (corresponding to simulated 10-year and 500-year flood occurrences). Results from all analyses indicated minimal backwater effects as a result of an overall minimal energy grade line slope and velocity head along Sni-A-Bar Creek.

The flood plains for the 100-year recurrence interval floods on the Sni-A-Bar tributaries were mapped to show the extent of inundated areas. The updated flooding characteristics will allow city managers to contrast changes in flood risk and zoning as determined through the National Flood Insurance Program.

Introduction

Although principal land use around the city of Grain Valley, located in eastern Jackson County, Missouri (fig. 1), is agricultural, new developments within and outside the corporate boundary reflect an increase in population and development that presents challenges concerning water-resource issues and planning. Flooding along the main stem of Sni-A-Bar Creek and tributaries (fig. 1) within the city limits of Grain Valley initiated concerns from city resource manag-

ers to address potential inadequacies in the current (2007) stream channels and structures to convey stormwater runoff. Of additional concern were potential backwater effects from bridges spanning the main stem of Sni-A-Bar Creek within the corporate limits. The availability of updated ground-elevation data, reflecting a greater accuracy than previous data and including updates of urbanization and developed infrastructure, provided the opportunity to update analyses of flooding along Sni-A-Bar Creek and selected tributaries. The updated flooding characteristics will allow city managers to contrast changes in flood risk and zoning as determined through the National Flood Insurance Program (NFIP) (Federal Insurance Administration, 1979).

A study was done by the U.S. Geological Survey (USGS) in cooperation with the city of Grain Valley, Missouri, to simulate the hydraulic characteristics of Sni-A-Bar Creek and selected tributaries within the corporate limits of Grain Valley. The study was performed for selected flood discharges using the latest available topographic and land-use information. Specific objectives were to analyze potential backwater along the main stem of Sni-A-Bar Creek from contracted openings at Gateway Western Railroad bridge, Interstate 70 bridge, and U.S. Highway 40 (fig. 2) using 10-, 50-, 100-, and 500-year recurrence interval flood flows; evaluate hydraulic characteristics of 10-, 50-, 100-, and 500-year recurrence interval floods along three selected Sni-A-Bar tributaries that flow through the corporate limits of Grain Valley, including Blue Branch, Yennie Avenue Drain, and Swiney Branch (fig. 2); and identify the extent of the 100-year recurrence interval flood plain along the three selected Sni-A-Bar tributaries (Blue Branch, Yennie Avenue Drain, and Swiney Branch).

Purpose and Scope

The purpose of this report is to describe the techniques and summarize the results of a study of the hydraulic characteristics of 10-, 50-, 100-, and 500-year recurrence interval floods along Sni-A-Bar Creek and tributaries Blue Branch, Yennie Avenue Drain, and Swiney Branch within the corporate limits of the city of Grain Valley, Jackson County, Missouri. Hydraulic analyses included the determination of backwater along the main stem of Sni-A-Bar creek as a result of con-

2 Hydraulic Analyses of Sni-A-Bar Creek and Selected Tributaries at Grain Valley, Jackson County, Missouri

Figure 1. Location of Sni-A-Bar Creek Basin within Jackson County, Missouri.

Figure 2. Location of Sni-A-Bar Creek main tributaries Blue Branch, Yennie Avenue Drain, and Swiney Branch.

tracted openings at waterway crossings. The 100-year recurrence interval flood plain was mapped for all three Sni-A-Bar tributaries.

Description of Study Area

The study area consisted of the Sni-A-Bar Creek Basin upstream from Howell Road near Grain Valley, Missouri (figs. 1, 2). The drainage area of the basin is about 94.8 square miles (mi²) and primarily consists of agricultural land use. The Sni-A-Bar tributaries of interest within the city of Grain Valley included Blue Branch, Yennie Avenue Drain, and Swiney Branch. Blue Branch has a drainage area of 15.9 mi² upstream from the junction with Sni-A-Bar Creek. The land use in the basin primarily is residential, but also includes agricultural and undeveloped areas (U.S. Department of Agriculture, 2006). Yennie Avenue Drain has a drainage area of 0.9 mi² encompassing the downtown part of the city of Grain Valley (fig. 2). The land use in this basin is a mix of residential, commercial, and industrial (U.S. Department of Agriculture, 2006; fig. 2). Swiney Branch has a contributing drainage area of 7.4 mi² and is located on the northern boundary of the city of Grain Valley (fig. 2). Land use in this basin predominantly is agricultural with some commercial, industrial, and residential areas (U.S. Department of Agriculture, 2006). Future land-use planning information indicates that the Swiney Branch Basin will be moderately developed with single-family residential, commercial, and industrial areas (Burns and McDonnell Engineering Company, 2004).

Methods

Multiple hydraulic models were developed to address the objectives of this study. The 10-, 50-, 100-, and 500-year flood discharges on the Sni-A-Bar Creek main stem were simulated using one-dimensional and two-dimensional hydraulic models. Analyses of the 10-, 50-, 100-, and 500-year recurrence interval floods and development of the 100-year recurrence interval flood plain on Blue Branch, Yennie Avenue Drain, and Swiney Branch were conducted using separate one-dimensional models for each tributary.

Development of One-Dimensional Models

The Hydrologic Engineering Center–River Analysis System (HEC-RAS) version 3.3.1 was used for the one-dimensional analyses. HEC-RAS is a graphical user interface (GUI) used to facilitate the use of a steady, gradually varied flow model developed by the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center (HEC; U.S. Army Corps of Engineers, 2002). The basic, steady-flow computational procedure is based on the solution of the one-dimensional energy equation. Energy losses were evaluated

by friction (Manning's equation) and contraction/expansion coefficients. Products from the HEC-RAS models consisted of water–surface profiles for each of the simulated flows; for the Sni-A-Bar Creek tributary models, results also included flood-plain maps of the 100-year recurrence interval flood. The flood-plain analyses were performed using utilities within HEC-RAS.

Cross Sections and Extent of Models

The purpose of the one-dimensional models was to develop an accurate representation of the hydraulic characteristics of the Sni-A-Bar main stem and tributaries. For this purpose, cross sections were located at primary slope breaks of the channel streambed profile and points of minimum and maximum cross-sectional area. In addition, cross sections were included in expanding reaches and bends (when possible) to minimize errors. Abrupt changes in main channel and flood-plain roughness also were considered when selecting the location of the cross sections. All cross sections were located perpendicular to the flow direction. Some cross sections were described using multiple-line segments to assure each segment was perpendicular to the flow along the whole section width. The final number of cross sections used in the simulations was determined as a function of the length of the reaches, the hydraulic complexity of the area, and the level of detail desired for particular reaches.

The one-dimensional step-backwater model of the Sni-A-Bar Creek main stem was constructed with 38 cross sections and 3 bridge structures used to hydraulically simulate a 2.3-mile (mi) reach from a location upstream from Howell Road to a location immediately downstream from the junction with Blue Branch (fig. 3). The model extent and cross-section locations used to represent the Blue Branch, Yennie Avenue Drain, and Swiney Branch models are provided in table 1 and figures 4 through 11.

Table 1. Length of stream and number of cross sections used in one-dimensional models of Sni-A-Bar Creek and tributaries.

Model	Stream length (miles)	Number of cross sections	Corresponding figure
Blue Branch	2.94	73	5
Blue Branch Tributary	.5	22	6
Yennie Avenue Drain	1.29	52	7
Yennie Avenue Drain Culvert overflow	.08	13	8
Yennie Avenue Drain upstream	.13	9	9
Swiney Branch	3.26	124	10
Swiney Branch Tributary	.91	35	11

Figure 3. Cross-section locations of a one-dimensional step-backwater model along Sni-A-Bar Creek, Grain Valley, Missouri.

The topographical information for the cross sections was extracted from a 2-meter (m) digital elevation model (DEM) comprised of Light Detection and Ranging (LiDAR) data. The extraction process was accomplished using a Geographic Information System (GIS) software extension, HEC-GeoRAS, developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers (U.S. Army Corps of Engineers, 2006). HEC-GeoRAS allows for the preparation of geometric data to be imported into HEC-RAS, and facilitates the process of exporting HEC-RAS results into a graphical format.

Hydraulic structures were defined using four cross sections in accordance with recommendations provided in U.S. Army Corps of Engineers (2002). These four cross sections included two upstream and two downstream from the structure. The two cross sections upstream are used to model the contracting reach occurring upstream from a hydraulic structure, such as a bridge or culvert. The two cross sections downstream are intended to model the expanding reach occurring at the exit of the hydraulic structure. Additional suggestions for the one-dimensional modeling of hydraulic structures and the

Figure 4. Study area for the one-dimensional models.

correct representation of expanding and contracting reaches are provided in U.S. Army Corps of Engineers (1995).

Cross-Section Attributes

Each cross section contained as many as 250 points consisting of a transverse station number and a ground elevation. The topographical information was obtained directly from a Triangular Irregular Network (TIN) file generated from the available LiDAR data. The distance-elevation information for each cross section was extracted using HEC-GeoRAS and exported directly into the HEC-RAS software.

Cross-section hydraulic characteristics were specified for multiple segments within each cross section, with subdivisions based on geometrical characteristics and coverage roughness. The first primary breakpoints were the left and right channel banks, which indicate the highest points of the main channel banks. Because most of the cross sections approximated trapezoidal shapes, the selection of the overbank points was determined primarily by abrupt changes in the transverse slope of the ground surface, as recommended by Dalrymple and Benson (1967).

Land use along the Sni-A-Bar Creek main stem reach includes a thick timber and brush riparian corridor that dissects flood plains used for recreation and agriculture. Manning's roughness values (*n*-values) were consistent with available literature (Barnes, 1967; Arcement and Schneider, 1989) and were used to account for friction losses within the model. A horizontal variation in *n*-values was applied to cross sections to account for lateral roughness variation. These estimates were based on aerial photographs (U.S. Department of Agriculture, 2006) of the study area and guidelines provided in Arcement and Schneider (1989) and Chow (1959). A summary of roughness values used in the HEC-RAS models of Sni-A-Bar Creek, Blue Branch, Swiney Branch, and Yennie Avenue Drain are provided in table 2.

Table 2. Roughness coefficients used in the one-dimensional models of Sni-A-Bar Creek, Blue Branch, Yennie Avenue Drain, and Swiney Branch.

Land use / material type	Roughness coefficients (Manning's <i>n</i> -values)
Natural stream	0.040–0.045
Pasture	.025–.055
Trees	.080–.125
Residential area	.080–.150
Gravel	.020–.030
Concrete	.011–.013
Corrugated metal	.021–.023

The term “*ineffective flow areas*” refers to areas where the velocity of the flow within a cross section is close, or equal, to zero. Ineffective flow areas are used in storage

calculations, but are not considered as an area of active flow (Brunner, 2002). HEC-RAS allows for the definition of these areas, which are small ponds on the sides of the channel. During the computational process, these areas will be considered as volume storage, but not for flow conveyance. Ineffective flow areas were defined whenever one or more of the following characteristics occurred:

- Flood-plain areas were substantially below the top of the channel bank and were not hydraulically connected to the channel downstream;
- Flood-plain areas within the hydraulic shadow of roadway encroachments caused by contraction and expansion of flow through bridge or culvert openings; or
- Flood-plain areas within the hydraulic shadow of other obstructions or irregularities in the stream valley flood plain.

Contraction and expansion coefficients also were defined for each cross section. In open channel flow, just as in closed conduit flow, head (energy) is lost because of channel friction and contraction and expansion of the flow. Contraction and expansion losses generally are negligible for flood and non-flood modeling situations when channel cross sections are similar, but may be substantial in the vicinity of obstructions to the flow including bridges and culverts. For Sni-A-Bar Creek main stem and tributaries, coefficients of contraction and expansion of 0.1 and 0.3 were used. For changes in cross sections near bridges or culverts, coefficients of contraction and expansion of 0.3 and 0.5 were used as recommended in U.S. Army Corps of Engineers (2002).

Topographic Information

The topography of the study area was determined using LiDAR data obtained from Jackson County, Missouri (Steve Marsh, Jackson County, written commun., 2006). These data were collected with aircraft-mounted lasers capable of recording elevation measurements at a rate of 2,000 to 5,000 pulses per second and producing a vertical precision of about 0.5 foot (ft) (National Oceanographic and Atmospheric Administration, 2007). LiDAR mapping of terrain uses a technique called “bare-earth filtering” by which scanned data points of above-ground features (trees and buildings) are removed, thereby leaving the bare-ground data. While employing the LiDAR information in developing cross sections for HEC-RAS models, some areas were observed to not be filtered properly. These areas exhibited extremely irregular ground elevations, probably from the presence of tree canopies or structures not recognized during the filtering process. This is not uncommon when dealing with LiDAR data (Mastin and Kresch, 2003). A simple moving average was computed on those uneven cross sections to smooth the irregularities.

In addition to the LiDAR data, some 670 horizontally and vertically referenced point coordinates were collected within the Sni-A-Bar Creek channel between the junction of

Figure 5. Cross-section locations of the one-dimensional model along Blue Branch, Grain Valley, Missouri.

Figure 6. Cross-section locations of the one-dimensional model along Blue Branch Tributary, Grain Valley, Missouri.

Blue Branch and Swiney Branch (fig. 2) using a Total Station (surveying instrument) with a 2-second accuracy. Additionally, 160 data points were collected to better define the channel cross sections at Blue Branch and Swiney Branch at the first bridges upstream from the junction with Sni-A-Bar Creek.

HEC-RAS Model Boundary Conditions

Boundary conditions, including inflow discharges and corresponding downstream stages, were determined for the simulated 10-, 50-, 100-, and 500-year recurrence-interval floods for all models. The Sni-A-Bar Creek and tributary models were developed using the assumption that no critical or super-critical flows were present. For this type of scenario, the normal depth computed using the downstream slope (table 3) and the flows along the stream (tables 4–11) were specified as boundary conditions.

Table 3. Downstream water-surface elevations defined for the one-dimensional models of Sni-A-Bar Creek, Blue Branch, Yennie Avenue Drain, and Swiney Branch.

Model	Recurrence Interval (year)	Downstream boundary condition (stage, in feet)
Sni-A-Bar Creek	10	765.9
	50	767.2
	100	767.6
	500	768.6
Blue Branch	10	796.9
	50	799.8
	100	800.7
	500	802.1
Blue Branch Tributary	10	798.5
	50	800.2
	100	801.0
	500	802.5
Yennie Avenue Drain (Downstream reach)	10	767.2
	50	768.0
	100	768.5
	500	769.5
Swiney Branch	10	768.8
	50	769.4
	100	769.7
	500	770.2
Swiney Branch Tributary	10	784.6
	50	786.1
	100	786.5
	500	787.4

Table 4. Discharges used in the Sni-A-Bar Creek one-dimensional model.

[numbers reported to the nearest unit]

Station (feet upstream from downstream model boundary)	Recurrence interval (year)	Discharge (cubic feet per second)
6,000	10	9,000
	50	14,100
	100	16,400
	500	21,800
12,500	10	8,580
	50	13,400
	100	15,600
	500	20,800

Table 5. Discharges used in Blue Branch one-dimensional model.

[numbers reported to the nearest unit]

Station (feet upstream from junction with Sni-A-Bar Creek)	Recurrence interval (year)	Discharge (cubic feet per second)
2,150	10	5,290
	50	8,331
	100	9,853
	500	13,462
3,100	10	5,160
	50	8,031
	100	9,482
	500	12,982
3,836	10	5,110
	50	7,981
	100	9,380
	500	12,780
4,733	10	2,451
	50	3,832
	100	4,471
	500	6,060

The inflow discharge corresponding to the 10-, 50-, 100-, and 500-year recurrence interval events on the Sni-A-Bar Creek main stem were computed using the developed regression equations for ungaged rural streams (Alexander and Wilson, 1995):

Figure 7. Cross-section locations of the one-dimensional model along Yennie Avenue Drain, Grain Valley, Missouri.

Figure 8. Cross-section locations of the one-dimensional model above the long culvert on Yennie Avenue Drain culvert overflow, Grain Valley, Missouri.

$$\begin{aligned} Q_{10} &= 170 A^{0.680} S^{0.378} & (1) \\ Q_{50} &= 305 A^{0.660} S^{0.356} & (2) \\ Q_{100} &= 376 A^{0.652} S^{0.346} & (3) \\ Q_{500} &= 569 A^{0.636} S^{0.321} & (4) \end{aligned}$$

with Q_T equal to the discharge associated with recurrence interval of time T, in cubic feet per second (ft^3/s); A is the drainage area, in square miles (mi^2); and S is the channel slope, in feet per mile (ft/mi). The drainage area and channel slope for the Sni-A-Bar Creek upstream from Howell Road was determined using Geographic Information Systems (GIS) software.

The downstream boundary water-surface elevations used in the Sni-A-Bar Creek main stem models were determined from observed record or from normal-depth computations using HEC-RAS and the specified inflows. Flood-frequency profiles were developed from the step-backwater model by identifying a normal-depth slope [0.0026 foot/foot (ft/ft)] that would best fit the observed high-water mark profile. This slope was assumed

to represent the valley-controlled flow condition present along Sni-A-Bar Creek and was used in conjunction with the 10-, 50-, 100-, and 500-year recurrence-interval flood discharges.

Table 6. Discharges used in the Blue Branch Tributary one-dimensional model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Blue Branch)	Recurrence interval (year)	Discharge (cubic feet per second)
805	10	2,546
	50	3,853
	100	4,647
	500	6,247

Figure 9. Cross-section locations of the one-dimensional model of the reach upstream from the long culvert (B-800) on Yennie Avenue Drain, Grain Valley, Missouri.

Table 7. Discharges used in the Yennie Avenue Drain downstream one-dimensional model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Sni-A-Bar Creek)	Recurrence interval (year)	Discharge (cubic feet per second)
1,548	10	470
	50	611
	100	696
	500	904
2,072	10	270
	50	341
	100	396
	500	474

The drainage areas of Blue Branch, Yennie Avenue Drain, and Swiney Branch are small in comparison to the Sni-A-Bar Creek Basin, and because of this disparity in size, the timing of the simulated peak flows was not going to coincide (all the tributaries would release their peak flow long before the peak from Sni-A-Bar Creek occurred at the junction). Each tributary was, therefore, modeled without considering any backwater effect from Sni-A-Bar Creek. Normal elevations computed from the average downstream slope were used as the downstream boundary condition for all main stem models and their tributaries.

Stream basins comprise a system of sub-basins, each having particular geomorphological and hydraulic characteristics. For this reason, discharge will vary within natural channels. The hydrologic study performed by Burns and McDonnell Engineering Company (2004) quantified changes in discharge along Blue Branch, Yennie Avenue Drain, Swiney Branch, and their respective tributaries. The discharge values used in the

Figure 10. Cross-section locations of the one-dimensional model of Swiney Branch, Grain Valley, Missouri.

Figure 11. Cross-section locations of the one-dimensional model of Swiney Branch Tributary, Grain Valley, Missouri.

USGS models for Blue Branch and Swiney Branch (and their respective tributaries) were based on the information provided in this hydrologic study for the conditions existing at the time. The discharge values for Yennie Avenue Drain were obtained from a 2005 study conducted by the city of Grain Valley to evaluate the effects of constructed stormwater detention ponds (Rick Arroyo, City of Grain Valley, written commun., 2007). All flows in USGS models were assigned to the cross section nearest to the location of a discharge change as reported in Burns and MacDonnell Engineering Company (2004).

Table 8. Discharges used in the Yennie Avenue Drain culvert overflow one-dimensional model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Sni- A-Bar Creek)	Recurrence interval (year)	Discharge (cubic feet per second)
1,823	10	270
	50	341
	100	396
	500	474
1,941	10	69
	50	147
	100	199
	500	279
1,944	10	270
	50	341
	100	396
	500	474

Bridges and Culverts

Most of the information regarding hydraulic structures (bridges and culverts) was lost from the LiDAR data through the filtering process. Consequently, the input data used in each HEC-RAS model for hydraulic structures were obtained from a previous hydraulic study of the area (Burns and McDonnell Engineering Company, 2004). Much of the structure information acquired was verified through onsite inspection, although a formal survey was not performed at each structure. Original plans of the hydraulic structures were not available.

Model representations of bridge structures at U.S. State Highway 40, Gateway Western Railroad, and Interstate 70 east and west bound lanes were constructed using bridge plans submitted by Jackson County, Gateway Western, and the Missouri Department of Transportation (MoDOT). East and west bound lane structures at Interstate 70 are separated by a median that is 35 ft wide, and both structures were simulated as a combined structure for flow computations. All the hydrau-

lic structures present in the tributary stream models are listed in table 12.

Table 9. Discharges used in the Yennie Avenue Drain upstream reach one-dimensional model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Sni- A-Bar Creek)	Recurrence interval (year)	Discharge (cubic feet per second)
2,243	10	270
	50	341
	100	396
	500	474

The presence of a 400-ft underground culvert (B-800) in Yennie Avenue Drain forced the application of an alternate approach to the traditional culvert modeling in HEC-RAS (Yennie Avenue Drain culvert overflow; table 8). At culverts (or bridges) HEC-RAS assumes a straight line as the transition between the water-surface elevations computed for the upstream and downstream cross sections. Although this method might be considered simplistic, it is effective for typical culverts and bridges when sufficient information is available to define both cross sections. In this particular case, many geomorphic features occur along the 400-ft reach upstream from the culvert; therefore, the solution was to use three separate models (M.T. Whitehead, U.S. Geological Survey, written commun., 2007). First, a model was run for the entire length of Yennie Avenue Drain. From this model, the water-surface elevation at the expansion (downstream) side of the culvert was obtained. This elevation was used as the boundary condition for the second model, which was used to estimate the overland flow on the ground above the 400-ft culvert. A third model was then developed using the upstream elevation computed by the second model and the total flow (overland plus culvert) as the boundary conditions. The first and third models for Yennie Avenue Drain were conducted using the unaltered flow at the downstream and upstream locations. For the second model, the flow conditions were modified to account only for the fraction of the total discharge that contributed to overtop the culvert (the difference of the total discharge minus the discharge passing through the culvert).

HEC-RAS Model Calibration

On June 3, 2005, the city of Grain Valley received more than 5 inches (in.) of rainfall that contributed to a valley-controlled flood. A valley-controlled flood can be defined as open channel flow that has submerged the channel and is controlled downstream by topographic relief and anthropogenic structures in the valley or flood plain. The profile of the June 2005 flood was developed from observed high-water marks located

Table 10. Discharges used in the Swiney Branch one-dimensional model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Sni- A-Bar Creek)	Recurrence interval (year)	Discharge (cubic feet per second)
760	10	1,762
	50	2,677
	100	3,295
	500	4,658
2,180	10	1,554
	50	2,345
	100	2,899
	500	4,082
2,946	10	975
	50	1,473
	100	1,730
	500	2,324
3,953	10	766
	50	1,229
	100	1,444
	500	2,016
	500	2,016
4,069	10	607
	50	915
	100	1,098
	500	1,533
	500	1,533
4,614	10	530
	50	812
	100	957
	500	1,345
	500	1,345
5,072	10	494
	50	766
	100	886
	500	1,250
5,193	10	431
	50	678
	100	763
	500	1,088

along the main stem of Sni-A-Bar Creek and lower reaches of the tributaries of Blue Branch, Yennie Avenue Drain, and Swiney Branch (fig. 12). High-water marks were surveyed and used in model calibration of the Sni-A-Bar Creek main stem models. Steady-state boundary conditions initially were set with a known water-surface elevation at the downstream

cross section. A peak discharge was selected based on the best fit of a simulated water surface to the observed high-water marks (table 13). Additional interpolated cross sections were added to provide an adequate transition of conveyance, and adjustments of roughness values and expansion and contraction coefficients were applied to aid in refining the simulated water-surface profile. The resulting peak discharge of the June 2005 flood was 8,700 ft³/s. Once the HEC-RAS model was calibrated to the known flood, the known starting water-surface elevation was replaced with a normal depth computation or energy-grade-line slope, which was used to define the downstream starting water-surface elevation that best represented the simulated profile.

Table 11. Discharges used in the Swiney Branch Tributary model.

[numbers are rounded to the nearest unit]

Station (feet upstream from junction with Swiney Branch)	Recurrence interval (year)	Discharge (cubic feet per second)
834	10	837
	50	1,264
	100	1,519
	500	1,967
1,370	10	823
	50	1,243
	100	1,494
	500	1,935
1,471	10	777
	50	1,169
	100	1,391
	500	1,801

A slope-area computation was evaluated along the main-stem study reach to provide an additional diagnostic in which to evaluate the June 2005 peak. To properly conduct this indirect method of evaluating peak discharge, the study reach should be straight, contracting, and have a minimum of 0.5 ft of fall (Dalrymple and Benson, 1967). Ultimately, no adequate channel reach could be obtained on the Sni-A-Bar main stem to properly evaluate the slope-area method because of the difficulty identifying a straight contracting reach with observed fall greater than 0.5 ft within the modeled reach.

Development of the Two-Dimensional Model

The hydraulic characteristics of a 3.5-mi reach of the Sni-A-Bar Creek main stem were simulated using the numerical hydrodynamic model Finite Element Surface Water Modeling System Flow and Sediment Transport Module (FESWMS

Table 12. Description of the hydraulic structures included in the Sni-A-Bar Creek and tributary one-dimensional models.

[ft, feet; dia., diameter; RCB, reinforced concrete box; CMP, corrugated metal pipe; CMPA, corrugated metal pipe arch; --, not applicable]

Model	Hydraulic structures identification	Type of structure	Dimensions	Material / Shape	Length (ft)
Sni-A-Bar Creek	U.S. Highway 40	Bridge	--	--	100
	Gateway Western railroad	Bridge	--	--	232
	Interstate 70	Bridge	--	--	518
Blue Branch	BB-100	Culvert	6 barrels–18 ft x 17½ ft	RCB	42
	BB-900	Bridge	--	--	22
	BB-1400	Culvert	3 barrels–14 ft x 14 ft	RCB	81
	BB-1600	Culvert	3 barrels–10½ ft x 12 ft	RCB	60
Blue Branch Tributary	BB-500	Bridge	--	--	22
Yennie Avenue Drain	B-110	Culvert	3 barrels–7 ft dia.	CMP	35
	B-400	Culvert	3 barrels–8 ft x 6½ ft	RCB	50
	B-500	Culvert	1 barrel–11 ft x 6 ft	RCB	18
	B-600	Culvert	1 barrel–6 ft dia.	CMP	61
	B-800	Culvert	1 barrel–6½ ft dia.	CMP	400
Swiney Branch	SB-100	Culvert	2 barrels–12 ft x 7 ft	RCB	25
	SB-200	Culvert	2 barrels–15 ft x 11 ft	RCB	68
	SB-1300	Culvert	1 barrel–12 ft x 8 ft	RCB	35
	SB-1700	Culvert	1 barrel–13 ft x 9 ft	CMPA	55
	SB-1800	Culvert	1 barrel–8 ft x 10 ft	RCB	50
	SB-1900	Culvert	1 barrel–9 ft x 9 ft	RCB	65
Swiney Branch Tributary	SB-300	Culvert	1 barrel–12 ft x 8 ft	RCB	44
	SB-500	Culvert	1 barrel–24 ft x 6 ft	RCB	56

FST2DH) version 3.2.2 (Froehlich, 2003) within the Surface Water Modeling System (SWMS) version 9.0. The 10-, 50-, 100-, and 500-year recurrence interval discharges were simulated to determine a generalized view of the inundation extent and flow characteristics of Sni-A-Bar Creek through selected bridge structures. FESWMS FST2DH is a two-dimensional depth-averaged finite-element model using the Galerkin finite-element method as a numerical procedure for solving differential equations representing conservation of mass and momentum. SWMS is a pre- and post-processor for the FESWMS FST2DH model.

The FESWMS FST2DH model used a two-dimensional computational mesh (fig. 13) to represent the modeled area, referred to as the full model reach, rather than a series of cross sections as with the one-dimensional HEC-RAS model. Detailed views of the focus reach (fig. 13) were used to better show the effects of bridge structures. Topographical information and roughness characteristics were specified for each

node in the mesh. The mesh consisted of 27,514 elements with an average element area of 3,100 square feet (ft²). The mesh was extended upstream and downstream from the city boundary to allow boundary conditions to stabilize within the area of interest. The mesh boundary was placed outside of the inundation extent of a 500-year recurrence interval event as defined by a previous one-dimensional model application supplied by the city of Grain Valley (Rick Arroyo, written commun., 2007). Mesh elements were constructed using the quadrilateral (patch) and paving mesh generation options within SWMS. Bridge piers and box culvert web walls were incorporated into the mesh using the pier construction utility within FESWMS FST2DH. Mesh quality tools within SWMS were used to identify and correct possible areas in the mesh that could affect the solution, including abrupt element area changes, minimum and maximum element angles, concave quadrilateral elements, and ambiguous element gradients.

Figure 12. Location of high-water marks from the June 3, 2005, flood along Sni-A-Bar Creek, Grain Valley, Missouri.

Table 13. Measured water-surface elevations along Sni-A-Bar Creek for the flood of June 2005, and simulated water-surface elevations from the one-dimensional model.

Location	Water-surface elevation	
	Measured (feet)	Simulated (feet)
180 feet upstream from Howell Road	766.0	766.0
820 feet downstream from Interstate 70 structures	771.5	771.6
36 feet upstream from Interstate 70 structures	772.4	772.5
63 feet downstream from Gateway Western Railroad	772.8	773.0
21 feet upstream from Gateway Western Railroad	773.1	773.3
61 feet downstream from U.S. highway 40 structure	774.8	774.9
30 feet upstream from U.S. highway 40 structure	775.1	775.1
Junction of Blue Branch and Sni-A-Bar Creek	775.7	775.6

Material properties for the finite element mesh were defined by delineating selected land-use types using a 2006 digital orthophotograph (U.S. Department of Agriculture, 2006) and assigning roughness and eddy viscosity coefficients to each material type (table 14). Manning's roughness coefficient values were assigned using onsite observations in conjunction with guidance from Arcement and Schneider (1989) and Chow (1959).

Table 14. Roughness and eddy viscosity coefficients used in the two-dimensional model.

Land use / material type	Manning's n roughness coefficient	Eddy viscosity (squared feet per second)
Channel	0.04–0.045	5
Cropland	.04	10
Forest	.08–.125	5–10
Grassland	.025–.055	5–10
Roads	.013	5

The topography of the study area was determined from a 4-meter (m) digital elevation model (J.M. Richards, U.S. Geological Survey, written commun., 2007) derived from the 2006 Jackson County LiDAR dataset. An original 2-m DEM produced from the LiDAR information was re-sampled into a 4-m DEM as the number of data points associated with the 2-m DEM exceeded the import capabilities of the SWMS software. The channel-survey points described in the one-dimensional computational model development section also were

included in the topographic data set and interpolated onto the model mesh. The upstream input discharge and downstream water-surface elevation boundary conditions for the 10-, 50-, 100-, and 500-year recurrence interval events in the FESWMS FST2DH model were similar to those used in the upstream and downstream boundaries of the HEC-RAS one-dimensional simulation of the Sni-A-Bar main stem (tables 3, 4, 15).

Table 15. Boundary conditions used in the Sni-A-Bar Creek two-dimensional model.

[ft³/s, cubic feet per second; ft, feet]

Model simulation	Boundary condition	
	Upstream (ft ³ /s)	Downstream (ft)
Calibration event 1	657	758.8
Calibration event 2	8,700	765.9
10-year recurrence interval	9,000	765.9
50-year recurrence interval	14,100	767.2
100-year recurrence interval	16,400	767.6
500-year recurrence interval	21,800	768.6

The two-dimensional streamflow simulations began with an iterative process known as model “spindown” in which the water-surface elevation was incrementally lowered at the downstream boundary condition to the target stage to ensure computational stability. The initial downstream water-surface elevation was set at a stage that would ensure all elements in the mesh were “wet”, and the target simulation discharge was used as the inflow boundary condition. The downstream water-surface differences between initial spindown simulations were between 5 and 10 ft, and this increment was decreased to 1 ft or less as the simulation conditions approached the target water-surface elevation. Iterative model runs were used as “hotstarts,” providing the initial conditions for the subsequent model runs. This process was repeated until the desired downstream water-surface elevation was achieved. Throughout the process of “spindown,” dry elements were manually disabled to prevent solution instability resulting from wetting and drying.

FESWMS Model Calibration

The FESWMS FST2DH model was calibrated to two observed floods to better ensure that the model could reasonably represent the actual conditions in the full model reach. Streamflows for the August 2006 event were within the channel banks and allowed for the isolation and adjustment of in-channel conditions (channel control) to better match observed

Figure 13. Diagram showing the computational mesh [full model reach and focus reach (inset)] used in the two-dimensional model of Sni-A-Bar Creek, Grain Valley, Missouri.

conditions. The June 2005 flood closely corresponded to the 10-year recurrence interval flood conditions (table 15). The root mean square error (RMSE) associated with the August 2006 in-channel calibration event was 0.53 ft (table 16). The simulation was more sensitive to minor modifications in the mesh elements than to modifications of roughness coefficients. The six-wide element configuration for the Sni-A-Bar Creek main stem channel was adequate for simulating over-bank flows, but additional refinement of the channel elements would be needed for in-channel flow applications. The RMSE for the June 2005 calibration event was 0.39 ft (table 16).

Table 16. Summary statistics for simulated and observed water-surface elevations used in the two-dimensional model calibration.

Model simulation	Flood	
	August 06	June 05
Number of observations	3	146
Maximum difference, in feet	.53	.78
Minimum difference, in feet	-.55	-.52
Mean difference, in feet	.16	.24
Median difference, in feet	.50	.31
Root mean square error, in feet	.53	.39

Sources of Errors in HEC-RAS and FESWMS Models

The numerical hydraulic simulations are simplified representations of complex and dynamic natural systems; therefore, the simplification of this natural system through mathematical formulas, discrete nodal calculation points, channel roughness estimates, and depth-averaged approximations, will result in errors. The cumulative effects of these errors for the Sni-A-Bar Creek main stem models were quantified through calibration, and are summarized in tables 13 and 16. Errors from input data result primarily from the measurement and representation of topographic and hydrologic characteristics.

Although the collection process of LiDAR data is extremely precise, the filtering process of the original signal is not. The filtering process used to obtain the “bare-earth” topographical information is based on mathematical approximations that sometimes fail to interpret the original data. The primary concern in post-processing LIDAR data is how to isolate the ground surface from objects such as vegetation or buildings (Alemseged and Rientjes, 2007). For the data used in this study, the filtering methods were not able to remove elevation information of some structures. Additionally, ground

elevations in regions of thick vegetation were reported as particularly irregular. A moving-average technique was used to “smooth” those irregularities.

Hydrologic measurements included collecting stream-flow and water-surface elevations used in the construction of elevation-discharge ratings. Errors associated with these data contributed to overall simulation errors. Streamflow measurements included errors associated with the measurement of water depth and velocity. Water-surface elevations were collected with an accuracy of about 0.06 ft (corresponding to the error of the reference benchmark) and precision of approximately 0.02 ft (corresponding to the accuracy and precision of the reference gage). Discharge values used in the calibration simulations have associated errors of 8 to greater than 10 percent.

Finally, the selections of some of the calibration parameters (for example, Manning’s n values, eddy viscosity values) for these models can be an additional source of error. Using guidelines, access to experimental reports, and modeling experience help minimize the frequency of these errors; however, in reaches where calibration procedures could not be performed, the results were based on the physical characteristics of the channel.

Hydraulic Analyses of Sni-A-Bar Creek (HEC-RAS Results)

Analyses of the flood of June 3, 2005 (table 17), and the 10-, 50-, 100-, and 500-year recurrence interval flood frequency water-surface profiles (fig. 14) were made to distinguish potential backwater resulting from contracted openings. Based on surveyed high-water marks, potential backwater was not a concern because no substantial deviation in water-surface elevation was noted from surveyed marks upstream and downstream from each structure. Backwater from contracted openings can be considered a function of energy losses because velocity increases as water moves through the opening during sub-critical flow. As velocity increases through contracted openings, water becomes “backed up” upstream to a point where sufficient velocity head is established to accommodate the increased velocity through the respective opening. In the simulated reach, a backwater effect of 0.2 ft at the junction of Sni-A-Bar Creek with Blue Branch for the June 2005 flood was based on the inclusion of contracted openings minus the exclusion of such openings.

Results from all analyses indicated minimal backwater effects as a result of an overall minimal energy-grade-line slope and velocity head along Sni-A-Bar Creek. The water-surface profile of Sni-A-Bar Creek generated from the HEC-RAS model (fig. 14) indicated that the Gateway Western Railroad bridge structure provided the greatest amount of contraction of flow within the modeled area. The step-backwater model provided a simulation of all structures along the full model reach, and a subsequent simulation with the removal of

Table 17. High-water mark and simulated water-surface elevations including and excluding contracted openings along Sni-A-Bar Creek for the flood of June 3, 2005.

Location	Water-surface elevations					
	Surveyed high-water marks (feet)	Including contracted openings (feet)	Excluding contracted openings (feet)	All contracted openings (Interstate 70 bridges excluded) (feet)	All contracted openings (Gateway Western Railroad bridge excluded) (feet)	All contracted openings (US Highway 40 bridge excluded) (feet)
180 feet upstream from Howell Road	766.0	766.0	766.0	766.0	766.0	766.0
820 feet downstream from Interstate 70 bridges	771.5	771.6	771.6	771.6	771.6	771.6
36 feet upstream from Interstate 70 bridges	772.4	772.5	772.4	772.2	772.5	772.5
63 feet downstream from Gateway Western Railroad bridge	772.8	773.0	772.6	772.8	773.0	773.0
21 feet upstream from Gateway Western Railroad bridge	773.1	773.3	772.7	772.1	773.1	773.3
61 feet downstream from U.S. highway 40 bridge	774.8	774.9	774.8	774.9	774.9	774.9
30 feet upstream from U.S. highway 40 bridge	775.1	775.1	774.8	774.1	775.1	774.9
Junction of Blue Branch and Sni-A-Bar	775.7	775.6	775.4	775.6	775.6	775.4

the railroad structure exclusively. The results at the location at the upstream face of the railroad structure showed a water-surface elevation difference from 0.2 to 0.8 ft (corresponding to simulated 10- to 500-year flood occurrences, fig. 14). The maximum propagated backwater effects estimated with the one-dimensional model ranged from 0.5 ft to about 1.5 ft upstream from contracted openings (fig. 14). The wastewater treatment facility downstream from the three bridge crossings caused an estimated backwater ranging from about 0.2 to 0.4 ft at the junction of Swiney Branch with Sni-A-Bar Creek (table 18).

Hydraulic Analyses of Sni-A-Bar Creek (FESWMS Results)

The FESWMS FST2DH output consisted of a two-dimensional depiction of water-surface elevations, inundation area, water depths, and depth-averaged velocity information for the 10-, 50-, 100-, and 500-year recurrence floods. The water-surface profiles through the bridge structures simulated using FESWMS (fig. 15) also indicated that backwater

effects from these constrictions were not substantial. Water-surface longitudinal profiles through the three bridges for the four floods indicated a water-surface elevation change ranging from 0.1 to 1.0 ft between the bridge openings and locations about 250 ft upstream from the openings, with the largest elevation changes occurring through the Gateway Western railroad bridge (fig. 16). Maximum water depths in the main channel were about 24 to 28 ft (table 19) with water depths in the flood plain generally 3 to 5 ft deep during the four events (fig. 17). The area of inundation increased from 994 acres for the 10-year event to 1,166 acres for the 500-year recurrence interval event (table 19).

Maximum depth-averaged velocities in the study reach exceeded 10 feet per second (ft/s) in the four simulated floods, with maximum velocities through the bridge openings ranging from about 3 to 10.5 ft/s (table 19, figs. 18–19). The maximum velocity at the Gateway Western Railroad Bridge and Interstate 70 bridge openings increased with an increase in flow (fig. 18) as all the flow was contained within the bridge openings. An estimate of the flow pathways for the 10-, 50-, 100-, and 500-year recurrence interval flows were generated for the focus (films 1–4) and full (films 5–8) model reaches.

Figure 14. Simulated water-surface elevation profiles along Sni-A-Bar Creek, Grain Valley, Missouri.

Table 18. Water-surface elevations with and without wastewater treatment plant impoundment at the junction of Swiney Branch and Sni-A-Bar Creek.

[WWTP, wastewater treatment plant]

Event	Water-surface elevation	
	with WWTP impoundment (feet)	without WWTP impoundment (feet)
Indirect flow measurement—June 2005	770.85	770.60
Indirect flow measurement—August 2006	762.31	762.12
10-year recurrence interval discharge	770.75	770.50
50-year recurrence interval discharge	773.26	772.92
100-year recurrence interval discharge	773.80	773.57
500-year recurrence interval discharge	775.30	775.08

Figure 15. Water-surface elevations of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, Grain Valley, Missouri, simulated using a two-dimensional model.

50-YEAR RECURRENCE INTERVAL EVENT

Figure 15. Water-surface elevations of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, Grain Valley, Missouri, simulated using a two-dimensional model—Continued.

Figure 15. Water-surface elevations of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, Grain Valley, Missouri, simulated using a two-dimensional model—Continued.

500-YEAR RECURRENCE INTERVAL EVENT

Figure 15. Water-surface elevations of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, Grain Valley, Missouri, simulated using a two-dimensional model—Continued.

Figure 16. Water-surface elevation profiles through bridges along Sni-A-Bar Creek, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval floods simulated using a two-dimensional model.

10-YEAR RECURRENCE INTERVAL EVENT

Figure 17. Water depths of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.

50-YEAR RECURRENCE INTERVAL EVENT

Figure 17. Water depths of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model—Continued.

100-YEAR RECURRENCE INTERVAL EVENT

Figure 17. Water depths of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model—Continued.

Figure 17. Water depths of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model—Continued.

Table 19. Summary statistics for 10-, 50-, 100-, and 500-year recurrence intervals for Sni-A-Bar Creek simulated using the two-dimensional model.

Summary statistic	Simulation event recurrence interval			
	10-year	50-year	100-year	500-year
Inundated model area, in acres	994	1,100	1,130	1,170
Maximum water depth, in feet	23.8	25.4	26.4	28.0
Maximum depth-averaged velocity in model reach, in feet per second	10.4	10.9	11.0	10.6
Maximum depth-averaged velocity at U.S. Highway 40 bridge, in feet per second	4.33	3.63	3.10	2.47
Maximum depth-averaged velocity at Gateway Western Railroad bridge, in feet per second	6.45	6.79	8.56	10.5
Maximum depth-averaged velocity at Interstate 70 bridge, in feet per second	6.38	7.13	8.30	9.65

Hydraulic Analyses of Sni-A-Bar Creek Tributaries

The HEC-RAS results of the simulations of the Sni-A-Bar Creek tributaries—Blue Branch, Yennie Avenue Drain, and Swiney Branch—included generated water-surface elevation profiles for the 10-, 50-, 100-, and 500-year floods, and generated flood-plain maps for the 100-year recurrence interval floods. Water-surface elevation profiles are provided in figure 20. The Yennie Avenue Drain water-surface profile (fig. 20c) was composed of the results of three different models, and these results were combined in one profile to show their continuity.

Hydraulic Structures Performance

Once the water-surface profiles were generated, a more specific analysis of the hydraulic structures was performed. In this analysis, each structure was checked for overtopping during each of the events being evaluated (10-, 50-, 100- and 500-year recurrence floods). The flow and overtop above each hydraulic structure are listed in table 20. Even though some structures did not indicate overflow in the graphical output of the model, based on the numerical results, the areas surrounding the structure were submerged during certain events. These hydraulic structures were considered as overtopped for the analysis of those particular events.

Structures along Blue Branch Creek indicated a variable capacity to convey the simulated floods. Structure BB-900 had sufficient capacity to convey the flows from each event without overtopping. Structure BB-100 failed to convey the 500-year flow event, whereas structures BB-1400 and

BB-1600 had no capacity for events greater than a 10-year event without overtopping. The bridge present on Blue Branch Tributary (structure BB-500) was not overtopped in any of the modeled events.

Structure B-400, on Yennie Avenue Drain, had enough capacity to convey the flows from all events. Structure B-110 failed to carry the flow from the 100- and 500-year events. The rest of the structures present on Yennie Avenue Drain failed to convey any of the events without overtopping.

The structures present along Swiney Branch were able to convey the flows for the 10- and 50-year recurrence interval events with the exception of structures SB-1300 and SB-1700, which were overtopped during the 50-year event. None of the structures had enough capacity to convey the 100- and 500-year events without overtopping, with the exception of structure SB-1900, which was not overtopped during any of the events modeled. The Swiney Branch Tributary structures were overtopped during the 100- and 500-year events. Structure SB-500 on this stream also was overtopped during the 50-year event.

Flood Plain Determination

The extent of the flood plain determined for Blue Branch, Yennie Avenue Drain, and Swiney Branch is shown in figures 21 through 23. The flood plain for each stream and its respective tributaries were plotted on the same map to show continuity and transition at the junctions. The updated flood-plain maps will allow the city managers to contrast changes in flood risk and zoning as determined through the National Flood Insurance Program (NFIP) (Federal Insurance Administration, 1979).

10-YEAR RECURRENCE INTERVAL EVENT

Figure 18. Water velocities of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, simulated using a two-dimensional model.

Figure 18. Water velocities of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, simulated using a two-dimensional model—Continued.

100-YEAR RECURRENCE INTERVAL EVENT

Figure 18. Water velocities of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, simulated using a two-dimensional model—Continued.

500-YEAR RECURRENCE INTERVAL EVENT

Figure 18. Water velocities of 10-, 50-, 100-, and 500-year recurrence interval floods along the full model reach of Sni-A-Bar Creek, simulated using a two-dimensional model—Continued.

10-YEAR RECURRENCE INTERVAL EVENT

Figure 19. Water velocity magnitude and direction of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.

50-YEAR RECURRENCE INTERVAL EVENT

Figure 19. Water velocity magnitude and direction of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.—Continued

100-YEAR RECURRENCE INTERVAL EVENT

Figure 19. Water velocity magnitude and direction of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.—Continued

500-YEAR RECURRENCE INTERVAL EVENT

Figure 19. Water velocity magnitude and direction of 10-, 50-, 100-, and 500-year recurrence interval floods along the Sni-A-Bar Creek focus reach simulated using a two-dimensional model.—Continued

Figure 20. Water-surface elevation profiles of A, Blue Branch, B, Blue Branch Tributary, C, Yennie Avenue Drain, D, Swiney Branch, and E, Swiney Branch Tributary, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval events simulated using a one-dimensional model.

Figure 20. Water-surface elevation profiles of A, Blue Branch, B, Blue Branch Tributary, C, Yennie Avenue Drain, D, Swiney Branch, and E, Swiney Branch Tributary, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval events simulated using a one-dimensional model.—Continued

Figure 20. Water-surface elevation profiles of A, Blue Branch, B, Blue Branch Tributary, C, Yennie Avenue Drain, D, Swiney Branch, and E, Swiney Branch Tributary, Grain Valley, Missouri, for 10-, 50-, 100-, and 500-year recurrence interval events simulated using a one-dimensional model.—Continued

Table 20. Summary of the performance of hydraulic structures in Blue Branch, Yennie Avenue Drain, and Swiney Branch one-dimensional simulations.

[ft³/s, cubic feet per second; in., inches; --, no overtop; s.o.m., separate overflow model]

Model	Hydraulic structures identification ^a	Type of structure	10-yr		50-yr		100-yr		500-yr	
			Discharge (ft ³ /s)	Overtop (in.)	Discharge (ft ³ /s)	Overtop (in.)	Discharge (ft ³ /s)	Overtop (in.)	Discharge (ft ³ /s)	Overtop (in.)
Blue Branch	BB-100	Culvert	5,290	--	8,331	--	9,853	--	13,462	9.24
	BB-900	Bridge	5,110	--	7,981	--	9,380	--	12,780	--
	BB-1400	Culvert	5,110	--	7,981	6.24	9,380	16.92	12,780	32.6
	BB-1600	Culvert	2,450	--	3,832	6.24	4,471	13.80	6,060	26.0
Blue Branch Tributary	BB-500	Bridge	2,546	--	3,853	--	4,647	--	6,247	--
	B-110	Culvert	470	--	611	--	696	2.88	904	4.44
	B-400	Culvert	270	--	341	--	396	--	474	--
	B-500	Culvert	270	3.96	341	6.84	396	7.92	474	9.12
Swiney Branch	B-600	Culvert	270	8.76	341	12.72	396	15.00	474	16.68
	B-800	Culvert	270	s.o.m	341	s.o.m	396	s.o.m	474	s.o.m
	SB-100	Culvert	1,762	--	2,677	--	3,295	.48	4,658	6.72
	SB-200	Culvert	1,554	--	2,345	--	2,899	7.08	4,082	18.0
Swiney Branch Tributary	SB-1300	Culvert	975	--	1,473	8.88	1,730	11.64	2,324	17.52
	SB-1700	Culvert	607	--	915	.72	1,098	7.56	1,533	15.24
	SB-1800	Culvert	530	--	812	--	957	.84	1,345	9.48
	SB-1900	Culvert	431	--	678	--	763	--	1,088	--
Swiney Branch Tributary	SB-300	Culvert	837	--	1,264	7.80	1,519	5.16	1,967	9.60
	SB-500	Culvert	823	--	1,243	--	1,494	6.24	1,935	16.32

^aLocation of the hydraulic structures indicated in figures 5–11.

Figure 21. Simulated flood plain for the 100-year recurrence interval flood along Blue Branch and Blue Branch Tributary, Grain Valley, Missouri.

Figure 22. Simulated flood plain for the 100-year recurrence interval flood along Yennie Avenue Drain, Grain Valley, Missouri.

Figure 23. Simulated flood plain for the 100-year recurrence interval flood along Swiney Branch and Swiney Branch Tributary, Grain Valley, Missouri.

Summary

A study was done by the U.S. Geological Survey, in cooperation with the city of Grain Valley, Jackson County, Missouri, to simulate the hydraulic characteristics of Sni-A-Bar Creek and selected tributaries within the corporate limits. The 10-, 50-, 100-, and 500-year recurrence interval streamflows were simulated to determine potential backwater effects on the Sni-A-Bar Creek main stem and to delineate the floodplain boundaries on the tributaries.

Results using one-dimensional simulations illustrated potential backwater ranging from 0.5 ft to 1.5 feet upstream from contracted openings. As backwater propagated upstream to the junction of Sni-A-Bar creek and Blue Branch, the reach simulated with structures and the reach simulated without structures resulted in a water-surface elevation difference from 0.2 to 0.5 feet (corresponding to simulated 10-year and 500-year flood occurrences).

The water-surface profiles through the bridge structures within the model area indicated that backwater effects from the constrictions were not substantial. The water-surface profile of Sni-A-Bar Creek generated from the one- and two-dimensional models indicated that the Gateway Western railroad structure provided the greatest amount of contraction of flow within the modeled area. The results at the upstream face of the railroad structure indicated a water-surface elevation difference from 0.2 to 0.8 feet (corresponding to simulated 10-year and 500-year flood occurrences). Results from all analyses indicated minimal backwater effects as a result of an overall minimal energy grade line slope and velocity head along Sni-A-Bar Creek.

Analyses were conducted on the overtopping of hydraulic structures along three Sni-A-Bar Creek tributaries—Blue Branch, Yennie Avenue Drain, and Swiney Branch. The results indicated that on Blue Branch, two of the four structures (BB-1400 and BB-1600), fail to convey flows greater than a 10-yr event. On Yennie Avenue Drain, three of the five (B-500, B-600, and B-800) structures were overtopped for all the modeled events. Most of the structures along Swiney Branch performed well under the 10- and 50-year events. Swiney Branch Tributary structures performed as expected, overtopping only for the 100- and 500-year recurrence interval events, with the exception of structure SB-300, which experienced overtopping during the 50-year event.

The flood plain for the 100-year recurrence interval floods on the Sni-A-Bar tributaries were mapped to show the extent of the inundated area. This effort will assist city managers in recognizing changes in flood risk and zoning as determined through the National Flood Insurance Program.

References Cited

- Alemseged, T.H., and Rientjes, T.H.M., 2007, Uncertainty issues in hydrodynamic flood modeling, *in* Spatial Data Quality 2007 5th International Symposium Proceedings, Enschede, Netherlands, 2007, 6 p.
- Alexander, T.W., and Wilson, G.L., 1995, Techniques for estimating the 2- to 500-year flood discharges on unregulated streams in rural Missouri: U.S. Geological Survey Water-Resources Investigations Report 95-4231, 33 p.
- Arcement, G.J., Jr. and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.
- Barnes, H.H., Jr., 1967, Roughness characteristics on natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.
- Brunner, G.W., 2002, HEC-RAS, river analysis system hydraulic reference manual: U.S. Army Corps of Engineers Hydrologic Engineering Center CPD-69, Davis, Calif., 350 p.
- Burns and McDonnell Engineering Company, 2004, Storm-water master plan for the city of Grain Valley, Missouri: Kansas City, Mo., Project 34130, 52 p.
- Chow, V.T., 1959, Open channel hydraulics: New York, McGraw Hill, Inc., 680 p.
- Dalrymple, Tate, and Benson, M.A., 1967, Measurement of peak discharge by slope-area method: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A2, 12 p.
- Federal Insurance Administration, 1979, Flood insurance study, city of Grain Valley, Jackson County Missouri: Federal Insurance Administration, Flood Insurance Study Report, Washington, D.C.
- Froehlich, D.C., 2003, User's manual for FESWMS FST2DH—Two dimensional depth-averaged flow and sediment transport model, release 3: Federal Highway Administration, Publication Number FHWA-RD-03-053, 178 p.
- Mastin, M.C., and Kresch, D.L., 2003, Application of LIDAR terrain mapping to flood-hazard mapping, *in* Symposium on the Hydrogeology of Washington State, 4th, Tacoma, Wash., 2003.
- National Oceanic and Atmospheric Administration, 2007, About LiDAR data, accessed September 12, 2007, at <http://www.csc.noaa.gov/products/sccoasts/html/tutlid.htm>.

- U.S. Army Corps of Engineers, 1995, *RD-42 Flow transitions in bridge backwater analysis*: U.S. Army Corps of Engineers Institute for Water Resources, Hydrologic Engineering Center, Davis, Calif., 81 p.
- U.S. Army Corps of Engineers, 2002, *HEC-RAS River Analysis System User's Manual*, v. 3.1: U.S. Army Corps of Engineers Institute for Water Resources, Hydrologic Engineering Center, Davis, Calif., 408 p.
- U.S. Army Corps of Engineers, 2006, *HEC-GeoRAS*, accessed November 15, 2006, at <http://www.hec.usace.army.mil/software/hec-ras/hec-georas.html>.
- U.S. Department of Agriculture, 2006, *National agriculture imagery program*, accessed August 18, 2006, at <http://www.msdis.missouri.edu/data/naip2006/index.htm>.

Publishing support provided by:
Rolla Publishing Service Center

For more information concerning this publication, contact:
Director, USGS Missouri Water Science Center
1400 Independence Road
Rolla, MO 65401
(573) 308-3667

Or visit the Missouri Water Science Center Web site at:
<http://mo.water.usgs.gov>