STEAMBOAT CREEK FLOOD STUDY

Carla Muscarella, PE, CFM and Todd Cochran, PE, CFM

AUTHORS: Civil Engineers, Manhard Consulting, 3300 Highlands Parkway, Suite 255, Smyrna, Georgia 30082
REFERENCE: *Proceedings of the 2007 Georgia Water Resources Conference*, held March 27–29, 2007, at the University of Georgia.

Abstract. This paper will present the development, analysis, calibration, and results of a comprehensive hydrologic and hydraulic study performed for the Steamboat Creek watershed, located in Reno, Nevada. The purpose of the study was to establish accurate Base Flood Elevations (BFEs) in support of a number of residential developments proposed along Steamboat Creek. There had been several studies performed over the past decade, which each study producing very different peak flows. Encompassing over 240 square miles, the Steamboat Creek watershed is tributary to the Truckee River, one of the most protected rivers in Nevada. Citizens who reside along Steamboat Creek and its tributaries have experienced a marked increase in flooding within recent years; flooding widespread enough that even casual discussion of new development within the watershed results in a high level of concern and emotion, clearly seen during meetings that were held with the local residents. Outdated floodplain mapping and conflicting studies, combined with the already existing flood hazards threatening residences, properties, and thoroughfares, drove the need for a comprehensive, defensible watershed analysis to be completed. Extensive coordination with the US Army Corps of Engineers (USACE), the City of Reno, Washoe County, and the National Oceanic and Atmospheric Administration (NOAA) took place to ensure the final product was a reliable "predictor" of the anticipated watershed's physical response to a flood event. NEXRAD radar rainfall data, which was incorporated into the modeling, greatly advanced the model calibration and verification efforts.

PROJECT OVERVIEW

The Steamboat Creek watershed is a 240 square mile area, with 83.9 square miles discharging to Washoe Lake, which can accommodate runoff from all but the most extreme storm events. Elevations within the watershed range from 10,800 in the headwaters to 4,370 in the lower reaches. Total precipitation depths of a 1% annual chance event (100-year storm) range from 2.1 to 11 inches, depending on the location within the watershed. This project involved the development and calibration of a HEC-HMS hydrologic model for the entire 240 square mile watershed and a HEC-RAS hydraulic model for 11 miles of Steamboat Creek.

Steamboat Creek is a major tributary to the 105-mile long Truckee River, which flows through Reno, NV. The Truckee River begins at the outlet of Lake Tahoe in the Sierra Nevada Mountains and terminates at Pyramid Lake in northwestern Nevada. The Truckee River is a major flooding source for the City of Reno and other communities downstream. USACE is in the process of completing an extensive study of the Truckee River watershed and several major tributaries including Steamboat Creek. USACE's study will recommend a series of flood control projects aimed at reducing flooding risks in the City of Reno, City of Sparks, Washoe County, and surrounding communities. Preliminary recommendations from this study include a large flood control dam and a series of levees in the Steamboat Creek watershed.

COORDINATION WITH REGULATORY AND LOCAL AGENCIES

At the time Manhard was contracted to develop this study, engineers at USACE Sacramento office was in the process of developing a parallel study in support of a regional flood control project along Steamboat Creek. Engineers from Manhard and the USACE met in May 2006 to discuss both analyses. Modeling approaches, rainfall distribution, loss methodology, existing flow diversions, and snowmelt effects were among the topics covered. It was agreed upon during the meeting that both project teams would continue to coordinate to further the quality of both parties' results.

The portion of Steamboat Creek studied lies within both the City of Reno and Washoe County. Both of these entities have a clear interest in the results of the analysis. Flooding along the creek has become increasingly more common following rain events and local citizen groups have formed to voice strong resistance to proposed development within or adjacent to the floodplain. Outdated floodplain mapping and conflicting studies along Steamboat Creek begged the question – "Where are the true 100-year floodplain limits along Steamboat Creek?"

Figure 1. Flooding of SR395 on-ramp (12/31/05)

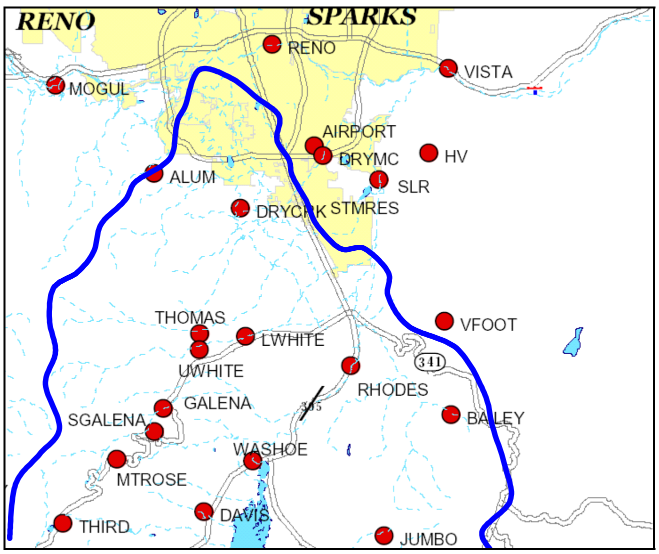

Figure 2. ALERT Rainfall Gage Network in the Steamboat Watershed

PUBLIC CONCERNS

Several public meetings were held during the last few years to discuss the proposed developments within the watershed, with flooding being the primary focus and topic of discussion. A number of well-organized Homeowners Associations (HOAs) banded together, combined financial resources, and hired outside engineering consultants to attack these projects based on the belief that flooding would be worsened if these developments were allowed to be constructed.

MODELING AND ANALYSIS

Extensive effort took place to accurately define the physical characteristics of the study area. It is well known within the field of hydrology that the proper determination of model parameters (physical losses, soils, land cover, lag times) is crucial in the development of a defensible model. Qualified engineers and ecologists conducted field and stream walks. Photo and audio documentation, field sketches, as well as substantial verbal coordination with the Corps and local agencies, were performed. Field survey along Steamboat Creek consisted of 142 natural sections and 9 structures at roadway crossings.

Existing Models

The Steamboat Creek watershed is a very complex hydrologic system, including numerous flow diversions, inter-basin transfers, and extreme grade changes within the basin. Given this fact, Manhard determined it prudent to construct both the hydrologic and hydraulic models from the ground up versus utilizing the existing models as a basis for construction. While existing studies were re ferred to for results comparison, the data contained within those studies was not used directly within the Manhard model unless field verification was performed and the data subsequently confirmed.

Hydrologic Modeling

The goal of the hydrologic modeling task was to develop a calibrated model that could be used to more accurately estimate peak runoff rates from a number of design storms. Key watershed parameters were developed using GIS data provided by Washoe County and the City of Reno. Subbasins were delineated using 2-foot topography to create drainage areas with homogeneous slopes and land use.

For soil losses, the NRCS Curve Number methodology was originally used. The NRCS soil survey was used to determine the hydrologic soil group. This information was intersected in ArcMap GIS with a detailed land use coverage that was developed from recent aerial photography.

The soil losses for each time step are subtracted from the total rainfall amount to produce the excess precipitation. The SCS dimensionless unit hydrograph method was utilized to transform the rainfall excess into runoff. This method uses the lag time (0.6*Time of Concentration) to develop a hydrograph for each subbasin.

The SCS transformation method uses a constant of 484, which is commonly referred to as the peaking factor. This is an average value derived from hundreds of unit hydrographs developed from small urban basins. To use this method accurately, the peaking factor should be increased in steep basins and decreased in flat basins. The peaking factor varies from approximately 300 in flat basins to 600 in steep basins. However, changing this constant is not an option within the current version of HEC-HMS. Studies have shown the SCS method to accurately predict 24-hour runoff volumes. However, the distribution of runoff is not realistic due to the shortcomings of the infiltration concept in the SCS method (Brevnova).

The S-Curve method was used as an alternative method to more accurately model the rainfall to runoff process. Three S-curves were developed by the Sacramento district of the USACE. Two curves were for mountainous areas and one for valleys. The S-curves were constructed from a series of unit hydrographs of length *t* by the process of successive lagging by *t* and summing the discharge values (ordinates) to represent the hydrologic response of a basin to a rainfall event of infinite duration.

A major consideration in the hydrology of Steamboat Creek watershed is flow diversions. As the runoff transitions from steep mountainous streams to the foothills and mildly sloped valley, braided and divergent flow patterns naturally occur. As the basin was developed, man-made diversions have been constructed to control these unpredictable flow patterns. Additionally, an irrigation canal that provides water from the Truckee River divides the watershed. The canal runs perpendicular to the channels and overland flow directions. During the 100-year event, it was determined that the capacity of the canal was not a major factor in diverting flows due to its size and flat slope. However, it has a significant impact in more frequent storm events.

For the design storm, NOAA Atlas 14 data was used to determine total rainfall amounts and rainfall distribution. The total rainfall amounts change significantly from the eastern side of the Sierra mountain range to the valley. A grid of the isopluvial rainfall totals was used to develop a grid within GIS, which was used to estimate an average precipitation for each subbasin.

Although the Reno area is shown in TP-40 to be in the SCS Type II zone, this rainfall distribution was found to not be truly representative of typical rainfall events in the region. The 5-minute through 24-hour rainfall totals were used to develop a project storm distribution for each individual subbasin.

Model Calibration

Due to the large variation in peak flows that have been estimated for the Steamboat Creek watershed in previous hydrologic studies, model calibration was an important part of this project. Previous modeling efforts using traditional SCS TR-55 methodology were suspected to greatly overestimate both peak flows and total runoff volumes.

NEXRAD radar rainfall data was obtained for two recent storm events. The December 31, 2005 event was a major flooding event and was used as the calibration event. A smaller storm from February 27, 2006 was chosen as the verification event.

The NEXRAD data was calibrated using a network of rain gages within the watershed from the ALERT gage system. Vieux and Associates in Norman, Oklahoma performed this complex calibration of the 1km NEXRAD grid at 5-minute intervals. A basin average was also computed for each subbasin at each time increment. This data was entered as a gage for each subbasin in HEC-DSS (a hydrologic database used by HEC-HMS).

This detailed, spatially accurate rainfall data was paired with four stream gages within the watershed. The four stream gages included one on the Galena Creek tributary and three along the mainstem of Steamboat Creek. The most upstream gage on Steamboat Creek, Rhodes Drive, recorded a peak flow of 3,600 cfs during the 2005 New Year's Eve storm. The two gages downstream, Geiger Grade Road and Short Lane, recorded a peak flow of 3,000 cfs despite an increased drainage area. It was determined that the decrease in peak flows was a result of floodplain attenuation between the gages. High water marks along Steamboat Creek were also surveyed immediately following the storm event.

Initial runs of the HEC-HMS model using the methods described above resulted in peak flows approximately 200-350% higher than those estimated by the gage records. Estimated runoff volumes were approximately 200% of the total hydrograph volume estimated by the gage data.

Parameter Calibration. The SCS curve numbers were the first parameter to be modified. After performing several sensitivity runs, the initial curve numbers were decreased by 10 units. Additionally, the initial abstraction ratio was increased from 0.2 to 0.3. This combination resulted in a peak flow that matched the Rhodes Drive gage but still produced a larger volume. The results of this curve number adjustment provided values that are much lower than those typically used in the region. The increased initial abstraction is also not common practice.

Figure 3: Steamboat Creek

For these reasons, other methods were explored.

The Green and Ampt method was then used for comparison to the SCS method. Initial parameters for the Green and Ampt method were developed using the soil texture in the NRCS Soil Survey and literature values. The Green-Ampt parameters include the Initial Loss (Ia), Hydraulic Conductivity (Ksat), Suction Head, and Porosity (Dtheta). The four parameters were calibrated to more closely match the gage data. The results with this method provided a closer match to the measured runoff volumes while staying within typical accepted values for the input parameters.

Snowmelt. USACE determined that the consideration of snowmelt during the design storm was essentially a "wash". At the higher elevations in the watershed, a ripe snow pack absorbed a portion of the falling precipitation reducing the runoff, while in the lower elevations additional runoff was realized. Ultimately, the conditions served to cancel each other out regarding actual runoff seen within Steamboat Creek. USACE used the HEC's SNOW model, which evaluates ambient temperature, wind speeds, and several other parameters to develop a outflow hydrograph to simulate the snow melt process.

Manhard's hydrologic models included snowmelt by implementing the less complex temperature index method in HEC-HMS. The results were checked against the results of USACE's SNOW model and adjusted. There was significant discussion of whether or not to include the snowmelt modeling in the hydrologic analysis.

Hydraulic Modeling

The hydraulic modeling for this study included the construction of a detailed steady flow HEC-RAS model for 11 miles of Steamboat Creek. This model was used to estimate BFEs, which were used to delineate the 100-year floodplain.

The unsteady flow option may be explored further in the future. It is believed that this would provide a more accurate estimation of water surface elevation along the relatively flat slopes of Steamboat Creek. The unsteady flow model would also improve the hydrologic model by providing a more accurate reach routing along the mainstem of Steamboat Creek. The current model uses the Muskingum method that has been calibrated to stream gage data.

STUDY RESULTS

The primary result of this study was a more accurate and defensible estimation of runoff volumes, peak flows, and flooding extents along Steamboat Creek. Regulatory agencies can feel confident that proposed flood control dams, levees, channels, and culverts are designed with adequate safety factors. Following construction of the USACE recommended flood control projects, the local residents can be assured that they will remain safe from future flooding and benefit from reduced flood insurance rates, if needed. Local municipalities and developers can be confident that new infrastructure constructed is hydraulically adequate without paying for grossly over designed facilities.

A secondary result was an extensive look at different hydrologic modeling mythologies and how they simulate stormwater runoff compared to actual gauged storm events. Varied interests from multiple parties in the results of this watershed analysis led to productive discussions among the water resources engineering and floodplain management communities in the region. In October 2006, a formal round table meeting was conducted to discuss how future flood studies should be conducted and how these guidelines could be incorporated into a new version of the Washoe County Hydrologic Criteria manual that is currently under review.

The results of this project reach beyond the semi-arid southeast. Many of the hydrologic modeling methods discussed should be evaluated for their applicability to different regions in Georgia. Although the SCS methodology appears to work well for the rolling hills of the piedmont region of Georgia, there are several alternative methods that are more applicable to the mountainous and costal plains regions. These include soil loss, hydrograph transformation, and design storm distribution.

LITERATURE CITED

U.S. Army Corps of Engineers. 1994. Engineering and Design - Flood-Runoff Analysis, EM 1110-2-1417, U.S. Army Corps of Engineers, Washington, D.C.

Soil Conservation Service. 1986. "Urban Hydrology for Small Watersheds," Technical Release 55, U.S. Department of Agriculture, Washington, DC.

Brevnova, Elena V. 2001. Green-Ampt Infiltration Model Parameter Determination Using SCS Curve Number (CN) and Soil Texture Class, and Application to the SCS Runoff Model, Morgantown, West Virginia.