Panel Decision & Report

SRP NVDC122811 Douglas County, NV

July 16, 2012

National Institute of BUILDING SCIENCES

Table of Contents

Summary

Based on the submitted scientific and technical information, and within the limitations of the SRP, the panel has determined that FEMA's data does not satisfy NFIP mapping standards defined in FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners (NFIP standards) and must be revisited.

Introduction

This report serves as the recommendation to the Federal Emergency Management Agency (FEMA) administrator from the National Institute of Building Sciences (NIBS) Scientific Resolution Panel (SRP). SRP's are independent panels of experts organized, administered and managed by NIBS for the purpose of reviewing and resolving conflicting scientific and technical data submitted by a community challenging FEMA's proposed flood elevations. The SRP is charged with helping to efficiently resolve appeal and protest issues between FEMA and communities by acting as an independent third party in the effort to obtain the best data possible for the community's Flood Insurance Rate Maps (FIRM's).

Panel

Panel ID: NVDC122811
Panel Name: Douglas County, NV
FEMA Region: IX
Panel members:

- **Dr. Lee Azimi, P.E.,** DeKalb County, GA
  Dr. Azimi brings over 27 years of experience in academic research, as consultant and educator in the areas of civil infrastructure management, design, construction, and water resources engineering. He has served in numerous committees and regional councils and as a technical advisor for water resources protection and conservation and development of technical, regulatory, and policy standards. He currently works in the north Georgia metro area and his activities include management and administration of regional flood hazard mitigation and mapping program.
- **Dr. Richard Hawkins, P.E., P.H,** Professor Emeritus, University of Arizona, Tucson, AZ.
  Dr. Hawkins has 50 years of experience in engineering, hydrology, and natural resources, in education, research, and agency and consulting practice. Recently retired from the University of Arizona, he taught a variety of courses in hydrology, modeling, hydraulics, sediment, water quality, fire science, and statistics. He has published extensively in his specialty fields of small watershed hydrology and rainfall-runoff modeling, with accent on land condition impacts. He has taught continuing education courses on rainfall-runoff for ASCE and local flood control interests. He also served on the faculties of SUNY-Syracuse, and Utah State University, and has experience with the US Forest Service, USDA-ARS, and the California Department of Water

Resources, and was selected as a Distinguished Visiting Scientist with the USEPA in Corvallis OR. He has received a number of awards for professional service and scholarship, and has had numerous international assignments.

- **Roger Kilgore, P.E., D.WRE, F. ASCE**. Principal, Kilgore Consulting and Management, Denver, Colorado.
  Mr. Kilgore is a professional engineer with 30 years of experience in water resources engineering and research and is Principal of Kilgore Consulting and Management. He has performed and directed numerous hydrologic and hydraulic studies to establish floodplains and has assessed coastal, alluvial fan, and riverine flood damage for the NFIP and other clients. Mr. Kilgore currently teaches hydrology, hydraulics, and coastal engineering principles on behalf of the Federal Highway Administration. His research efforts include development of statistical tools to assess the joint probability of flooding for the National Academies of Engineering.
- **Albert Liou, P.E.,** Co-Founder and Principal, Pacific International Engineering, Edmonds, WA
  Mr. Liou is a professional engineer with 41 years of experience in water resources engineering. In the last 10 years he has served as the chief hydraulic/hydrologic engineer and the project manager for clients including FEMA Region VIII and various communities, on more than two dozen NFIP related projects located in the mountain states and the Pacific Northwest. He has performed and directed FIS, DFIRM, LOMR, CLOMR, Appeal, and levee analysis/design/ certification per 44CFR65.10 regulations.
- **Dr. Vijay Singh.** Professor, Texas A&M University, College Station, Texas.
  Dr. Singh is a professional engineer and a professional hydrologist. He has 38 years of experience in teaching, research and consulting in hydrologic and water resources engineering. He has taught a variety of courses in hydrologic and hydraulic modeling, stochastic modeling, and entropy theory-based modeling. He has served as a consultant to various private engineering companies and government organizations-both national and international. He has published extensively in the areas of hydrology, hydraulics and water resources. He has authored/co-authored 18 books and has received numerous research grants from federal agencies.

Basis for Appeal

On April 4, 2008, FEMA posted and advertised the PFIS and PFIRM for Douglas County to replace the effective 1999 FIS and FIRM. The flood zone area delineated in the 2008 preliminary maps increased compared with the effective maps. The community provided peer-review assessments and restudy documents concluding that the FEMA data/analyses are “technically incorrect due to error in application of hydrologic, hydraulic or other methods or use of inferior data in supplying such methods.” The documentation provided by the community is listed below.

By letter dated September 3, 2008, the community formally appealed the PFIS and PFIRM. A meeting with FEMA and the community occurred on January 8, 2009 to discuss the community’s concerns. By letter dated April 2, 2009, FEMA denied the community's appeal. On June 5, 2009, FEMA moved forward to make the new FIRM effective January 2010 with a letter of final determination.

On September 18, 2009, the community filed a complaint against FEMA in US District Court. On October 28, 2011, a settlement agreement was reached, which among other items, included submitting the scientific and technical information to a Scientific Resolution Panel (SRP) for review and recommendations. The scope of the SRP review is limited to the scientific and technical issues.

Data Submitted by the Community and FEMA

The following data used to generate the challenged flood elevations and the contesting data submitted by Douglas County, NV has been provided to the panel:

FEMA

1. Two page summary and timeline of key events surrounding appeal.
2. Northwest Hydraulic Consultants (NHC), 2005. "Hydrology Report for the Douglas County FIS," April.
3. Northwest Hydraulic Consultants (NHC), 2005. "Hydraulic Analyses, Douglas County, Nevada," April.
4. MAP IX summary of principal points of appeal by Manhard and RO Anderson.
5. MAP IX responses to Manhard and RO Anderson technical review comments submitted as part of appeal.
6. Meeting minutes from 8/4/09 coordination meeting.
7. MAP IX memorandum comparing effective, Northwest Hydraulic Consultants (NHC), Manhard, and RO Anderson studies in Douglas County.
8. Letter from FEMA Map Coordination Contractor formally accepting the NHC hydrology for use in floodplain mapping.
9. Comparison chart of base flood discharges in Douglas County.
10. Memorandum from NHC dated 4/8/09 acknowledging a flow correction to the HEC-RAS hydraulic model for Buckeye Creek.
11. Formal FEMA response letter to Douglas County appeal.
12. Presentation to the panel on June 5, 2012 and follow-up information requested by the panel as a result of the presentation.

Community

1. Manhard Consulting Ltd (MCL), 2008. "Peer review of the 2008 Preliminary Flood Insurance Study, Douglas County, NV," July.
2. Manhard Consulting Ltd (MCL), 2008. "Buckeye Creek Watershed Restudy" September.
3. RO Anderson Engineering (ROA), 2007. "Flood Study, Hellwinkel Linear Parkway and Flood Channel," May.
4. RO Anderson Engineering (ROA), 2007. "Detailed Flood Hydraulics Study of Buckbrush Wash to Support Conditional Letter of Map Revision," August.

5. RO Anderson Engineering (ROA), 2008. "Detailed Flood Hydraulics Study of Martin Slough Upstream from U.S. Highway 395 and Downstream from Toler Avenue, Minden and Gardnerville, Nevada to Support Letter of Map Revision," June.
6. RO Anderson Engineering (ROA), 2008. "Technical Review of Provisional Flood Insurance Study and Flood Insurance Rate Maps of Douglas County, NV," August.
7. Presentation to the panel on June 5, 2012 and follow-up information requested by the panel as a result of the presentation.

In addition, the court settlement agreement was provided to the panel. This document contained additional emails and memos considered by the panel in its review.

Summary of Panel Procedures

A kickoff meeting was held March 16, 2012 via teleconference / web-based presentation (as were all subsequent meetings). A Chair of the panel was appointed by acclamation. The Chair's responsibility for coordinating and communicating with the Institute, the panel, and role in completing the report was discussed. During the first meeting the schedule and milestones for completing the SRP were also established. The panel was tasked to review the technical information and other data provided by the community and by FEMA. Both individual communications between panel members and joint deliberation with the Institute Director were held.

A second meeting was held on April 24, 2012 to review progress, discuss initial impressions, and review the scope of the panel's responsibility. The panel was tasked to place review observations in the context of FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners" (G&S).

A third meeting was held on May 15, 2012. Further discussion of the issues took place. The panel was notified that the community had requested an opportunity to present and the panel agreed to the request.

The fourth meeting was held on June 5, 2012 with the panel, the Institute, the community and FEMA. Both the community and FEMA were allowed to give presentations. The panel was then allowed to ask questions to both parties to clarify issues and evaluate the disagreements. Both the community and FEMA were offered the opportunity to provide additional technical information to the Institute based on overall content of the call.

A fifth meeting was conducted on June 19, 2012 to discuss the presentations and review technical and process issues.

A draft report outlining the SRP program, procedures, technical data reviewed, and oral presentation from community and FEMA was prepared. This report was modified to a final report containing conclusions regarding the overall technical superiority of the information submitted to the Institute by both the community and by FEMA. A vote was held within the parameters of the Institute's rules, and the panel's final decision was based on a unanimous vote of the five panel members.

Recommendation

The Panel recommends acceptance of the community protest. FEMA's data does not satisfy NFIP mapping standards defined in FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners (NFIP standards) and must be revisited. The panel is making this recommendation because the FEMA analyses do not comply with its Guidelines and Specifications in several key ways:

1. The proposed discharges were not compared to available flood-frequency data within the watershed and in nearby gaged watersheds.
2. Regression estimates on smaller watersheds and higher elevation watersheds were used for comparison even though their values were well outside the bounds of the equations. Although it may be justified in some cases to do so, FEMA did not even address this question.
3. Stage-discharge information potentially available for calibration and validation of the hydraulic models was not evaluated or used.
4. Sensitivity analyses of the hydraulic modeling were performed on several parameters, but not discharge, which was recognized as being highly variable. This, combined with a lack of any assessment of county flood history in comparison to the previously effective floodplain boundaries, renders the proposed boundaries somewhat arbitrary.
5. There was no corresponding sensitivity study or statement on the hydrologic models.
6. Entirely excluding one-dimensional stream channels in two-dimensional floodplain modeling reduces somewhat flood flow conveying capacity of the floodplain. A lack of any assessment and justification for the channel conveyance exclusion further renders the proposed base flood elevations and boundaries arbitrary.

In the rationale for the panel's findings, these points, and others are discussed in more detail. The panel also finds that the county data does not meet standards, thus the recommendation that the study should be revisited. In the panel's opinion, FEMA exhibited a bias to be conservative in its discharge estimates and floodplain extents while the community exhibited a bias to minimize impacts to landowners. The record shows discussion of a "blue ribbon committee" and a "hydrology working group." The record does not show these forums, or any other meetings/communications, were used to partner in arriving at the most appropriate analyses in compliance with the Guidelines and Specifications.

During its oral presentation to the panel, the county indicated that it is nearly completed with a restudy of Buckeye Creek that it plans to submit to FEMA. If it does so, this restudy could be an integral part of revisiting the subject flood study.

Rationale for Findings

A comparative memo prepared by FEMA summarizes the differences in proposed floodplains prepared by FEMA and the community for Buckeye Creek and Buckbrush Wash. The community did not present floodplain delineations for Johnson Lane Wash, Sunrise Pass Wash, and Airport Wash. The panel addressed several issues raised by the community, as well as issues identified by the panel in its review. In its analysis, the panel references the Guidelines and Specifications for Flood Hazard Mapping Partners (G&S) (FEMA, 2003). Because it was not available at the time of the flood study, the panel did not use the November 2009 version of Appendix C of the Guidelines and Specifications.

Hydrology

The FEMA study contractor, NHC, applied the HEC-HMS computer program as a rainfall-runoff modeling tool for generating hydrographs needed to perform hydrologic routing through the watershed subbasins and as inputs to the two dimensional hydraulic models. Within the HEC-HMS model, the Green-Ampt loss function was selected for infiltration, the Muskingum method was selected for hydrologic reach routing, and the NRCS (SCS) unit hydrograph was selected for rainfall runoff transformation. 3-hour "cloudburst" and 24-hour "frontal" storms were constructed from the NOAA-14 precipitation database. NHC stated that it could not calibrate the HEC-HMS model because of the lack of coincident streamflow and precipitation data for the study area. Rather, the models were "validated" by comparison with USGS regression equation peak flow estimates and HEC-HMS parameters were adjusted to reproduce the regression estimates to some degree. Several of the steps taken were criticized by the county and are discussed below.

Method Selection

Both FEMA and the county selected the HEC-HMS rainfall-runoff computer program for their hydrologic analyses. Although this is not a point of disagreement, discussion of this selection is a relevant prelude to the subsequent points of disagreement.

The G&S present a hierarchy of methods in the following preferred order: 1) frequency analysis of flow data at gaging stations, 2) USGS regression equations, and 3) rainfall-runoff modeling. The G&S requires that the chosen method be appropriate for the site and recognizes that in certain cases, such as this one, hydrographs are needed for some or all parts of the analyses. Relevant parts of the G&S are as follows:

> *"The Mapping Partner that is performing the hydrologic analysis shall apply frequency analysis of flow data at gaging stations, using procedures provided in Bulletin 17B (Interagency Committee on Water Data, 1982) wherever possible. When the systematic record at a gaging station is less than 50 years, the Mapping Partner that is performing the hydrologic analysis shall weight the results with estimates from other methods, such as USGS regression equations." (Section C.1.2.1)*
>
> *"The regression equations are to be applied only to streams having characteristic parameter values that are within the range of values of the gages used to develop the regression equations." (Section C.1.2.1)*

The preference for frequency analysis of gage data and regression equations is generally because they represent measured data with a statistical basis for evaluating the accuracy of the flow estimates through confidence limits and standard errors. In this case, the evaluation of both parties was that there were insufficient flow gage data to solely rely on frequency analysis. Both further concluded that the available regression equations had such large standard errors that they could not be the sole basis for hydrologic estimates. A further limit on the regression equations was that several of the basins in this study were either too small or at too low of an elevation for the regression equations to be applicable.

These conclusions left both parties with the rainfall-runoff alternative. The selected HEC-HMS computer program offers several different hydrologic modeling choices with many different input parameters required for each method. Proper choices are key to the effective application of the software. Furthermore, when used in a purely deterministic manner, as both parties did, the software provides no statistical measures of accuracy or confidence limits. This reality increases the importance of the modeler's skill as well as the need for effective calibration/validation of the model.

HEC-HMS Application

The county challenged several of FEMA's choices in the application of HEC-HMS. The four major criticisms related to the design storm, the unit hydrograph, the Muskingum routing parameters, and the exclusion of culverts.

Design Storm

Synthetic design storms were used by FEMA because of the lack of measured precipitation data in the study area as reported by FEMA. The county (MCL, 2008a) questioned the use of synthetic design storms. FEMA (NHC, 2005a) identified three precipitation gages, but neither FEMA nor the county produced or used data from these gages. Therefore, both opted to use a design storm, though there were differences in the selection of the rainfall depth, duration, temporal distribution, and spatial distribution. The FEMA G&S states the following:

> *"Where feasible, in coordination with Federal and State agencies, the Mapping Partner that is performing the hydrologic analysis shall select a reasonable rainfall distribution for the model to best simulate floodflows corresponding to a frequency analysis in accordance with the guidance of Bulletin 17B (Interagency Advisory Committee on Water Data, 1982)." (Section C.1.2.1)*

Both FEMA and the county used NOAA Atlas 14 (2004) for deriving design storm depths for given recurrence intervals. The atlas provides estimates spatially across large regions that extrapolate or interpolate rainfall estimates in areas where there is sparse rainfall gaging data. Storm depths obtained from the atlas are the result of spatial averaging in some areas and the effects of local physiographic factors in certain regions may not be adequately reflected. However, these data are reasonably current and the use of the atlas is common practice and is recommended by FEMA.

FEMA (NHC, 2005a) obtained rainfall depths from NOAA Atlas 14 for 5-minute to 24-hour durations corresponding to 2-, 10-, 50-, 100-, and 500-year recurrence intervals and used spatial analysis to determine the average precipitation over each basin for each duration and each recurrence interval. They analyzed both short duration and long duration events. Area reduction factors were employed for 6- and 24-hour durations from curves published in NOAA Atlas 2 and reduction factors for 12-hour duration were obtained by interpolation.

FEMA used EM 1110-2-1411 (USACE, 1965) criteria for distributing 6-hour precipitation into 5-minute intervals as per HEC-HMS guidelines. For computation of peak flows for watersheds less than 20 square miles, NHC used the centered 3-hour hyetograph in HEC-HMS. The county (MCL, 2008b) developed alternative temporal distributions including what they referred to as the "average NOAA 14 model rainfall" and the "mixed NOAA 14 model rainfall" with the rationale to better account for local conditions. The county argued that following US Army Corps of Engineers (USACE) guidelines may not be appropriate to simulate a 3-hour convective cloudburst storm at this location. ROA (2008) observed that – with loss rates dictated by the Green Ampt infiltration model with values taken from SSURGO - in their modeling of Buckbrush Wash and Sunrise Wash changing only the design storm temporal distribution resulted in changes in estimated peak flow between two and three orders of magnitude. The difference between the two estimates of design storms can have an appreciable effect on the flood hydrographs and flood elevations. The storm preferred by ROA, from a USACE study of Truckee Meadows, was not provided to the panel.

With regard to spatial distribution, the lack of precipitation gage data and relatively small watershed sizes (except for Buckeye Creek), justified the assumption that precipitation was uniformly distributed in a given basin according to the FEMA analyses. In the county study of Buckeye Creek (MCL, 2008b), the county disaggregated the rainfall depths using lower depths in the eastern, lower elevation subbasins and higher depths in the western, higher elevation subbasins. The assumption of uniform depth over a watershed is never strictly true, but is not an uncommon practice. FEMA and the county analyses presented alternative views of design storm composition. However, neither party supported their preferred approach with calibration/validation.

Unit Hydrograph

The county objected to the use of the NRCS (formerly SCS) unit hydrograph and the standard peaking factor of 484. The NRCS unit hydrograph is widely applied for floodplain studies and the shape of the unit hydrograph can be adjusted through the peaking factor to better adapt the shape to flatter or steeper watersheds than represented by the standard peaking factor. Typically smaller peaking factors can be used on flatter slopes and larger peaking factors on steeper slopes. Any adjustments to the peaking factor must be accompanied with other shape adjustments to insure that the volume under the unit hydrograph remains at one unit.

The county restudy of Buckeye Creek (MCL, 2008b) employed the Clark unit hydrograph in the HEC-HMS model arguing without background support or documentation that its shape is more applicable to the site and that it has more adjustable parameters. The Clark method employs a time-area diagram and a linear reservoir. If the parameters of the Clark method can be estimated accurately, then the Clark method may produce more accurate results. Arguably, by incorporating physiographic characteristics for computing the storage factor, such as length of main water course, length to the centroid, and slope, the Clark method will better represent the rainfall-runoff process. However, since no calibration/validation was conducted nor any comparison with the SCS unit hydrograph made, the results are merely different.

In the restudy of Buckbrush Wash (ROA, 2007) it was noted that a Los Angeles unit hydrograph was used in the 1999 floodplain study. No information on this unit hydrograph was provided to the panel.

Arguments can be made for or against any method, but the ultimate arbiter is calibration/validation and sensitivity analyses. Neither FEMA nor the county engaged in this critical activity.

Muskingum Routing

FEMA (NHC, 2005a) used Muskingum channel routing in the HEC-HMS modeling. Muskingum routing is governed by two parameters, K and x, where K represents the time of travel of a flood wave through the reach and x is a weighting parameter between inflows and outflows to the reach. K is directly computed based on the site conditions. Neither FEMA nor the county provided the panel with the data for computing K values so the panel could not evaluate which may be more technically correct. The parameter, x, cannot be computed directly from measurable data and is often used in calibration. Although FEMA and the county used different x values, the county analysis showed insignificant difference in flow values (MCL, 2008a).

The panel had some concerns with the use of the Muskingum routing at this site. This technique is not recommended when significant overbank flows are present as is usually the case in flood studies in medium to mildly sloped watersheds. For large rivers the Muskingum routing is acceptable but for small creeks, its usefulness is doubtful. Nevertheless, choice of method was not an issue between the parties. Differences in x values appear to be inconsequential and differences in deriving the K values were not documented for the panel.

Culvert Representation

Based on the information provided to the panel, FEMA did not consider the storage routing at culverts and potential flow attenuation caused by temporary storage behind the embankments. This omission was criticized by the county (MCL, 2008a), but it is not apparent that the county included any culverts in the Buckeye Creek restudy (MCL, 2008b). In many circumstances culverts, and their associated upstream storage, do make a significant difference in the hydrologic routing, but neither party assessed the importance of culverts in the routing.

Calibration/Validation

One of the concerns raised by the county was the use of regional regression equations, with standard errors approaching 100 percent, as a reference point for “calibrating” the HEC-HMS rainfall-runoff model. This raises a larger issue of the effective calibration and validation of the hydrologic modeling. FEMA’s G&S addresses this topic in several places:

> *“Calculated discharges for a Flood Map Project (including those determined by regression equations and/or computer models) must be compared to available floodflow-frequency data.” (Section 1.4.2.4)*
>
> *“The Mapping Partner that is performing the hydrologic analysis shall compare the proposed flood discharges to all available floodflow-frequency data that exist for the study area to ensure compatibility.” (Section C.1.2.1)*
>
> *“The Mapping Partner that is performing the hydrologic analysis may calibrate the rainfall-runoff model against the various flood discharges of a frequency analysis. Regardless of whether models*

> *have been calibrated against historical events, further calibration may be required to produce floodflows from the 10-percent-annual-chance, 2-percent-annual-chance, 1-percent-annual-chance, and 0.2-percent-annual-chance rainfall that are comparable to the floodflows from the frequency analysis, if records are available. If reasonable matches cannot be reached by maintaining calibration parameters within acceptable ranges, then the Mapping Partner that is performing the hydrologic analysis shall review the model methodology and its application to the watershed." (Section C.1.2.1)*
>
> *"The reviewing Mapping Partner shall compare the proposed 1-percent-annual-chance flood discharges from the rainfall-runoff model to the flood discharges from USGS regional regression equations (if they are applicable) and to flood discharges at gaging stations in the vicinity."(Section C.2.3)*
>
> *"Even if the criteria for flood discharge reasonableness are satisfied, a review of the rainfall-runoff model is advisable to determine that the model was applied appropriately. Recommendations to use a reasonable flood discharge in the hydraulic model cannot be made if the calculation of the flood discharges was incorrect and yielded reasonable flood discharges only by chance. Such a study is subject to appeal or protest on the basis of being scientifically or technically incorrect."(Section C.2.3)*

It is clear from these statements that FEMA recognizes the importance of maximizing the use of existing data and information in the development of discharge estimates. This includes investigation of event frequencies other than the one-percent flood. This emphasis on calibration and comparison also suggests that the objective is to derive the best estimate of the base flood discharge, not a conservative estimate of the base flood discharge.

It appears that FEMA's objective may have been to be conservative with the hydrology. Thomas (2004b) stated that his objective in review of the discharges was to exceed the regression estimates and maximum observed discharge values. It is not the panel's understanding that being conservative is consistent with the actuarial nature of the flood insurance program.

Flood Frequency Data and Regional Regression Equations for Peak Flow Validation

Calibration and verification of rainfall-runoff models, such as HEC-HMS, is ideally performed with several sets of observed rainfall and discharge event data. Other options are to compare with flood-frequency data derived from gage data and regression equations. The goal is to provide an assessment of the "reasonableness" of the proposed 1-percent-annual-chance flood discharges and, if necessary, to suggest alternative methods that may provide more reasonable flood discharges. Flood discharges may be determined directly from gage data in areas where stream gages are located, or may be estimated based on data from gages in nearby areas having similar characteristics. Appropriate transfer function techniques should be utilized for establishing flood discharges at the un-gaged location, ensuring that the selected transfer technique considers the difference in the drainage areas at the gaged and un-gaged sites.

Neither FEMA nor the county identified event-based rainfall and discharge data for model calibration. Therefore, the rainfall-runoff model was constructed without calibration and compared with other sources and adjusted if needed. This comparison/adjustment process is what is being referred to in the FEMA study as "calibration."

A USGS gaging station within the study area on Buckeye Creek at Minden, NV (10309070) was identified by FEMA (NHC, 2005a), but was not used in any way. Nor was it used by the county. In addition, there are several nearby gages that appear to be potentially representative of site conditions that were also not used by either party. Gages at Bryant Creek (10308800), East Fork Carson River (10309000), Clear Creek (10310500), and Brunswick Canyon (10311450) all had sufficient record lengths to be included in the applicable USGS regression study (Thomas, et al., 1997) and each was still in operation over ten years later at the time of the FEMA hydrologic study. For FEMA to have failed to use this flood-frequency data is technically incorrect, inconsistent with FEMA guidelines, and insufficient for sound engineering practice.

It is appropriate to also examine the regression equations. FEMA (NHC, 2005a) assessed the use of the regression equations developed by Thomas, et al. (1997) as well as those by Thomas and Sexton (1997), and decided to use the first set of equations. Although NHC recognized that these equations were subject to large uncertainty, they used them for estimating peak flows nonetheless. The issue of large standard error inherent to these equations was brought out by the county (MCL, 2008a). In Horvath (2011) it was indicated that the regression equations may not be appropriate for the study watersheds for two reasons. First, the major source of Douglas County flooding, the Pine Nut Mountains, receive significantly less precipitation than the majority of watersheds represented in the stream gage data employed in the regional regression equations. Second, it was argued that it is inappropriate to use equations with such large standard errors. No documentation of the first claim was provided. With respect to the second point, all would agree that the standard errors are large, which would limit their usefulness for comparison. In fact, the large standard error for the 1 percent frequency equation is the equivalent to a gage record length of 3.8 years.

In this particular situation the standard error of prediction for the USGS regression equations were reported as high as nearly 100 percent. The factors that may cause large standard errors are the result of both the combined impact of large variability and short flood records and the sparse gage station network, thereby making regionalizing of flood frequency predictions more difficult. These conditions all exist in the western portion of the U.S. and conversely, smaller standard errors are generally found in the eastern U.S., where longer periods of records, denser sampling networks, more uniform hydrology and climate, and less variability among station events exist. The modeling error is that portion of the error that cannot be reduced by additional data collection. The sampling error can be reduced by operating the stations longer, by adding sampling stations to the network, or by a combination of both. The primary goal and objective has to be to minimize inherent parameter estimation errors using all available measurements. That is precisely why use of the gage records discussed above is critical. Nevertheless, the proper use of the equations is not outside the bounds of the G&S.

However, several of the basins to which the regression equations were applied are smaller than the applicable basin area range and at lower elevations than the applicable elevation range. Although there are times when reasonable extrapolation is acceptable practice, it is counter to the G&S as stated earlier (C.1.2.1) and is issue is not addressed by FEMA.

Finally, proper calibration makes use of multiple events so that the "right answer" is less likely to be determined from adjusting the wrong parameter. Rather than calibrating to a single 100-year event, it would have been technically correct to calibrate to the 10-year and 500-year events and "validate" to the 100-year event. This would increase the confidence that the rainfall distributions and rainfall losses are reasonably represented.

Calibration using Doppler Rainfall Data

Because of its widespread use, the rain gage has become the standard for measuring surface rainfall. Although gage accuracy is usually high, the main problem is that the measurement is essentially at a point and data are sparse compared to a Doppler radar (or NEXRAD) sample volume that yields rainfall over a much larger area. Radar measurement of rainfall (R) are correlated to radar instrument power return (Z), which is expressed as a radar instrument reflectivity factor converted to a radar estimate of rain rate, through an empirical Z-R relationship. This conversion relationship and the inability in operational settings to directly measure rainfall impedes exact specification of precipitation accumulation. Caution should be exercised using Doppler radar rainfall measurement alone as there are many known sources of random and systematic errors causing precipitation estimation errors resulting in underestimation or overestimation of more than 200 percent. Co-estimation optimization techniques for spatial interpolation which combine rain gage and radar measurements of precipitation are known to offer considerable improvements and should be utilized if the goal is to exploit the advantages of vast spatial coverage offered by Doppler radar rainfall measurements. Neither FEMA nor the county identified or used Doppler rainfall data for calibration or verification.

Reconciliation with effective discharges

> *"the Mapping Partner that is performing the hydrologic analysis shall provide detailed documentation of the changes that have been addressed in the restudy and why flood discharges developed for the restudy are more accurate than those developed for the effective FIS. If the reason for the restudy is an improved method, the Mapping Partner that is performing the hydrologic analysis shall provide documentation as to why the alternative method is superior and shall obtain RPO approval to use the improved method." (Section C.1.2)*

The "effective" discharges are those discharges underlying the floodplain study that determined the regulatory floodplain that is currently in effect. At the time of the analyses that are the subject of this report, the effective discharges were based on a 1999 floodplain study. FEMA (NHC, 2005a) documented the numeric values of the effective discharges, but did not make any attempt to explain the differences between them and the proposed discharges. The effective discharges were said to be based on an "analysis of extreme events." It is not consistent with good practice and FEMA guidelines to ignore the effective hydrology.

The county (MCL, 2008a) performed a sensitivity analysis comparing the use of NOAA Atlas 2 rainfall depths available at the time of the effective study and NOAA Atlas 14 rainfall depths. For Buckeye Creek, MCL reported a 100-year peak discharge of 6870 cfs for the latter and 2878 for the former while making no other modeling changes.

Additional Observations

The following topics were not raised by either party, but were discussed by the panel.

Rain-on-snow events

In this general area it is not uncommon to observe flood peaks in mountainous watersheds due to the combination of rainfall and snowmelt. The probability of occurrence of a flood peak due to the combination of rain and snowmelt does not follow the same distribution as that due to rain alone or snowmelt alone. Analyses by USGS-Nevada (Nevada Water Science Center, 2012) show a history of rain-on-snow floods in the vicinity, and they are evident in the local records. Gaged data and regression estimates derived from gaged data effectively include rainfall-driven and rain-on-snow driven flood events. Although HEC-HMS is capable of modeling rain-on-snow events, these options were neither used nor discussed and only rain driven events were considered in the rainfall-runoff modeling by both FEMA and the county. Validation and calibration of the snowmelt modeling in HEC-HMS would be difficult, if not impossible, with the limited data available for such purposes.

Transmission Losses

The hydrologic routing analyses performed by both FEMA and the county assumed no transmission losses within the channels and over land. Transmission losses are not uncommon in arid areas and on alluvial fans. Neither FEMA nor the county provided information that this issue was adequately considered.

Hydraulics

The FEMA study contractor used MIKE 21 for modeling much of the watershed, including the alluvial fan areas. HEC-RAS was used in limited channelized locations.

Mass balance errors and convergence in MIKE 21

FEMA (NHC, 2005b) evaluated the mass balance in MIKE 21 modeling at several time intervals and compared the cumulative volume of water input into the model from all sources and volume of water accumulated by the model. It was reported that each hydraulic model tended to generate water mass, with the exception of Johnson Lane Wash model, during the simulation of 100-year flood event. It was stated that the mass balance errors were due to computational errors though the report was not specific on the nature of those errors. It was reported that errors translated into no more than 0.07 foot errors in flow depth, though they continued to increase with simulation time. Mass-balance acceptability is generally a matter of professional judgment and the panel is not aware of any quantitative FEMA standards on this issue.

Another point worth noting is that no “sinks” were incorporated in the MIKE 21 modeling by NHC. The implication is that all the flow that is input to the model flows to the downstream boundaries where it builds up throughout the simulation. This may lead to higher water elevations.

Exclusion of 1-D channels

In hydraulic simulation, the neglect of 1-D channels would change the flow pattern within the watershed. Intuitively, it would seem that this neglect would lead to greater flow distribution and depths in the floodplain. This is observed by the county in Buckbrush Wash (ROA, 2008). Thus, NHC's estimates of inundation and floodplain boundaries might be overestimated because they did not include 1-D channels in their 2-D MIKE 21 modeling. In the 2009 version of the G&S (section C.3.3.3) it is stated that models with the capability for 1-D channel modeling within the 2-D flows should be used for floodplains with clearly defined channel systems. If the study would be completed today, it would appear that the modeling was inconsistent with this guidance. However, this guidance was not included in the 2003 G&S in effect at the time of the study.

Use of Uniform Roughness Coefficients in 1D and 2D Modeling

The use of uniform roughness is not uncommon in hydraulic modeling. Both FEMA (NHC, 2005b) and the county (MCL, 2008b) used uniform roughness values, although the former used a Manning's n value of 0.07 and the latter a value of 0.035. Both values can be justified. It can be stated that neither violated the FEMA guidelines. Spatial information on vegetation, slope, flow direction, channels, culverts, overland flow plains, etc. is important to determine the type of hydraulic model to be used but this information is lacking in the reporting.

Culvert Representation

FEMA (NHC, 2005b) did not include culverts in their hydraulic simulations and, based on their sensitivity analysis, reasoned that their inclusion did not make a significant difference to the flood zone designations. However, in Buckeye Creek, reported depth changes up to 6.8 ft with a more typical range of 0.5 to 1 ft do not seem insignificant to this panel. NHC states that changes to estimated floodplain extents is not significant, but does not quantify the potential change. This is unfortunate given the county's contention that the proposed floodplain is over estimated in the NHC study.

However, the county restudy of Buckeye Creek (MCL, 2008b) did not include these culverts either meaning the county did not offer alternative data for the panel to consider. Although in many circumstances culverts, and their associated upstream storage, do make a significant difference in hydraulic modeling, neither FEMA nor the county used culverts in their analyses leading the panel to conclude that this approach is acceptable in this case.

Hydraulic Model Calibration/Validation

One of the concerns raised by the county was the increase in floodplain size and the economic effect on the county of this increase over the effective study. Their claim was that this increase is not justified and is not supported by observations of county staff and landowners regarding flood history in the county. This raises a larger issue of the effective calibration and validation of the hydraulic modeling. FEMA's G&S addresses this topic in several places:

> *"Models must be calibrated to measured profiles, estimated profiles, or reliable high-water marks from observed flood events whenever possible." (Section 1.4.2.4)*

> *"The reviewing Mapping Partner shall compare the proposed regression estimates to gaging station estimates in nearby watersheds having similar characteristics to those of the studied streams. The reviewing Mapping Partner may obtain estimates of 1-percent-annual-chance flood discharges at nearby gaging stations from published USGS regional flood reports if the frequency curves were published in the last 10 years and if no major floods have occurred in the intervening time. Otherwise, floodflow-frequency estimates for the gaging stations are to be updated in accordance with Bulletin 17B (Interagency Advisory Committee on Water Data, 1982)." (Section C.2.2)*
>
> *"Wherever possible, the Mapping Partner that is performing the hydraulic analysis shall calibrate hydraulic models using measured profiles, reliable high-water marks, or reliable stage information at stream gages for past floods. Models must match known high-water marks within 0.5 foot." (Section C.3.1)*
>
> *"Before preparing work maps, the Mapping Partner that is performing the hydraulic analysis shall reconcile the 1-percent-annual-chance Flood Profile proposed for the Flood Map Project with all available published or unpublished information." (Section C.3.1)*
>
> *"Where necessary, and with FEMA approval, the reviewing Mapping Partner shall conduct detailed sensitivity tests to verify questionable modeling parameters and approaches. The reviewing Mapping Partner shall ensure that models have been calibrated against all available high-water marks and/or post-flood hazard verification data, if included in the scope of the hydraulic analysis. All concerns shall be resolved by coordination between FEMA and the community, the Mapping Partner, the model developer (if necessary), the revision requester, or the appellant." (Section C.5.2.2)*

The FEMA hydraulic modeling (NHC, 2005b) with MIKE 21 and HEC-RAS was not calibrated to any observed data or supported by flood history information. Neither FEMA nor the county identified high water marks or equivalent field data for calibration. However, this assessment did not address USGS stage and/or discharge available at Buckeye Creek at East Valley Road (10309075), Johnson Wash at Fremont Drive (1030909087), and possibly other sites. FEMA (Thomas, 2004) was aware of the Johnson Wash gage during the hydrologic reviews. Although stage information as reported online is incomplete, a review of the available data and the basis for the discharge estimates should have been assessed for potential use in calibration.

To address the lack of identified calibration data, sensitivity analyses were performed on several parameters and none were concluded to have a significant effect on the floodplain. However, no sensitivity analysis was performed by FEMA on changes in discharge. Such a sensitivity analysis would have been appropriate to enable comparisons with the effective floodplain and local observations. Omission of this activity is not acceptable practice.

Other Issues

This section provides comments on related topics to the subject floodplain study and delineation that are not strictly classified as related to hydrology or hydraulics.

Accuracy of LiDAR mapping

The county (ROA, 2007) reported that there was a difference of about 0.8 foot between datum-adjusted LiDAR elevations and field surveyed elevations and therefore LiDAR-based topography needs to be adjusted accordingly. They (ROA, 2008) also provided comments that map accuracy of some of the revised map panels did not meet FEMA standards. In the appeal resolution letter (April 2, 2009) FEMA provided a response to this comment. The panel did not receive any information as to whether either party believes this remains an issue.

FEMA Response to County Comments

FEMA and the county are partners in managing flood risks in Douglas County. Among several aspects of this partnership is the ability of the county to provide inputs on the hydrology and hydraulic study needs, comments on study methods and results, and the opportunity for appeals and protests. Implied in this relationship is that both parties respect the process. The G&S states the following:

> *"The sole basis of an appeal, as indicated in Section 67.6 of the NFIP regulations, is the possession of knowledge or information indicating that the BFEs proposed by FEMA are scientifically or technically incorrect. The proposed BFEs are considered scientifically incorrect if the methodology or assumptions used in the determination of the BFEs is inappropriate or incorrect. The BFEs are considered technically incorrect if the BFEs were based on insufficient or poor quality data, analysis contains mathematical or measurement errors, or physical changes have occurred in floodplain." (Section 1.5.2.3)*
>
> *"In accordance with Section 67.8 of the NFIP regulations, FEMA shall "review and fully consider any technical or scientific data submitted by the community that tend to negate or contradict the information upon which the proposed determination is based." FEMA also shall consider all technical or scientific data submitted in support of a protest." (Section 1.5.2.3)*

The panel was not provided with information on the issues discussed or resulting resolutions at the meeting between the county, the Nevada Division of Water Resources, and NHC on 1/20/04, the meeting between NHC and the county on 10/28/06, the coordination meeting between FEMA and the county on 3/5/07, and the technical coordination meeting between FEMA and the county on 1/8/09. The panel was provided with minutes from a meeting between FEMA and the county on 8/4/09 and comments and responses in FEMA's 4/2/09 letter to the county.

In the comments and responses, FEMA is generally dismissive of the County comments, except those with mathematical or measurement errors. Those comments regarding methodology or assumptions, as well as insufficient or poor data were typically responded to by saying the FEMA analysis is acceptable and further discussion may be conducted in a hydrology working group led by Douglas County. Little, if any data or technical/ scientific rationale is provided. This approach does not appear consistent with FEMA's responsibility to review and fully consider comments. Furthermore, in the minutes of the 8/4/09 meeting there appeared to be a commitment from both parties to participate in a "blue ribbon committee" to resolve remaining technical questions. (In its 4/2/09 letter to the county, FEMA also mentioned a "hydrology working group" to further discuss issues.) From the record in the panel's possession, there does not seem to have been any follow-up on these committees, perhaps because timely resolutions were not possible at that late date.

Additional Recommendations and Comments

In addition to discussion above, the panel offers the following comments and recommendations:

1. The judgment of scientifically or technically correct is informed by the G&S and sound engineering practices. Since there is no universal definition of the latter, individual experience is needed to make this determination.
2. Limiting the panel to information initially submitted may make it difficult to fully assess scientific or technical correctness. The panel should have more latitude for requesting information and data it deems critical to resolving the dispute.
3. The question of which of two analyses or methods is more scientifically or technically correct should be separated from the question of whether the data negate or contradict FEMA data. To answer the second question, a parallel study must be completed by the community. The community may not have the resources or expertise to accomplish this, but that shouldn't negate the possibility that important points have been identified by the community.
4. FEMA G&S should address when to consider rain-on-snow hydrology, land use condition changes, and transmission losses in rainfall-runoff modeling.
5. Flood risk determination and development of flood hazard boundary maps based solely on heuristic hydrologic and hydraulic computations accompanied by complete or partial disregard of actual historical measurements and information should be accompanied by a heightened emphasis on careful quality assurance and control (QA & QC) of model data entry and development and documentation of quality assurance process. The G&S should include and emphasize model development QA & QC process and documentation.
6. The G&S should specify statements of model output error and sensitivity appropriate for selected inputs.
7. The County may wish to consider development of a local network of volunteer-cooperator rain gages.

References

FEMA, 2003. "Guidelines and Specifications for Flood Hazard Mapping Partners."

Horvath, Mary, 2011. "Douglas County FIS Review, Tech Memo #2, Assessment of FIS," memo to Mahmood Azad, Douglas County Community Development – Engineering, May 3.

Nevada Water Science Center, 2012. Retrieved from http://nevada.usgs.gov/crfld/index.htm.

NOAA Atlas 14, 2004. National Weather Service.

Northwest Hydraulic Consultants (NHC), 2005a. "Hydrology Report for the Douglas County FIS," April.

Northwest Hydraulic Consultants (NHC), 2005b. "Hydraulic Analyses, Douglas County, Nevada," April.

Manhard Consulting Ltd (MCL), 2008a. "Peer review of the 2008 Preliminary Flood Insurance Study, Douglas County, NV," July.

Manhard Consulting Ltd (MCL), 2008b. "Buckeye Creek Watershed Restudy" September.

RO Anderson Engineering (ROA), 2007. “Detailed Flood Hydraulics Study of Buckbrush Wash to Support Conditional Letter of Map Revision,” August.

RO Anderson Engineering (ROA), 2008. “Technical Review of Provisional Flood Insurance Study and Flood Insurance Rate Maps of Douglas County, NV,” August.

Thomas, Blakemore E. H.W. Hjalmarson, and S.D. Waltemeyer (1997). “Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States,” USGS Water-Supply Paper 2433.

Thomas, Wilbert and Patti Sexton, 1997. “Regionalization of Flood Flows in Eastern Sierras Region of Nevada and California,” Proceedings of the 21st Annual Conference of the Association of State Floodplain Managers,” Little Rock Arkansas, April 28- May 2.

Thomas, Will, 2004a. “Douglas County, NV Hydrology Review,” email to Les Sakumoto, June 19.

Thomas, Will, 2004b. “Douglas County Hydrology Revisions,” email to Joey Howard, October 8.

USACE, 1965. “Standard Project Flood Determinations,” EM 1110-2-1411, March.