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David Baird
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Re: Independent Engineering Review of Neffs Creek Flood Hazard Assessment TSDN

Dear David:

The purpose of this memorandum is to discuss the independent review findings for the engineering data, methodology, calculations, and determinations from the Neffs Creek Flood Hazard Assessment Technical Support Data Notebook prepared by JE Fuller, March 2016. The primary purpose for the review is to determine if the study followed the FEMA Guidance for Flood Risk Analysis and Mapping Alluvial Fans.

Study Overview

The Neffs Creek alluvial fan study was prepared for FEMA as part of the Risk Mapping, Assessment, and Planning (Risk MAP) program to provide residents of the Olympus Cove area with an understanding of the flood risk potential resulting from the Neffs Creek alluvial fan formation. The study was completed through a three-stage approach to evaluate the geological characteristics of the alluvial fan formation, make determinations regarding its extent and characteristics, and perform hydraulic analysis to predict the flood risk potential. The three stages are identified in the study as:

- Stage 1: Recognizing and Characterizing Piedmont Landforms
- Stage 2: Defining Active vs Inactive alluvial Fan Flooding
- Stage 3: Defining the 100-Year Floodplain

The independent technical review will follow the three-stage approach and provide an overview of each phase followed by a discussion and comments regarding findings. Considerations and Recommendations will be provided as part of the summary and conclusion of the technical review.

Stage 1: Recognizing and Characterizing Piedmont Landforms

The objective of stage one is to determine if the Olympus Cove area can be classified as an alluvial fan landform by evaluating the sediment composition, stream flow path morphology, vegetation, location, and extent. Each of these items was evaluated using information available from previous studies, NRCS soil maps, USGS geological maps, and field observations.

Review Discussion

Based on the FEMA guidelines and the available data collected and presented in the JE Fuller report, stage one of the delineation process was followed properly. While the soils mapping interpretations would limit the alluvial fan to a smaller area, the surficial geologic mapping provides further insight for a larger alluvial fan area. The evidence is clear that the

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Olympus Cove area can be classified as an alluvial fan. The stage one data and findings are consistent with FEMA guidance and standards.

Stage 2: Defining Active vs Inactive Alluvial Fan Flooding

Defining active and inactive areas of the alluvial fan is done by evaluating the depositions, erosion, and unstable flow path potential on the alluvial fan. The determinations focus on the age of the fan formation, composition of deposits and evidence of flooding and flow path uncertainty over the past 1000 years.

Review Discussion

The USGS and NRCS soil maps suggest that the most recent alluvial fan depositions occurred during the late-Holocene period which ranges from 5,000 years ago to current day. The age of the alluvial fan deposits and the evidence of flow path uncertainty within historical photos clearly defines the alluvial fan as active. There is evidence in the areal images from 1930s and1950s that flow path uncertainty dominated the morphology characteristics of the alluvial fan and much of the fan shows evidence of avulsions with braided channels.

Some minor adjustments to the active areas defined in the JE Fuller study could be made based on the soils mapping, but none of those adjustments would impact the actual areas included in the floodplain. The evidence suggest that the alluvial fan is active, and the flood risk analysis should consider the possibility of channel instability and flow path uncertainty. JE Fuller's determination of active alluvial fan follows FEMA guidance and standards for stage two.

Stage 3: Defining the 100-Year Floodplain

The 100-year floodplain analysis is used to delineate the risk of flooding on the active alluvial fan landform. The primary components of analysis comprise of the Hydrology and Hydraulics.

Hydrology

The hydrologic analysis utilized in the JE Fuller study was developed from the Salt Lake County Neffs Canyon Creek Master Plan completed by Hansen Allen and Luce in 2007. The detailed hydrologic analysis uses the NRCS TR-55 methodology supplemented with site specific analyses and reduction factors. The analysis results in a 1-percent annual chance discharge of 300 cubic feet per second at the canyon mouth. The rainfall runoff model uses mathematical calculations to determine the amount of runoff that will result from a rainfall event of a specific magnitude. Rainfall runoff models are generally calibrated to known runoff events from stream gages and USGS regional regression equations to help improve the accuracy of the model. USGS regional regression equations are developed using many stream gage stations throughout the state to predict runoff probability for stream that do not have a gaging station.

Review Discussion

The hydrologic rainfall runoff analysis was compared to the FEMA guidance and standards for General Hydrologic Considerations and Hydrology: Rainfall-Runoff Analysis. The hydrology guidance and standards section 7.1 states,

> "The Mapping Partner reviewing hydrologic analyses based on rainfall-runoff models **must compare the proposed base flood discharges to the flood discharges from USGS regional regression equations (if applicable); to flood discharges at gaging stations in the vicinity of the study; to the effective discharges; and to other hydrologic estimates as appropriate**. If the rainfall-runoff model was calibrated to discharge-frequency relations (stream gages and/or regional regression equations), most of the hydrologic review has been completed. If not, the reviewing Mapping Partner must plot the flood discharge estimates from these sources against drainage areas on logarithmic paper to determine if the proposed base flood discharges are reasonable. The proposed base flood discharges from the rainfall-runoff model are considered reasonable if they are generally within one standard error (68-percent confidence interval) of the regression and gaging station estimates. Differences between the proposed and effective discharges must be documented in the hydrology report and an explanation given as to why they are different. If the proposed discharges are determined to be unreasonable, the model parameters should be reviewed to determine if they are within the range of engineering practice. The model parameters should either be revised to conform to engineering practice, or their values justified."

The project study does not discuss the comparison of the peak flow rate (300 cfs) from the rainfall runoff model to the USGS regional regression equations or adjacent gage stations. CRS Engineers prepared a comparison of the peak flow rates with adjacent gages using Bulletin 17C methodology prescribed in the FEMA guidance and standards. CRS Engineers also compared the flows to the USGS regional regression equations as outlined in USGS SIR 2007-5158. The result of the CRS analysis show that the regression equations and nearby gaging stations do not provide a good comparison with the peak flow determined in the rainfall runoff model. FEMA did not provide justification for the flow rate discrepancies; however, some portion of these discrepancies can be attributed to watershed slope. The Neffs Canyon watershed is very steep and thus will produce higher peak discharge events than watersheds that have more mild canyon slopes.

Table 1: Peak Discharge Comparison

Stream Name	Location	Watershed Area (mi2)	Method	Years of Record	100-year Peak Discharge (cfs)	Low Confidence Limit (0.16) (cfs)	High Confidence Limit (0.84) (cfs)
Neffs Creek	Canyon Mouth	4.2	Rainfall Runoff (HAL Study)	N/A	300	Undetermined	Undetermined
Neffs Creek	Canyon Mouth	3.67	Regression Equations (StreamStats)	N/A	107	54	161
Mill Creek	Canyon Mouth	21.7	Stream Gage Bulletin 17C	1899 – Current (107 Record Peaks)	150	134	171
Mill Creek	Canyon Mouth	21.7	Regression Equations (USGS SIR 2007-5158)	63	143	73	214
Emigration Creek	Canyon Mouth	18.4	Stream Gage Bulletin 17C	1902 – Current (92 Record Peaks)	160	135	202
Emigration Creek	Canyon Mouth	18.4	Regression Equations (USGS SIR 2007-5158)	57	132	66	198
Red Butte Creek	Red Butte Reservoir, Fort Douglas	7.25	Stream Gage Bulletin 17C	1964 – 2019 (56 Record Peaks)	114	90	157
Red Butte Creek	Red Butte Reservoir, Fort Douglas	7.25	Regression Equations (USGS SIR 2007-5158)	42	113	57	170

The rainfall storm distribution used in the project hydrology study by Hansen Allen and Luce (HAL) is a proprietary storm distribution that was developed by Vaughn Hansen and Associates in 1985. Vaughn Hansen later became one of the founders of HAL. The 100-yr 24-hr storm distribution used in the analysis should not be confused with the Farmer-Fletcher distribution, which was based on 10-years of rainfall data from 1960-1970 and developed a 1-hour, 2-yr and 10-yr storm distribution. The controlling storm distribution for the 100-yr 24-hour event was developed by HAL using their company proprietary storm distribution. The HAL storm distribution from 1985 is cited in the text of the document as (VHA, 1985), however, there is no documentation in the references sections for the actual publication citation. FEMA guidance and standards for storm distributions states,

> "The choice of temporal storm distribution must be fully documented. If the source of the distribution is not a federal, state, or regional agency, the documentation must include a detailed description of the derivation of the distribution, including sources of data and the means of fitting those data to a particular distribution."

Documentation of the 100-yr 24-hour storm distribution is not provided in the project study, and the distribution was not developed by a federal, state, or regional agency. Additionally, the HAL distribution was not used for the remainder of the studies developed as part of the Salt Lake County Risk MAP project. The distribution used on the remainder of the studies in Salt Lake County was the NOAA Atlas 14 Temporal Storm Distribution. As part of the Salt Lake County Risk MAP project FEMA studied Midas, Bingham, and Rose creek that are located on the west side of Salt Lake County. FEMA did not approve the Southwest Canal and Creek Study as hydrology documentation for the west creeks, knowing it used a similar distribution as is being accepted in the HAL Study. There is inconsistency between what FEMA approved for Neffs Creek and what was approved for the other streams in the Risk MAP Study.

CRS Engineers obtained a copy of the HAL hydrologic rainfall runoff model developed in the USACE HEC-HMS software and revised the storm distribution to determine the impacts of the distribution on the model results. The distribution used for this comparison was the NOAA Atlas 14 Temporal Storm Distribution with a 24-hour duration, second quartile, and 50% probability. This distribution is interpolated to match the model calculation time step of 3 minute and input into the model for the upper, middle, and lower basins for comparison at the canyon mouth. The storm distribution was the only parameter that was revised in the model which resulted in a decrease of 30 cfs with a peak flow rate of 270 cfs.

CRS Engineers also compared the peak discharge using the SCS Type II distribution and found that the peak discharge at the canyon mouth increased 200 cfs to a peak discharge of 500 cfs. The comparisons of rainfall distribution shows that the HAL distribution used in the study compares well with the NOAA Atlas 14 rainfall distribution and suggests that the rainfall distribution used can be validated by distributions developed by federal agencies.

Hydraulics

Hydraulic modeling is used to predict how the peak flow rate will descend from the apex of the fan downstream to the terminal point of the model which was selected as Wasatch Blvd. A 2-dimensional (2-D) hydraulic model was used to develop the depths and velocities of the flood event over the alluvial fan surface. Seven individual hydraulic scenarios were evaluated to determine the maximum flood depth and velocity over the alluvial fan and simulate the flow path uncertainty. The composite mapping was produced by compiling the maximum depths and velocities into one dataset.

Review Discussion

The 2-D hydraulic model developed for Neffs alluvial fan was compared to the FEMA guidance and standards for 2-D modeling and alluvial fan hydraulics. The study report steps through each of the parameters that were developed for the 2-D hydraulic modeling scenarios. This review found consistency between industry standard practice and the parameters that were developed for control of the model simulations.

FEMA allows for composite methodology to be used in alluvial fan hydraulic modeling. The composite study simulates active alluvial fan flow path changes by adding levees that divert flow down various flow paths. The location, length, and direction of these levees was developed based on engineering judgement and know bifurcation location based on aerial imagery and topography. An evaluation of these levee diversion locations was done through a site visit to look at the potential for flow path uncertainty at each location. Additionally, the potential for debris accumulation at each location was evaluated to determine if the scenarios could realistically occur during the 100-yr flood event.

The study indicates that 33,800 cubic yards of debris will be produced during this discharge event which will cause major avulsions and flow path uncertainty. Based on the quantity of material it seems feasible for the channels and flow paths to be cutoff and re-directed as modeled in the hydraulic scenarios. The engineering judgement for placement of the debris dams seems to be applied in a consistent manner to direct flow down known channel bifurcations to mimic what will happen in a large debris flow event.

The floodplain mapping produced by the study is a compilation of maximum flow and velocities. Although this approach is conservative it provides a realistic representation of the risk for flooding down each of the historic flow paths. The depth and velocity maximums are consistent with FEMA guidance and standards and were developed from the composite study simulations.

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Conclusions and Recommendations

The Neff's Creek alluvial fan independent review looked at each component of the study and compared them to the FEMA guidance and standards. The three-stage approach used by the study is in accordance with FEMA guidance and standards. The only deviations from standard found involved parameters used in the hydrologic study. Modifications to the hydrology for the study to bring it into conformance with FEMA guidelines would result in lower flow rates being modeled over the alluvial fan. The lower flow rates may result in a smaller flood zone and possibly reduce the number of houses that are in the flood zone, but it will not revise the designations of the flood hazard Zone AO and have the same restrictions.

Recommendations

CRS Engineers recommends that the hydrologic deviations from FEMA standard be provided to FEMA for review and comment to determine if they warrant an official appeal. The following questions should be asked to FEMA for a response.

1. The peak discharge comparison between the FEMA study, USGS regional regression, and stream gages shows that the determined flows do not fall within the confidence limits required in the FEMA guidance. Would FEMA accept a flow rate of 100 cfs based on calibration of the Hansen Allen and Luce hydrologic model?
2. Will FEMA provide documentation of their review of the hydrologic analysis that supports compliance with all FEMA guidance and standards?
3. The storm distribution used from the hydrologic study was not developed from a federal, state, or local agency. Will FEMA recommend a storm distribution that complies with FEMA guidance and is most appropriate for the Neffs Creek watershed?
4. Do the deviations from FEMA hydrology guidance and standards warrant an official community appeal?

FEMA may provide additional data that supports their determinations for the hydrology and provide clarification for the deviations.

A formal appeal to FEMA must be submitted within the 90-day appeal period which began on March 11^{th}. The cost for producing a formal appeal would be equal to the cost for producing a letter of map revision (LOMR). CRS Engineers recommends making improvements on the alluvial fan including a debris basin, channel improvements, and culvert improvements. These improvements will help minimize the flood zone by providing capacity for the 100-year event and reduce the risk to community members. Upon completion of such improvements, a request for a LOMR should be submitted to FEMA to revise the flood delineation.

Sincerely,
CRS Engineers

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