October 26, 2000

Michael Buckley, Director
Flood Hazard Mapping Technical Services Division
Federal Emergency Management Agency
500 C Street SW
Washington, DC 20472

Dear Director Buckley,

I have attached additional information relating to the flood insurance study and Base Flood Elevations for Richland and Lexington Counties contained in the September 26, 2000 Preliminary Revised FIRM. The additional information pertains to

- Historical floods
- Hydrological modeling methods
- The timing of levee breaks and peak flows
- An additional gauge on the Broad River
- Gauge information for the Congaree River

I will continue to provide assistance in your investigation; please feel free to contact me with any questions.

Sincerely,

[redacted]

cc: Dr. Paul Sandifer, SC DNR

cc: [redacted] SELC

Additional Information on FEMA's 9/26/00 Appeal Resolution for Congaree River in Richland and Lexington Counties, South Carolina

October 26, 2000

1 Introduction

This document is a supplement to the appeal of the new Base Flood Elevations for Richland and Lexington Counties. We would note that several of the issues brought up in the Appeal Resolution have not been broached before, specifically the use of reliable stage data prior to 1892. Use of this additional information would produce increases in the Base Flood Elevations as great as the changes observed between the 8/27/99 draft and the 9/26/00 appeal resolution.

We will first review historical data, then provide new data relevant to hydrology and hydraulics modeling, discuss FEMA's methodology, propose a new approach for computing Base Flood Elevations, and answer additional questions raised by the FEMA Appeal Resolution.

2 Historical Data

This subsection seeks to confirm historical flood information reported in the August 26, 1908 newspaper (Attachment 1). In reviewing historical flood information, we found stage data given for the August 1852, May 1886 (apparently misidentified as a May 1885 flood), and September 1888 floods to be

Table 1: Historic Peak Stages and Flows

Water Year	Date	Peak Stage (ft)	Annual Peak Flow (cfs)
1852	August 30, 1852	38.4	330,400
1886	May 22, 1886	35.5	260,800
1888	September 12, 1888	37.7	313,600

consistent with historical accounts. Large floods also occured in May 1840 and February 1865, but time has not allowed us to provide supporting data for the levels appearing in the August 26, 1908 newspaper article. Based on the information provided in the following sections, we think the proper stage data for the floods can be found in Table 1.

We have included information on the Gervais Street Bridge, its gauges, and flood information relative to the bridge itself and its gauges. Anecdotal accounts of the depth, severity and velocity of the floods on the Richland County floodplain below Columbia are also described. All of this information supports the conclusion that the gauge readings for 1852, 1886 and 1888 provide a sound basis for calculating the respective flood volumes. Such dependable and available historic flooding information is directly relevant to FEMA BFE calculations and must be factored into flood elevation estimates.

2.1 The Gervais Street Bridge 1827-1927

The Gervais Street Bridge was completed in 1827 (four attempts by Wade Hampton to bridge the Congaree River at Gervais Street in the 1790's were destroyed by freshets). The original granite pilings and supporting shoulders (see Attachment 1 sketch) remained intact even when the superstructure was damaged in the 1852 flood and destroyed by the retreating Confederate Army in February 1865 (see Attachment 1 photograph). The superstructure was not replaced until December 1872, at which time, 5' granite blocks were added to the original pilings, which raised the floor of the bridge from approximately 31 feet to "36 feet above dead low-water level", according to the Army Corps of Engineers' report to the House of Representatives in 1885 (see Attachment 4). An accompanying photograph of the 36' 1908 flood confirms the height

of the reconstructed bridge's floor (see Attachment 1). The bridge remained intact until its removal in 1927. As such, it serves as an excellent benchmark for studying Columbia's flood history.

2.2 The Gauge on the Gervais Street Bridge

The period from 1884 to 1891 is actually not part of the historic period, but part of the continuous record, because daily stage readings were reported by the Signal Service as the quote below makes clear.

> River Reports for Rice Planters–In response to a very general desire in the country tributary to the Congaree and Santee Rivers for frequent reports of the height of the Congaree River at Columbia, arrangements have been made to have daily tests of the depth of the river made at the Congaree bridge and sent to The News and Courier. The reports (with those of the Savannah River) will be printed immediately below the Signal Service weather reports. They will enable the stockmen of the lower Congaree and the rice planters of Georgetown to know in time of the approach of freshets or dangerously high water. *Charleston News & Courier, January 19, 1884*

Daily observations from the Gervais Street Bridge gauge that appeared as part of the Signal Service's daily weather summary in the Charleston News and Courier actually begin January 17, 1884. Less regular reports may actually pre-date 1884. The first examples of daily reporting appear below.

> The Congaree River. Columbia, January 16–The height of the Congaree River at Columbia at 5 o'clock today was five feet and six inches, eighteen inches above low water and seven inches lower than at this time yesterday. *Charleston News & Courier, January 17, 1884*

> The Congaree River. Columbia, January 17–The height of the Congaree River at Columbia at 5 o'clock today was five feet, one foot above low water. *Charleston News & Courier, January 18, 1884*

A painted gauge is described in the National Weather Service publication Daily River Stages from 1893-1895 (see Attachment 3); this gauge is apparently the same gauge used prior to 1893 since measurements of the 1886 and 1888 floods are consistent with the calibrated height of the painted gauge . It was replaced by a brass gauge in 1896 (see Attachment 3) that was calibrated to exactly the same level as the painted gauge. A 1916 report (see Attachment 3) lists the identical gauge, but reports a different elevation, most likely due to the use of different benchmarks. The alternative suggestion would require that the same gauge on the same piling on the same bridge had been lowered 1.7' arbitrarily, presumably by blasting through solid rock. The corrigenda for the gauge list no correction for that period; the only corrections are some minor adjustments for 1930 (see Attachment 3). This supports the conclusion that the 1916 gauge is the same as the one used before 1916, though with an adjusted elevation above mean sea level.

2.3 1852 Flood

The 1852 flood occured at the end of August 1852. Official NWS publications list the flood's stage as 34.4' (151.42' NGVD–330,000 cfs). Accounts of the flood are consistent with this height given that the bridge, at that time, had a floor elevation of approximately 31 feet.

> The waters came up over a portion of its floor on the north side, and the flood beat against the weather boarding on the same side for many hours, but apparently without any effect. *Daily South Carolinian, August 31, 1852*

> At the time we last visited the Congaree Bridge, (twelve o'clock yesterday) the water was still as high as the flooring, though gradually receding. It had then fallen about two feet. *Palmetto State Banner, September 7, 1852*

Later accounts confirm that parts of the bridge were destroyed. The flood carried away sections of the superstructure. As the stage height for the 1852 flood is clearly part of NWS's published record in the Daily River Stages, the 1852 flood should be included in the analysis as part of the historical record.

2.4 1886 Flood

The 1886 flood occurred during the period when daily measurements from the Gervais Street Bridge gauge were printed as part of the Signal Service's daily weather summary in the Charleston News and Courier (see Attachment 1).

> Columbia, May 20.–The height of the Congaree River at Columbia at 4:30 o'clock yesterday was 15 feet 6 inches above low water, and 7 feet higher than at the same time yesterday and rising rapidly. *Charleston News & Courier, May 21, 1886*

> Columbia, May 21.–The height of the Congaree River at Columbia at 4:30 o'clock today was 31 feet above low water and 14 feet 6 inches higher than at the same time yesterday, and rising now slowly. Nearly at a stand since 1 o'clock. *Charleston News & Courier, May 22, 1886*

References to the gauge during the 1886 flood are consistent with eye-witness accounts of the flood and what we know about the height of the bridge.

> The water covered the great granite buttresses of the old bridge, about five feet below the flooring of the present structure...Old observers say the the river is three feet lower than it was then (in 1852)...the water was at noon within five feet of the flooring of the bridge. *Charleston News & Courier, May 22, 1886*

Note that the above account confirms the gauge reading for the 1852 flood.

> ..the water at its highest was within five feet of the flooring. *Charleston News & Courier, May 24, 1886*

> ...the water rushed under the bridge about five feet from the floor. *Columbia Register, May 22, 1886*

> In May, 1886, the highest was 31 feet 6 inches. *Charleston News & Courier, September 12, 1888*

I have included some accounts of flooding in the Richland County floodplain below. These accounts confirm that the floodplain acts as a floodway in large storms. A map of the downstream area from 1887 (see Attachment 4) helps to identify some of the farms mentioned in the account.

> The whole swamps are submerged, and houses in them seven feet above the ground are waist-deep in water, and can be paddled all over in boats...few have escaped who had stock in their swamps. *Charleston News & Courier, May 24, 1886*

> All the bridges on the Bluff road–more than twenty–of all sizes, have been carried off or damaged to a greater or less extent. The bridge over Gill's Creek, which had been but recently repaired by the Commissioneers, was lifted from the benches which supported it and carried about twenty feet away...Captain W.D. Starling reports the loss of all his cattle. The water was several feet over the "Mount," the highest point on the plantation, which has never been covered before. *Columbia Register, May 25, 1886*

2.5 1888 Flood

The gauge readings from the Congaree River were not part of the Signal Service's daily weather summary in the News and Courier in 1888, but gauge information is widely available in contemporary newspaper accounts. Examples are included below.

> The Congaree began falling last night after reaching a maximum height of 20 feet, and at 6 o'clock this evening measured only 15.5 feet. *Charleston News & Courier, September 9, 1888*

> The Congaree at 6 o'clock this evening had fallen five and half feet since the same hour yesterday and stood at ten feet. *Charleston News & Courier, September 10, 1888*

> It will be remembered that at dusk on Friday the height of the river was 20 feet, and that it fell next evening to 15.5 feet and yesterday at 7 P.M. to 10 feet. At 6 o'clock this evening the News and Courier's special observer reported its height at 19 $\frac{5}{8}$

feet. A representative of the Bureau went down to the Gervais street bridge at 9:30 tonight for the purpose of taking a final observation. The river was found to be exactly 22 feet high and rising at the rate of eight inches an hour. *Charleston News & Courier, September 11, 1888*

...at 3 P.M. today, the river had risen to a point less than 2 feet from the flooring of the bridge. *Charleston News & Courier, September 12, 1888.*

At 12:30 the river was 33 feet and slowly rising. The sills supporting the floor of the Columbia bridge are barely one foot from the water. *Charleston News & Courier, September 12, 1888*

At 6 o'clock this evening the Congaree at the Gervais street bridge had fallen to 26 feet. Its highest point yesterday was 33 feet 9 inches. *Charleston News & Courier, September 13, 1888*

I have also included accounts of flooding in the area of interest.

This morning the beautiful corn and cotton fields of yesterday were transformed into a sea of rushing yellow water. The cotton was torn up and ruined, while the corn was washed towards the ocean. During the night the treacherous Congaree had risen twelve feet and overflowed its banks and the fertile lands beyond. All the crops on the bottom lands on the big plantations of Aughtry, Griffin, Seegers and others are submerged and destroyed. Of course, all the river bottom crops on the Congaree, Broad and Saluda rivers have shared the same fate. *Charleston News & Courier, September 8, 1888.*

The ruin of the river planters in lower Richland is complete. Take for instance the two State plantations owned by Mr. John C. Seegers. His crops, which were magnificent, are utterly ruined, and he will deem himself fortunate if he can save a part of the stock on the place, which is probably entirely under water. *Charleston News & Courier, September 12, 1888*

> The swamp was full of water, running like a mill race. *Charleston News & Courier, September 13, 1888.*
>
> The five State farms–Big Lake, Green Hill and Gadsden, of Seeger's and Spigner's and Aughtry's–were good for 1,600 bales of cotton and 40,000 bushels of corn, half of which would have gone to the State. Perhaps not 10 per cent will be saved. *Charleston News & Courier, September 13, 1888*
>
> Superintendent Lipscomb had several boats hurriedly made at the Penitentiary yesterday, sent in wagons to Griffin's place. The work of the rescuers was very perilous as the fields were swept by a furious torrent. *Charleston News & Courier, September 13, 1888*

3 Hydraulics

The September 26, 2000 BFEs assume that floods will peak on the Lexington floodway before peaking in Richland County because the Lexington-side peak while the levees hold will be greater than the peak after the levees break. Thus the Lexington County BFE's were computed as though the levees were intact at the full height of the 100-year flood. That approach is too simple given the available historic knowledge about how a levee failure would in fact occur. FEMA must use the flow rate at which the levees would realistically fail in calculating BFEs in Richland and Lexington Counties. If that flow rate is less than 292,000 cfs, the BFEs in Lexington County would change significantly. Obviously, the proper analysis would propose a flow at which the levees would break and compare the BFE's for this flow (with the levees intact) to the BFE's for 292,000 cfs with the levees breached.

A reasonable flow at which the levees would breach would be 140,000 cfs, the flood at which the levees breached in 1976. If we look at the hourly gauge readings for the Congaree River for October 10-12, 1976 (Attachment 2), we see that when the breaks occurred (approximately 1 AM, October 11), the gauge reading was only 28.5 feet, corresponding to a flow of only 140,900 cfs. In addition, the levees broke in April 1964 at a similar flow (interestingly, they broke from interior pressure on the levees). If the levees break at only 28.5 feet, the water level may drop two or four feet on the Lexington side (as

stated by FEMA), but the river will rise another 8.3 feet before cresting. In that scenario, the peaks on the Lexington and Richland sides will coincide. If we use a larger failure trigger figure, 200,000 cfs (at which point overtopping of the levees will occur), the river will still rise 4.2 feet after the break, which again compensates for the temporary increase in storage on the Richland County side.

Clearly, Lexington County has been severely shortchanged in the current analysis. Its BFE's should be identical to Richland County's BFE's since the early peak before levee failure is most likely a false peak. In other words, Lexington County BFE's would be lower, compared to the September 26 map.

4 Hydrology

4.1 1930 Flood

In its latest analysis, FEMA correctly notes that 1930 should not be considered an unregulated event. In fact, it is an over-regulated event. If the flood event of 1930 occurred today, the flow from the Saluda River downstream of Lake Murray would have been greater. Lake Murray was at a level of only 249.4 feet on September 26, 1929 and rose to 292.2 feet over the next three days. On October 2, 1929, it rose from 299.9 feet to 305 feet. Based on the water storage capacity chart for Lake Murray published in 1930 (Attachment 2), this corresponds to storage of approximately 2.951 billion cubic feet, or an additional flow of 34,155 cubic feet per second from the Saluda River on October 2, 1929. This number is actually conservative, since estimated storage capacity from the 1930 chart is less than estimated storage from the more recent 1997 chart (Attachment 2). As an example, at 350 feet, the 1930 chart shows that each .1 foot rise stores .175 billion cubic feet while the 1997 chart shows that each .1 foot rise stores .181 billion cubic feet.

The 1930 flood is the most misrepresented event in the entire data record. If FEMA wants to adjust all pre-1930 floods downwards for a dam with no flood storage capacity, then the 1930 flood should be adjusted upwards 34,000 cubic feet per second to 337,000 cubic feet per second.

4.2 Broad River at Blairs

FEMA uses the Broad River at Richtex gauge to adjust pre-1930 flows. As an additional resource, another gauge on the Broad River straddles the pre-1930 and post-1930 time periods. The National Weather Service maintained a gauge on the Broad River at Blairs from 1905 to 1980. Attachment 3 contains gauge information, daily stage readings and all relevant corrigenda (which corrects flows from 1908 to 1915). The gauge was destroyed by the 1908 flood, so the peak listed for that flood (31.1') is unreliable. I have included annual peak stage data in Attachment 3. The omission in 1976 occurs because I failed to copy information for 1977 and because the National Weather Service published annual peaks for fiscal years rather than flood years starting in 1972.

Though no stage-discharge curve is available, MOVE.1 and MOVE.2 regression methods can be used just as easily with stage data as with discharge data.

4.3 Chance Exceedance of FEMA's 100-year Flood

There are five flood events in the past 150 years that exceed FEMA's 100-year flood of 292,000 cfs: 1852, 1888, 1908, 1928 and 1930. The probability of this occurence is only .017, which suggests that either our recent record is extreme or FEMA's estimate is unrepresentative. I suspect that FEMA's estimate is reasonable for "spring freshets", but is inappropriate for tropical storms. It is remarkable that all 5 floods which exceed FEMA's estimate were caused by tropical storms. In such cases, Bulletin 17B suggests that 100-year floods from disparate sources should be estimated separately and then "combined", though guidelines are vague on how the estimates should be combined.

The simple solution here would be, with over 100 years of data, to report the second largest observation (the sample 99th percentile) as the 100-year flood estimate. The second largest observation would either be the 1852 flood (330,400 cfs) or the 1930 flood (337,000 cfs). This estimator avoids a great deal of controversy over hydrological modeling.

If we insist on using 3-parameter gamma distributions for modeling, we need to pool estimates from the large tropical events (1852, 1888, 1908, 1916, 1928 and 1930) and the non-tropical events. The problem presented here is

not a mixture problem in the statistical sense because the source of each year's flood is known–this is a problem in which the data has been "pooled". In such situations, the 100-year flood would solve the following equation in x:

$$\int_0^x pf(u;\alpha_1,\beta_1,\tau_1) + (1-p)f(u;\alpha_2,\beta_2,\tau_2)du = .99$$

where p is the proportion of years a tropical storm occurs and $f(u;\alpha,\beta,\tau)$ is the density function for a three-parameter Gamma distribution (where α is the shape parameter, β is the scale parameter and τ is the lower boundary for the support). The solution can either be found by trial and error or by using a nonlinear root-finding algorithm (I used *uniroot* in *Splus*).

For non-tropical storms, $1-p$ was set to $\frac{147-6}{147} = .9592$, $\alpha_2 = 209.2275$, $\beta_2 = .03304592$, and $\tau_2 = 4.333361$. The 1886 flood was treated as a historical flood and 11 years of historical data (1887-1891 and the six tropical storm years) were considered censored. None of these floods were adjusted in computing the above parameter estimates by method of moments.

For tropical storms, $p = .0408$, $\alpha_1 = 1518.047$, $\beta_1 = .002472387$, and $\tau_1 = 8.905372$. No tropical storms are missing from the record, so no censoring was assumed in computing the above parameter estimates by method of moments. The peak flows were not adjusted.

Solving the above equation for x, I obtained a 100-year flood estimate of 340,149 cfs, which corresponds more closely with the history of tropical storms on the Congaree River.

5 Additional Issues

This section contains brief comments on FEMA's Flood Map Revision documents.

5.1 1964 Flood

I had forwarded a tape of April 1964 flood footage to FEMA, but FEMA lists the tape as "undated". I have included a newspaper photograph from 1964 (Attachment 1) that was obviously taken directly from the tape. The tape was provided to Mr. Herbert Hendrix of 3316 Leaphart Road, West Columbia

by Mr. Victor Tutte of The State in 1964. Mr. Hendrix transfered the tape to videotape, which I acquired from him. Mr. Hendrix can be reached at (803) 794-4819 for confirmation. I would like to reiterate the importance of this tape since it shows the levee breaking from *inside out* back into the Congaree, apparently just below the mouth of Gills Creek.

5.2 1928 Flood

FEMA also failed to acknowledge that the videotape provided to them contained footage of the August 1928 flood, including scenes of flooding and a flash flood along Gills Creek. This footage was obtained from the University of South Carolina Film Library from a movie reel labeled "September 1928" provided by the family of Susan Gibbes Robinson. Mr. Andrews Murdoch can be contacted at the USC Film Library at (803) 777-6841 to confirm the authenticity of the tape.