Federal Emergency Management Agency

Washington, D.C. 20472

FACSIMILE

October 3, 2000

[redacted]

I am faxing a copy of a memorandum dated July 12, 2000 from [redacted] to [redacted] regarding geotechnical characteristics of dikes along the Congaree River and adjacent lands. The purpose of the review was to gain some insight on modes of potential failure during the occurrence of a base flood flow event and the nature of flow in the floodplain areas along the Congaree River in Richland County. It was not our intent to establish definitive failure modes, nor did we use the failure scenarios in calculating BFEs. Based on these results and other information reviewed over the last several weeks, FEMA concluded that there will be significant flow of floodwaters in these areas.

In accordance with our guidelines and regulations, BFEs in Richland County, and the equal conveyance floodway in both Richland and Lexington Counties, were computed without consideration of the existence of the main stem dike. Also, in accordance with our guidelines, the BFEs in Lexington County were computed as though all the flow would occur there. In other words, the dike would not be breached. This approach accounts for the difference in the BFEs between Lexington and Richland Counties shown on the revised preliminary presented at the meeting in Columbia, SC last week.

In evaluating the impact of encroachment in the floodway, FEMA's procedure is to look at changes in flood levels associated with the passage of the base flood discharge. Since we have calculated two different flood elevations, the impact analysis must look at these two situations. These requirements are referenced in Part 60.3(d)(3), and in Part 65.7, and in the FEMA Guidelines and Specification on pages 7-3 through 7-5.

The approach that has been adopted is intentionally conservative because of the potentially catastrophic losses to life and property that would be realized in the event of a failed flood control structure, the uncertainty associated with probabilistic predictions, and the potential adverse impact on other property owners.

I trust this provides clarification to the issues you identified during our phone call earlier today.

Michael Buckley
Division Director
Technical Services Division
Mitigation Directorate

31 August 2000

MEMORANDUM

TO: [redacted]

FROM: [redacted]

SUBJECT: Richland County Levee, SC
Additional Geotechnical Review

At your request, I have made an additional review of the geotechnical features of the Richland County Levee project, taking into account the current estimation of the Base Flood Elevation. This memo supplements my memo dated 12 July 2000, and is addressed specifically to Levee Section 1, that portion of the levee system that lies upstream of the I-77 bridge. This includes cross-sections 1D through 25, as identified in the Report of Geotechnical Exploration, dated 10 August 1999, prepared by S&ME.

Critical sections

In my July memo, I identified Sections 1A - 1D and 11 - 12 as being most susceptible to failure by piping of the soil from the levee or the foundation, under the effect of the BFE. For Section 11 - 12, the current BFE is 141.1 ft, compared with the previous level of 139.9 ft. I have restudied the levee geometry, the soils conditions, and H/L (the ratio of hydraulic head to the levee base width), and find the previous analysis to be appropriate. Therefore, with the higher BFE, the H/L is increased somewhat, and this section is still considered potentially susceptible to failure by piping.

A restudy of Section 1A - 1D leads to no significant change in conditions, so it is still potentially susceptible to failure by piping.

In my July memo, I did not include Section 13 - 17 in the list of sections that appear most susceptible to piping failure. Upon restudy, I suggest that this section be added to the list. This section has a flat landside slope on the lower part of the levee, which would tend reduce the susceptibility to failure, but the review of the other factors leads to the conclusion that the stability of this section is marginal.

Width of breach

In my July memo, I estimated that failure of one section as a result of piping could create a breach in the levee 120 feet wide. This was based on the case history of the two failures that occurred on 11 October 1976, which resulted in breaches 110 ft wide and 95 ft wide, and it

recognized the fact that the BFE would be at a higher elevation than the flood level that occurred in 1976, and it would persist for a somewhat longer time. I have restudied the potential width of a breach, with a view to relating the width to differing values of hydraulic head, H/L, and soil conditions at different sections, but there is not enough information on variables, and not enough historical experience to justify an attempt to be more precise. Therefore, I repeat my suggestion that it be assumed that the levee would be breached over a distance of 120 feet at each section that failed as a result of piping of soil.

Number of breaches

Based on the experience of the two failures in 1976, it would be reasonable to assume that the levee could fail by piping at two or three weak locations during a single occurrence of the BFE.

12 July 2000

MEMORANDUM

TO: [redacted]

FROM: [redacted]

SUBJECT: Richland County Levee, SC
Geotechnical Review

I have reviewed geotechnical reports on the Richland County Levee project, with a view to estimating the potential for failure of levees during occurrence of the Base Flood Elevation event. Reports reviewed are:

(1) Geotechnical Investigation of Dike Failure, Metropolitan Wastewater Treatment Plant, dated 9 December 1976, prepared by Law Engineering Testing Company, Columbia, SC.

(2) Report of Geotechnical Exploration, Congaree Levee Sections 1 and 2, dated 10 August 1999, prepared by S&ME, Inc., Columbia, SC.

Law report. The Law report presents the results of investigations performed on two failures that occurred in the levee on Monday, 11 October 1976, near Columbia's Wastewater Treatment Plant. The peak river surface elevation at the time of the failures was 136 feet NGVD (according to the S&ME report). The BFE in this area, for present conditions, is about 137.4. The river flows were at or near the peak from 10 October to 12 October. Brief accounts of the two failures are included here because they represent the most likely mode of failure, and provide some insight into the size of breaches that might occur in the levee.

The "south failure" extended for 95 feet, measured along the axis of the levee. It occurred at about 2:00 in the morning, and was not actually observed in progress. The levee slope on the landside had a steep inclination of 1 vertical on 1.3 horizontal. There may have been some slumping of the slope immediately before the breach, but the failure appears to have been caused by piping of foundation or levee soils under the effect of seepage. The soils at the base of the levee were loose, fine silty sand and sandy silt.

The "north failure" extended for a distance of 110 feet, and was approximately centered about a 42-inch-diameter concrete pipe that passed beneath the levee. The failure occurred in the early morning on 11 October, and was observed by the superintendent of the wastewater plant. The landside toe was described as having a seepage boil following the development of a tunnel through

the levee above the concrete pipe. This could have been due to inadequate compaction of fill around the pipe, but in any case, the failure was the result of piping of soil from beneath the levee. The soils at the base of the levee were loose, medium sand and sandy silt.

The estimated ratios of hydraulic head across the levee to the base width of the levee, H/L, range from about 0.23 for the south failure to 0.13 - 0.17 for the north failure. Dependent upon laminations and variations in the soils, differences in horizontal and vertical coefficients of permeability, and the shape of the flow nets, the actual seepage exit gradient would be substantially larger than these values. The ratio of H/L is used here as a rough guide to compare the present conditions along the existing levee to the measurements that have been made at actual failure areas.

S&ME report. The S&ME report presents the results of geotechnical investigations performed along all of the levees in the area. Borings were made, generally at a spacing of 500 feet, without apparent adjustment for significant surface features, such as oxbows, natural levees, backswamp deposits, etc. This spacing of borings is a customary practice to provide an economical investigation for such a large area of interest. The investigations included Standard Penetration tests, soil sampling, laboratory tests, stability analyses and seepage analyses. The report discusses specific areas that display some degree of piping development, and recommends improvements to provide an acceptable degree of safety for the BFE event.

Influence of soil conditions. Review of an aerial photograph shows the presence of oxbows, point bar deposits, natural levees, and other features that are typical of an alluvial floodplain. This implies that there are wide variations in soil deposits, such as clays, silts and sands, and in their distribution, that would have significant effect on the potential for failure of the levees. The soil profiles show, in some cases, apparently continuous deposits of a single type of soil extending over distances of 1500 feet or so. However, this is the result of correlating strata between borings that are 500 feet apart, and it is likely that there are significant variations in the type and character of the soils within such a distance. This means that there is a considerable difference in potential for failure due to piping within these distances. The "N" values from the standard field penetration tests show significant variations vertically and horizontally within a given stratum.

I have attempted to classify the potential for piping failure at various locations by comparing soil type, penetration resistance, landside levee slope and H/L ratio for 19 cross-sections that were identified in the S&ME report, with the characteristics of the two sections that failed by piping in 1976. In terms of achieving a clear group classification this was only slightly successful, because there are so many combinations of features among the 19 sections.

Observed piping conditions. In Table 2, the S&ME report lists five cross-sections that had evidence of piping erosion at the locations of pipes that are beneath the levee, and one more section that has a sewer pipe beneath the levee without evidence of piping. These sections have H/L's for the BFE that are generally consistent with the H/L for the south failure. There are four additional sections that are questionable, based on soil types, H/L's and some evidence of erosion (not necessarily piping). The nine other defined sections appear to be less susceptible to piping.

The ten sections, as defined by S&ME, that appear to be most susceptible to piping are:

Most critical	Questionable
1A - 1D	67 - 69
11 - 12	70
28 -38	74 - 75
39 -45	76
46 -48	
63	

It will be noted that some of these encompass substantial lengths of levee, but because of the conditions mentioned previously, it is not likely that a piping failure would occur along the entire distance. These defined sections could be correlated with HEC sections. For the locations of the sections, refer to Figures 3 and 4 of the S&ME report.

Failure by piping. The most likely mode of failure of the levees is by piping. This has been demonstrated by the two areas that failed in 1976. Shear failure by itself is not a likely cause of breaching because of the low height of the levees, and the fact that they have gained some degree of stability through consolidation over many years. It is possible that there could be some sloughing and sliding of the steeper landside slopes, but this would probably be due to the effect of seepage causing piping and removal of some landside toe support, as is suspected in the south failure. The fundamental cause of failure is still piping.

Because of local variations in condition of the foundation and embankment soils, even within a single identified soil stratum, it is probable that failure would be rather localized, as in the 1976 failures, and would not extend over a great length of levee. Sand boils that are associated with piping of soils are typically localized. The surficial evidence of depositional features, and the variations that occur in natural levees and other deposits, suggest that failure would be local and unpredictable. Once a section of levee has been breached, the flood water on the landside will tend to create a back-pressure, reducing the hydraulic head across the levee, reducing the potential for piping, and tending to increase stability of adjacent sections of levee.

I understand that the flood level would rise to the BFE and fall within two or three days, which would limit the exposure of the levee to potential piping heads. While it is not possible to predict piping potential as being dependent on any specific length of time, a short time of flooding would tend to reduce the development of piping.

Recommendation. I suggest that the assumption be made that piping could cause failure at any of the ten most critical sections listed above, and that the levee would be breached over a distance of 120 feet in each section. This is a judgmental recommendation that considers flooding at a higher level and at a slightly longer period of time than occurred in 1976. It recognizes that these relatively low levees are not likely to erode to as wide a breach as has occurred in higher levees with well-defined strata over larger distances.

Overtopping. This review does not consider failure of the levees by overtopping. This is a hydraulic condition that is not initially related to the geotechnical conditions. Once overtopped, a levee will fail, and the extent of failure will depend upon the head above the crest of the levee, the type of soil in the levee, the duration of overtopping, and the length that is actually overtopped.

Recommendations by S&ME. The S&ME report recommends strengthening the levee and adding filters or flatter slopes to the landside. These provisions would bring the levees to a condition that would be expected to avoid failure by piping or shear failure, but not by overtopping. The provision of landside filter zones is especially effective in controlling seepage and piping.