POST-FLOOD RECONNAISSANCE: UPPER MISSISSIPPI RIVER FLOODING OF 2008

J. David Rogers, Ph.D., P.E., R.G.
Natural Hazards Mitigation Institute
Missouri University of Science & Technology

for the scientific meeting on

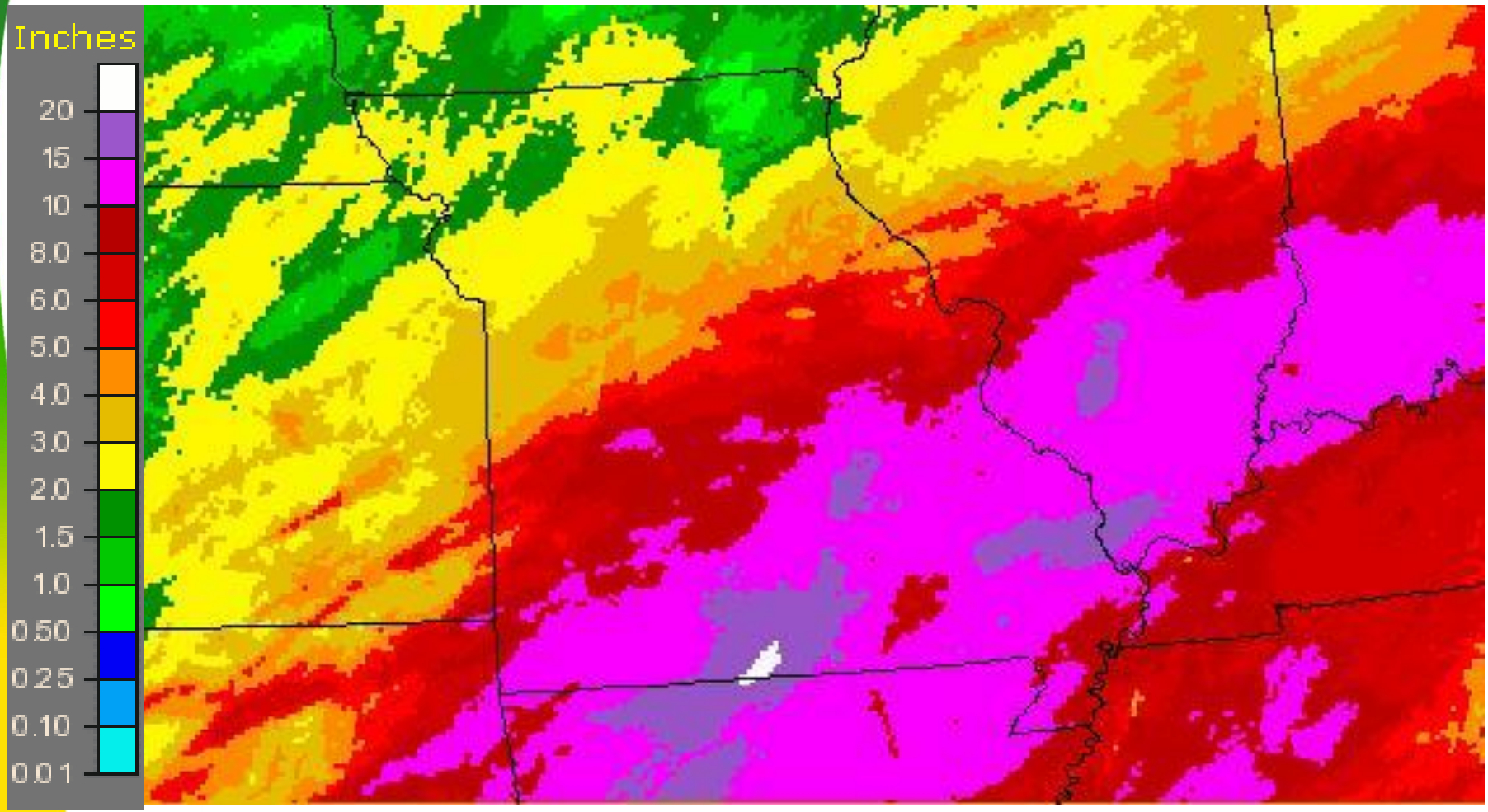
Finding the balance between Floods, Flood Protection, and River Navigation

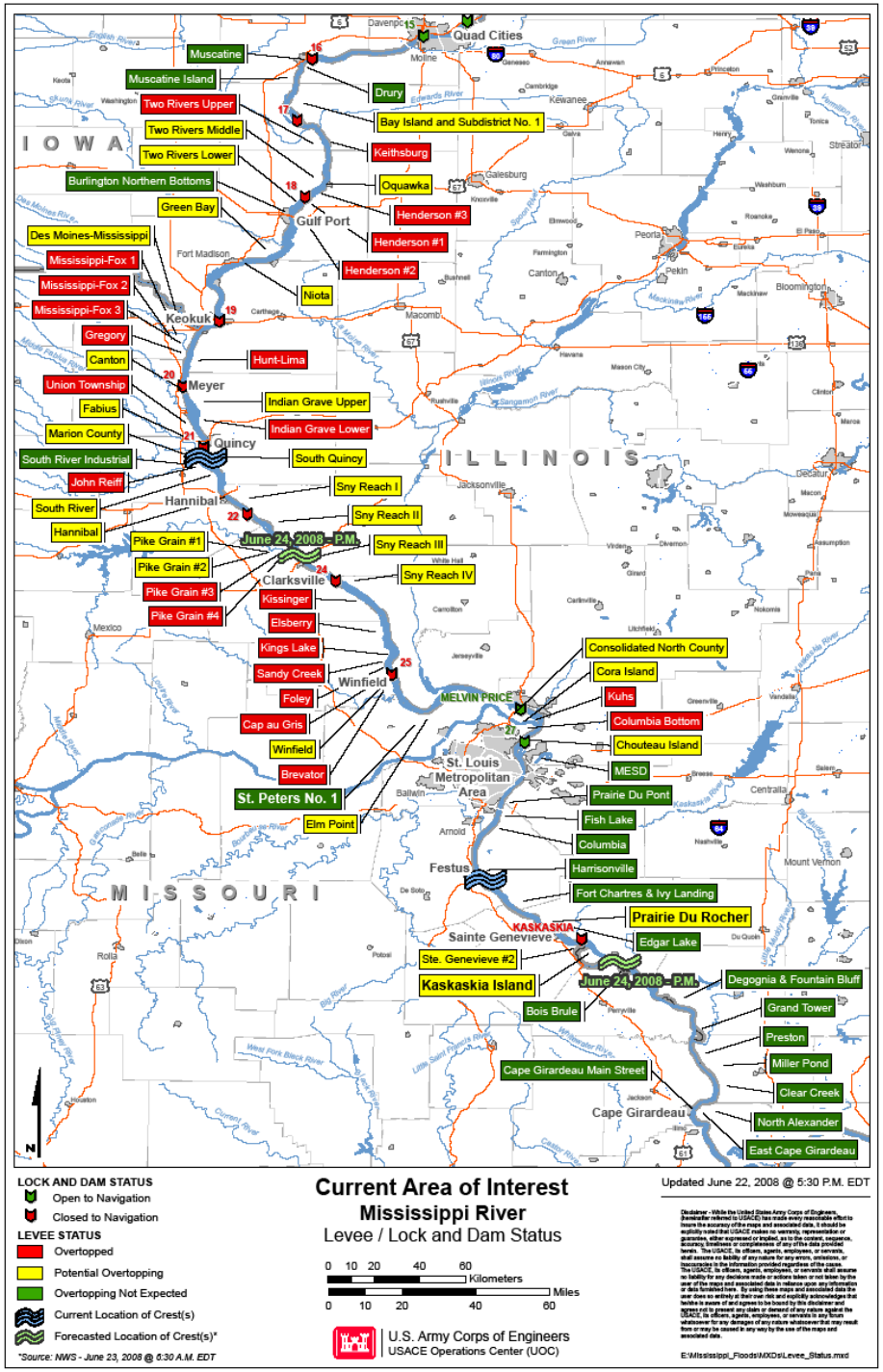
St. Louis University
November 11, 2008

NATURAL HAZARDS MITIGATION INSTITUTE

NSF

Heavy Precipitation in March 2008



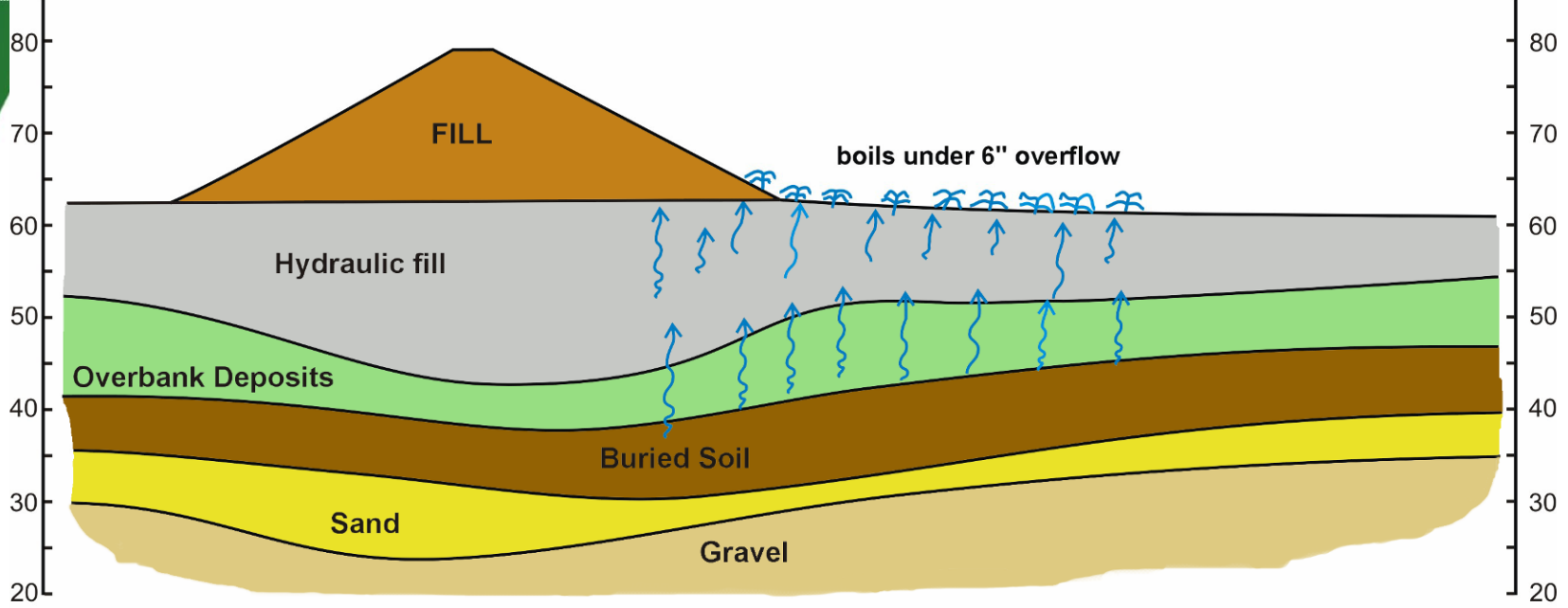


Summer 2008 Midwest Floods

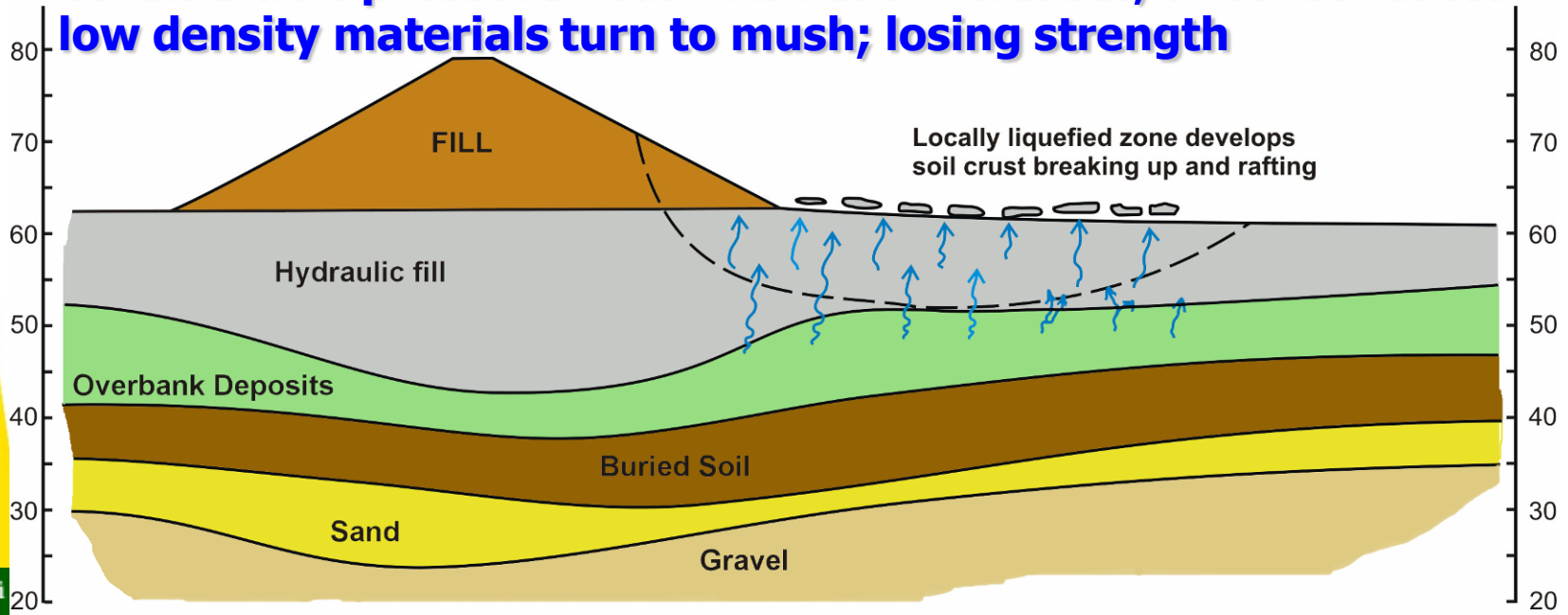
- Largest runoff event since 1993
- Record flows on lower Iowa River in Iowa and Salt Creek near Hannibal, MO
- No significant impacts on flood infrastructure downstream of St Louis
- Corps of Engineers dams probably shaved 1.5 to 3.5 feet off the peak flows

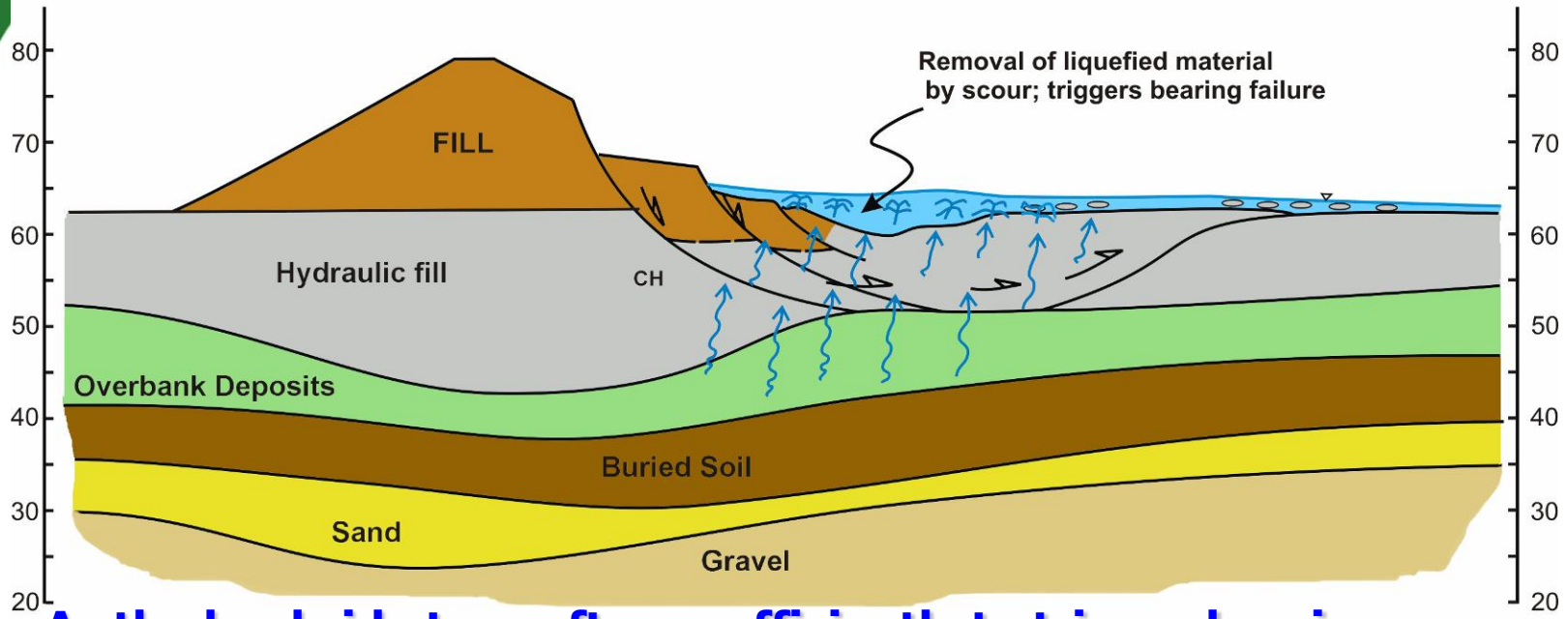
Concrete flood walls often used to protect high-value business districts


ROPOLITAN ST. LOUIS
SEWER DISTRICT

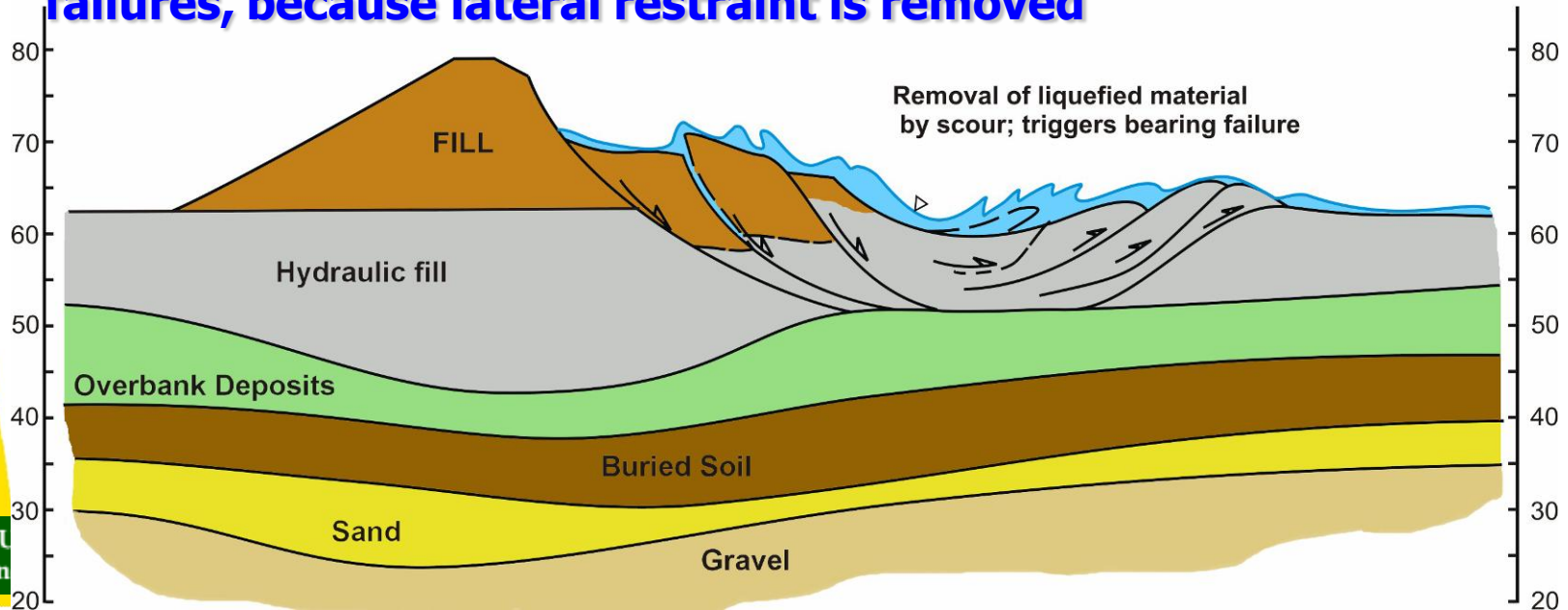


Hydraulic uplift is easily generated from confined aquifers under considerable pressure head. As head increases, unconsolidated low density materials turn to mush; losing strength

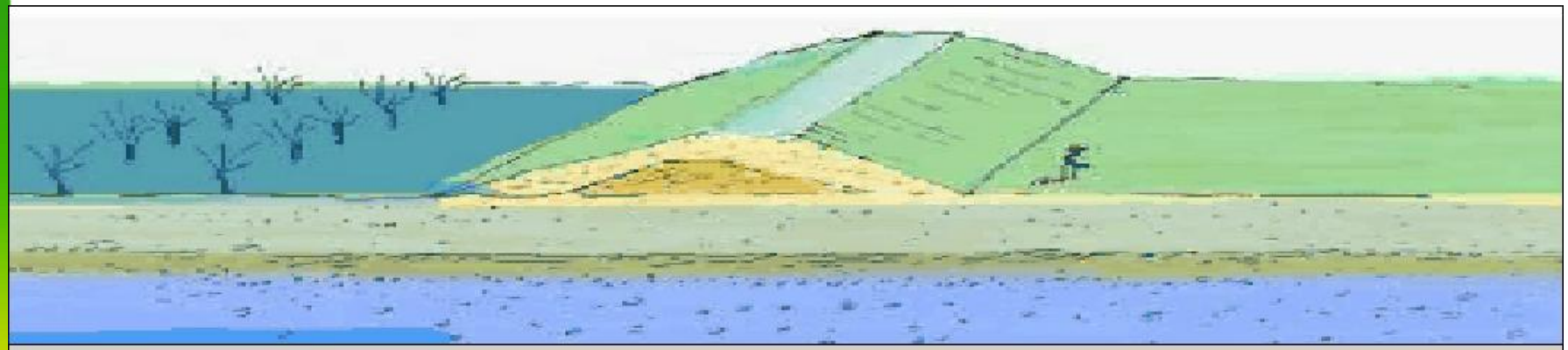




As the land side toe softens sufficiently to trigger bearing capacity failure; this is rapidly followed by retrogressive slope failures, because lateral restraint is removed

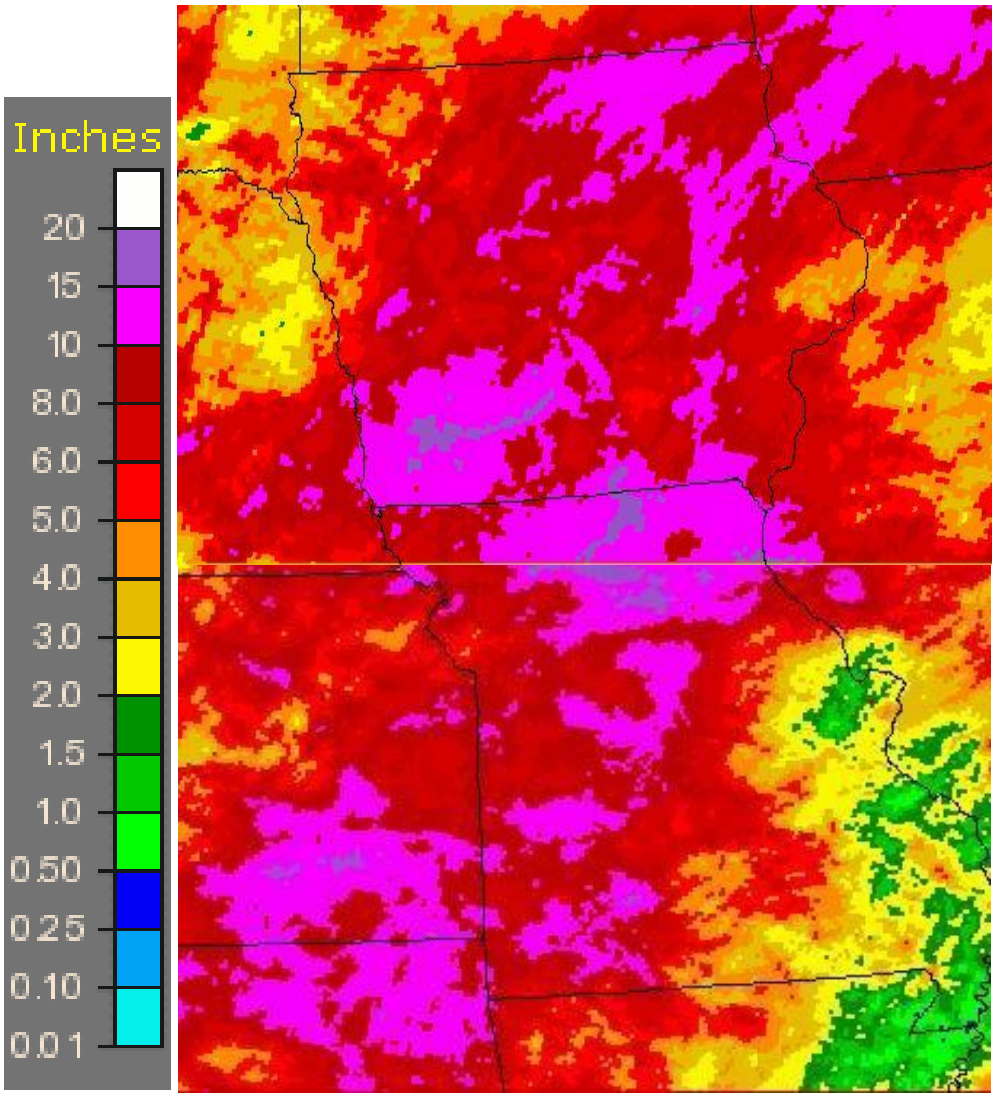


wetting fronts assail an earthen levee simultaneously



The number of wetting fronts depends on the stratigraphy and hydraulic conductitvity [permeability] of the channel deposits beneath the levee

Heavy Precipitation in June 2008



Missouri University of Science and Technology

MISSOURI S&T

Lock and Dam No. 22 at Saverton closed on June 14th

Missouri University of Science and Technology

MISSOURI S&T

L&D 22 re-opened on July 3rd

Missouri University of Science and Technology

MISSOURI S&T

Lock and Dam No 25 near Winfield closed down June 15th

Missouri University of Science and Technology

MISSOURI S&T

Sandbagged control shed at No 25; re-opened on July 5th

Missouri University of Science and Technology

Clarkesville survived using 8 ft high gravel filled bins

Missouri University of Science and Technology

MISSOURI S&T

Winfield-Pillsbury breach on June 18th. Note overtopping.

Missouri University of Science and Technology

MISSOURI S&T

Second story of house being rafted from Winfield-Pillsbury

Missouri University of Science and Technology

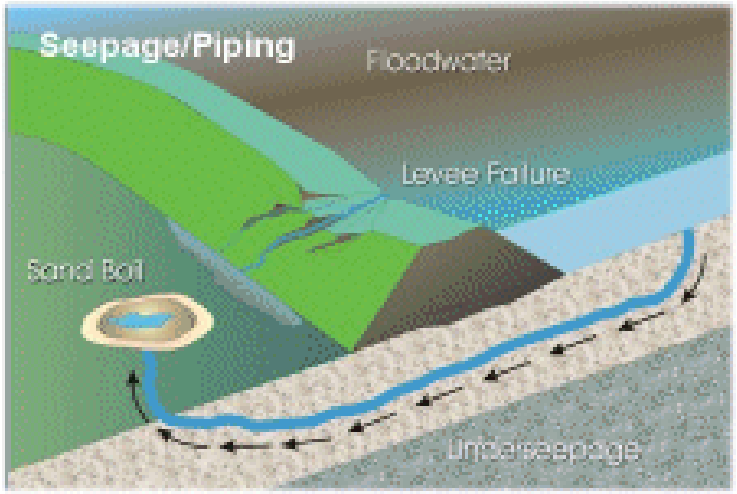
MISSOURI S&T

Battling hydraulic piping and seepage boils

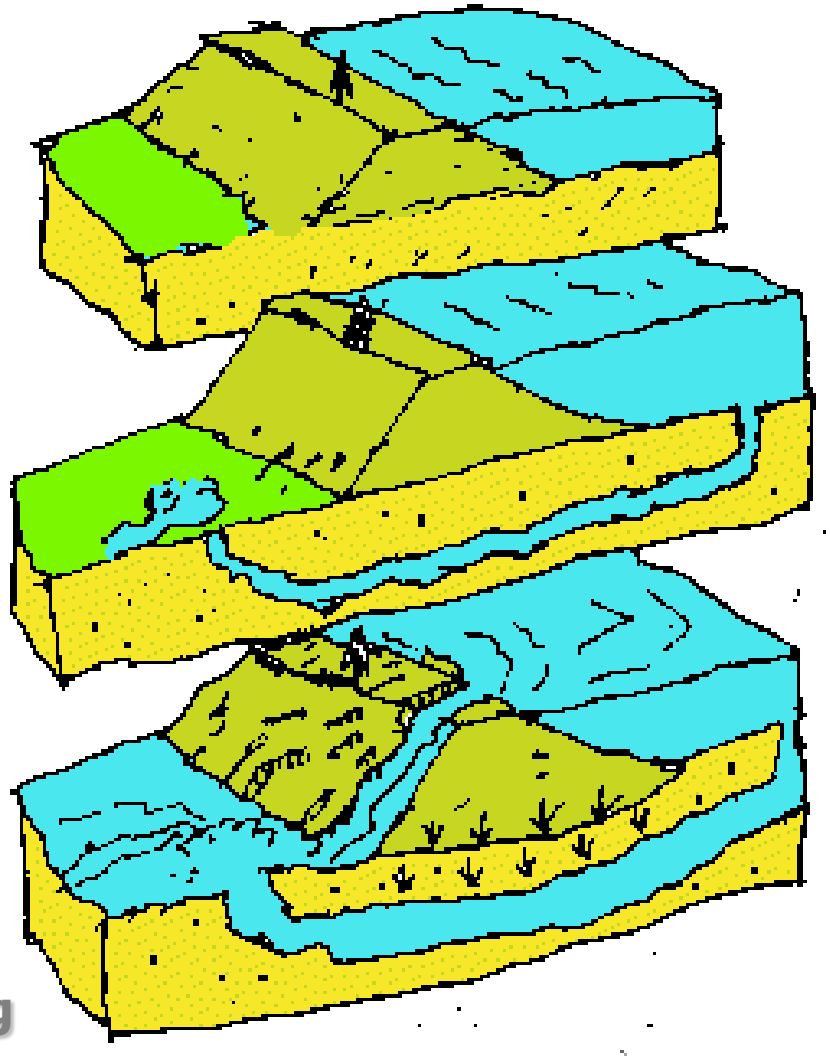
Massive boil

When hydraulic gradients > 1.0, piping of fine grained soils ensues.

The traditional model for piping-induced failure



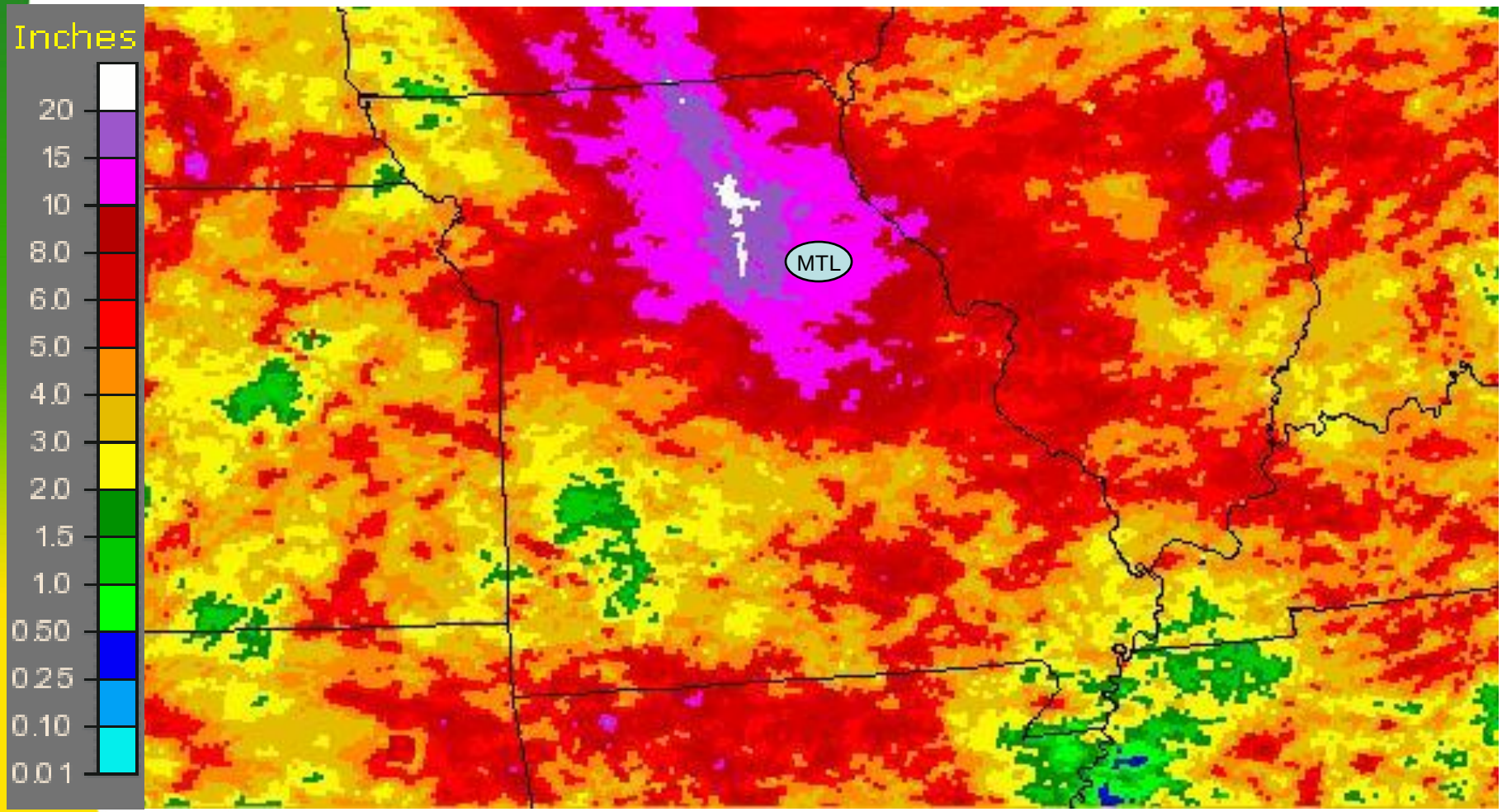
from State of California website in 1997

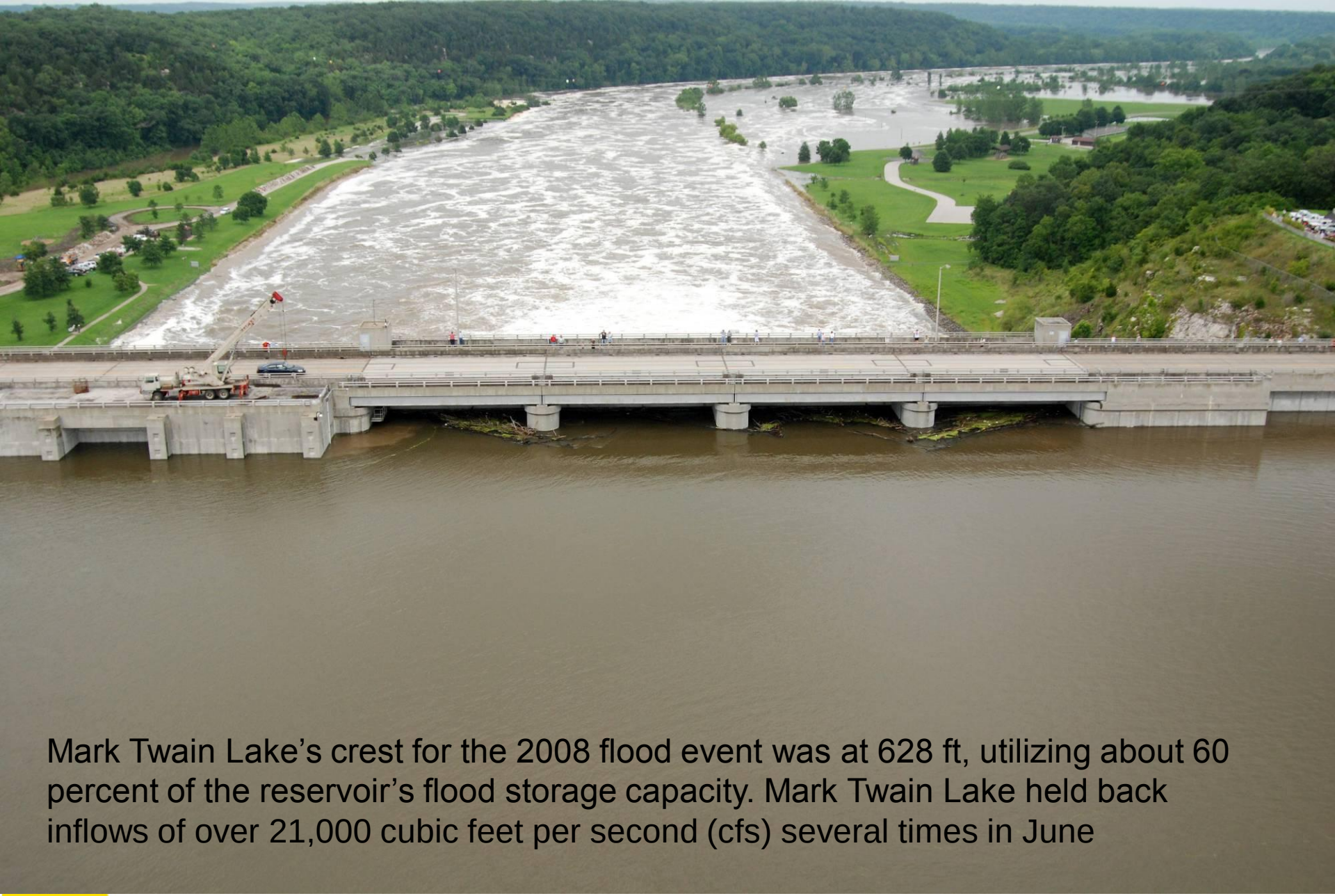


Traditional model for piping

- The traditional model for hydraulic piping envisions a conduit that is progressively eroded and enlarged by turbid seepage. This is a problem for levees founded on porous silts, typical of flood plains.

Precipitation in July 2008





Mark Twain Lake's crest for the 2008 flood event was at 628 ft, utilizing about 60 percent of the reservoir's flood storage capacity. Mark Twain Lake held back inflows of over 21,000 cubic feet per second (cfs) several times in June

Missouri University of Science and Technology

MISSOURI S&T

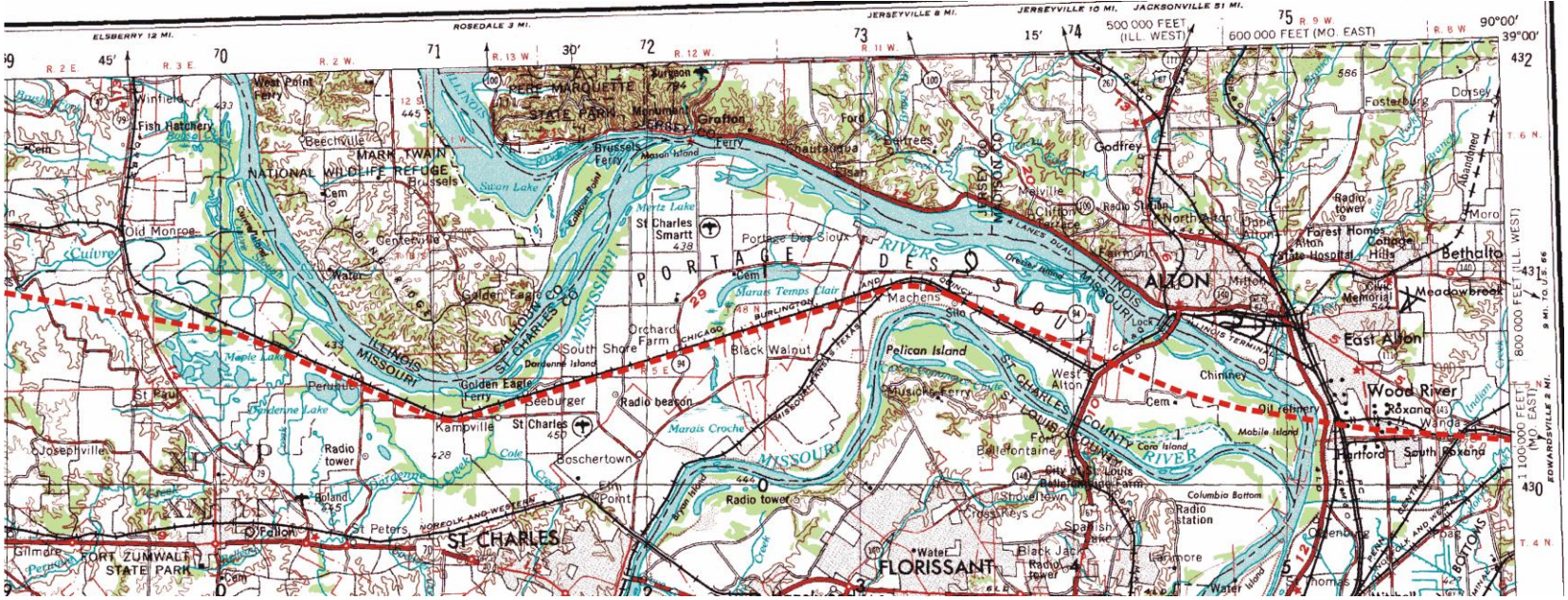
Spilling into Salt Creek at Clarence Cannon Dam

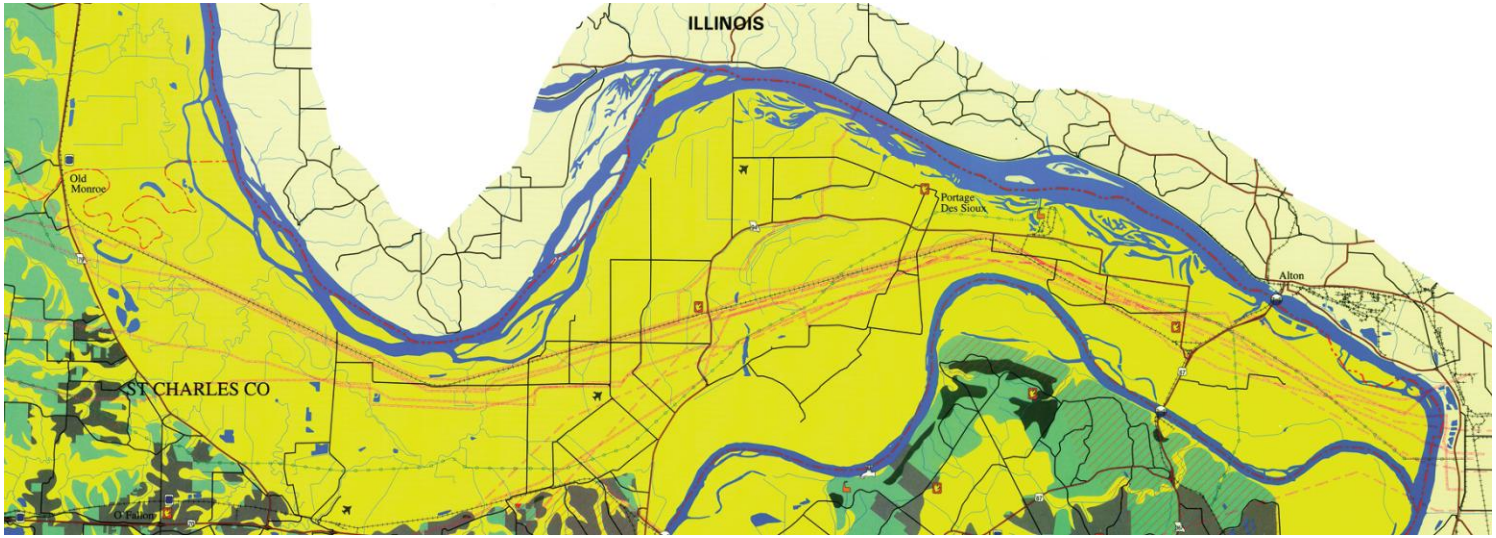
During the height of June's flooding, Mark Twain Lake, in conjunction with Truman Dam and Reservoir (Warsaw, Mo.), contributed to reducing the Mississippi River's stage at St. Louis and points south to Cape Girardeau approximately 3.5 ft.

Map

- **Breach at confluence point likely influenced by seepage along pipeline trenches. Failures here in 1993 and 2008.**

- **Pipeline breaks near Confluence Point. Note duck ponds and pipelines**





- **Buried pipelines are corridors of potential vulnerability, for floods and earthquakes**

Crossovers

- **Just about every place where a gravel-paved road crossed an agricultural levee, failure ensured by seepage through the gravel, even with sandbagging**

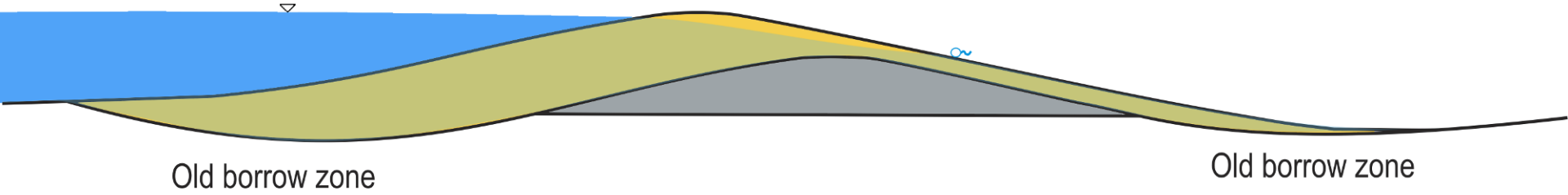
- **Seepage paths** often influenced by features such as tree root tracks, crayfish and/or ground squirrel burrows
- **Permeability** of silty earthen dikes close to the modern channel is about 1×10^{-3} cm/sec, or about 3 ft/day

- **Mud lines on tree trunks record the maximum flood levels adjacent to dikes that were breached**

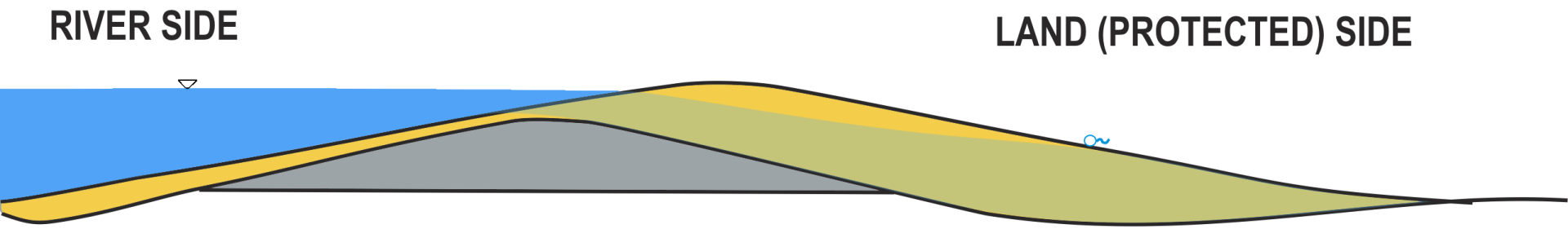
- **The Brevator District levees near Winfield survived 14 days of near-continuous overtopping, without failing**

- **Erosion tests of samples recovered from the Brevator levee revealed it had a much higher clay content than levees which did not survive overtopping**

TYPICAL EARTH CORE - SAND FILL LEVEE
WITH CENTRIC CORE & 5:1 SIDE SLOPES

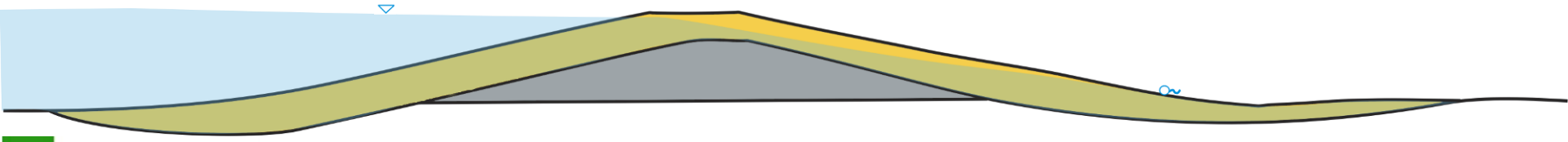


TYPICAL EARTH CORE - SAND FILL LEVEE
WITH RIVER SIDE CORE & 5:1 SIDE SLOPES

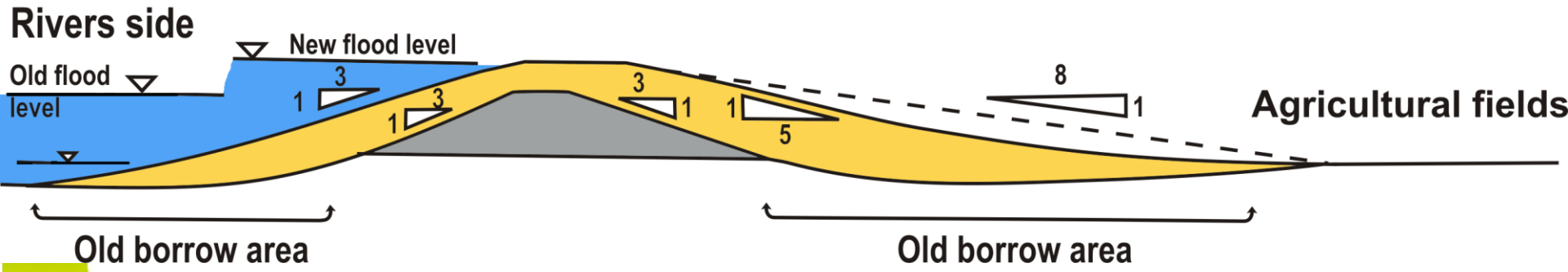


- **After the Spring 1965 floods the Rock Island District began employing sand fill shells over the pre-existing earthen agricultural levees**

TYPICAL EARTH CORE - SAND FILL LEVEE WITH CENTRIC CORE & 5:1 SIDE SLOPES

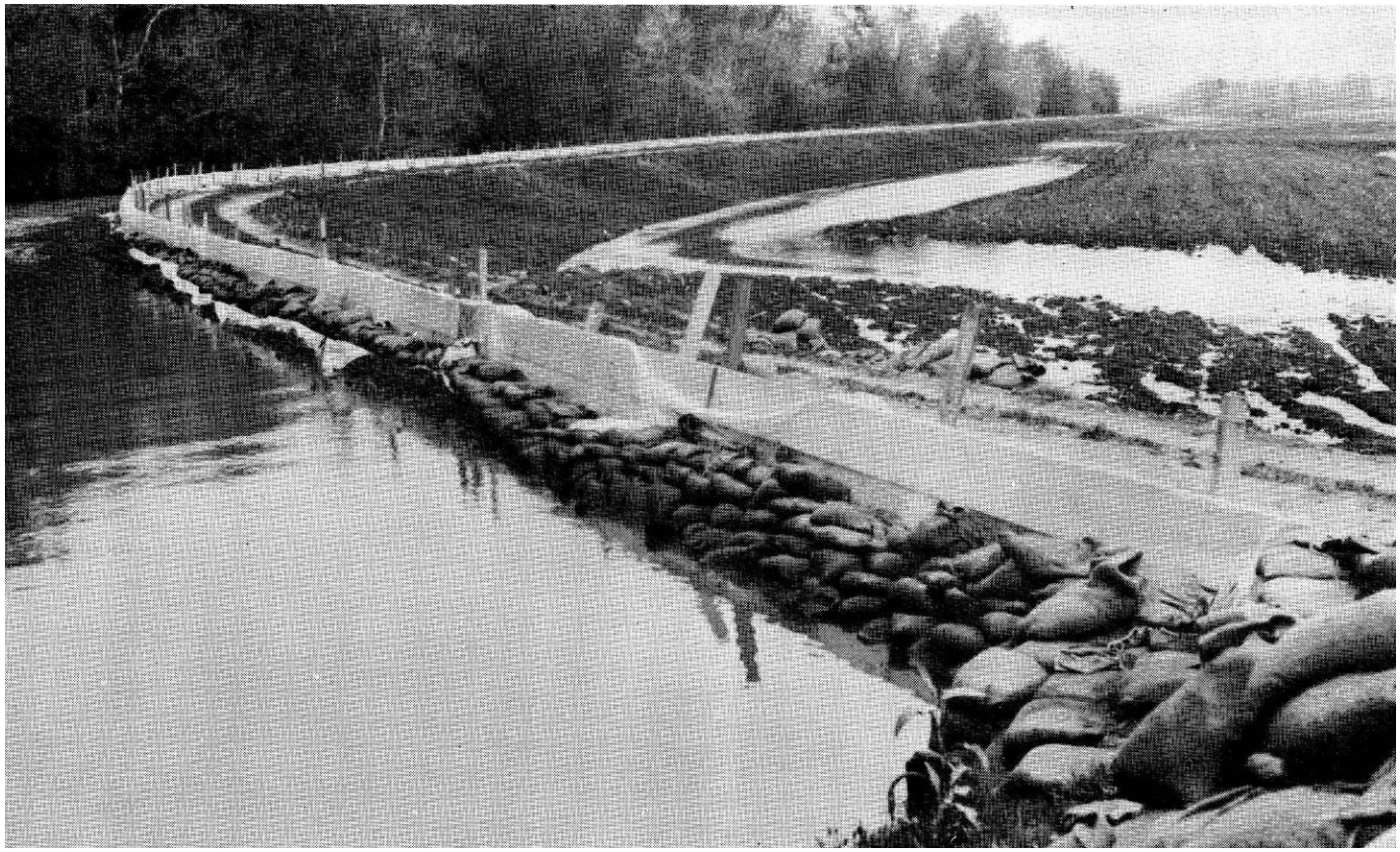


Typical Clay Core Sand Shell Levee



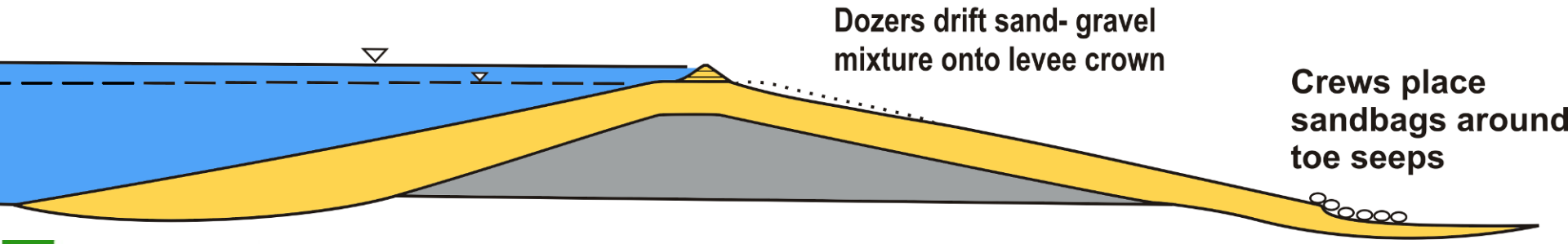
- The sand fill came from dredging of the navigation channel, using the districts O&M budget. This allowed levees to be heightened substantially with little capital outlay, as compared to conventional earthwork

Flash Boards

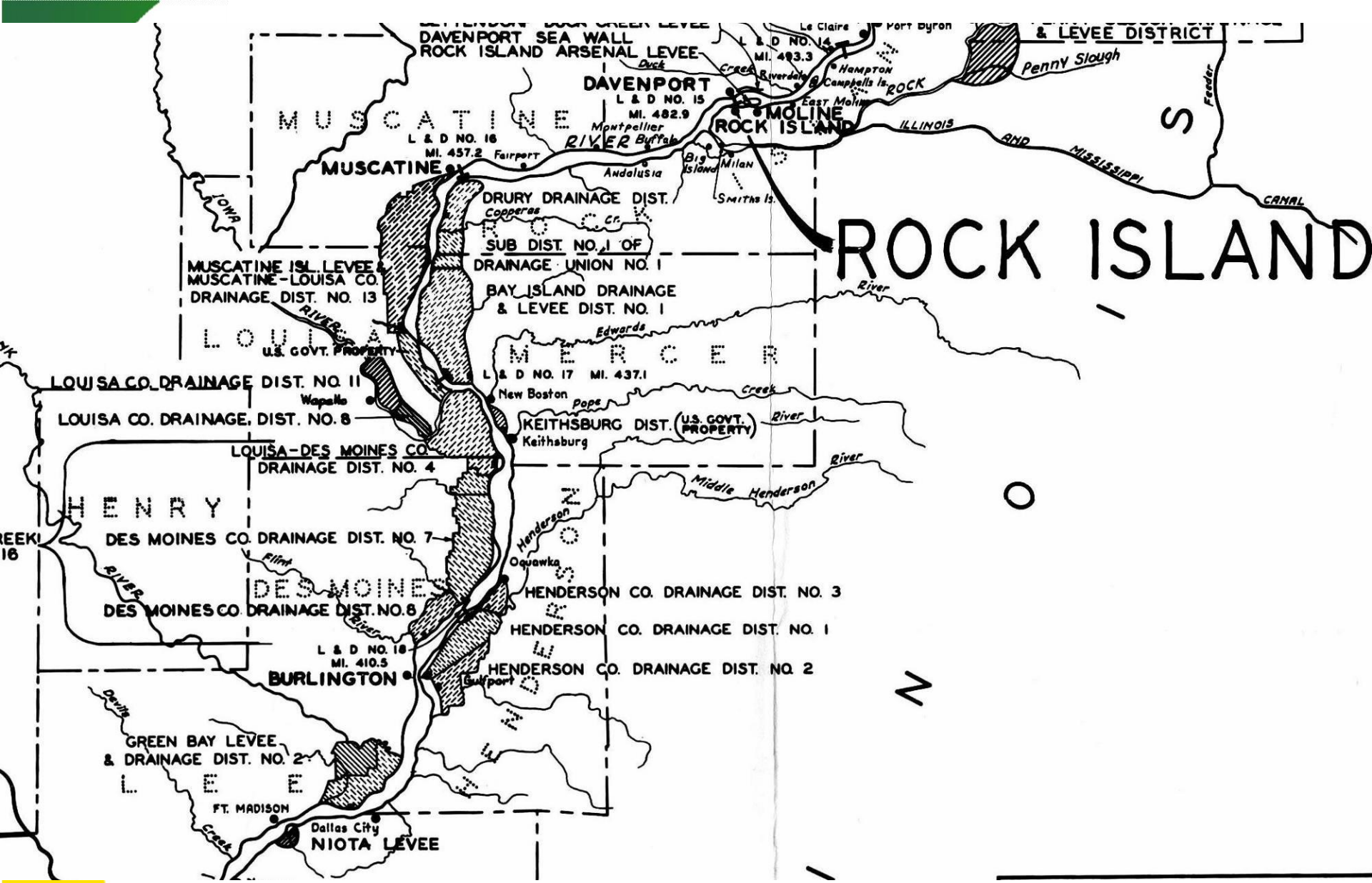


- **Prior to 1993 timber flash boards with plastic sheeting and sandbags were used to heighten levees during flooding**

Increased Flood Storage Using “Push-Ups”



- **After the 1993 floods the Rock Island District began using dozed sand “push-ups” instead of flash boards**



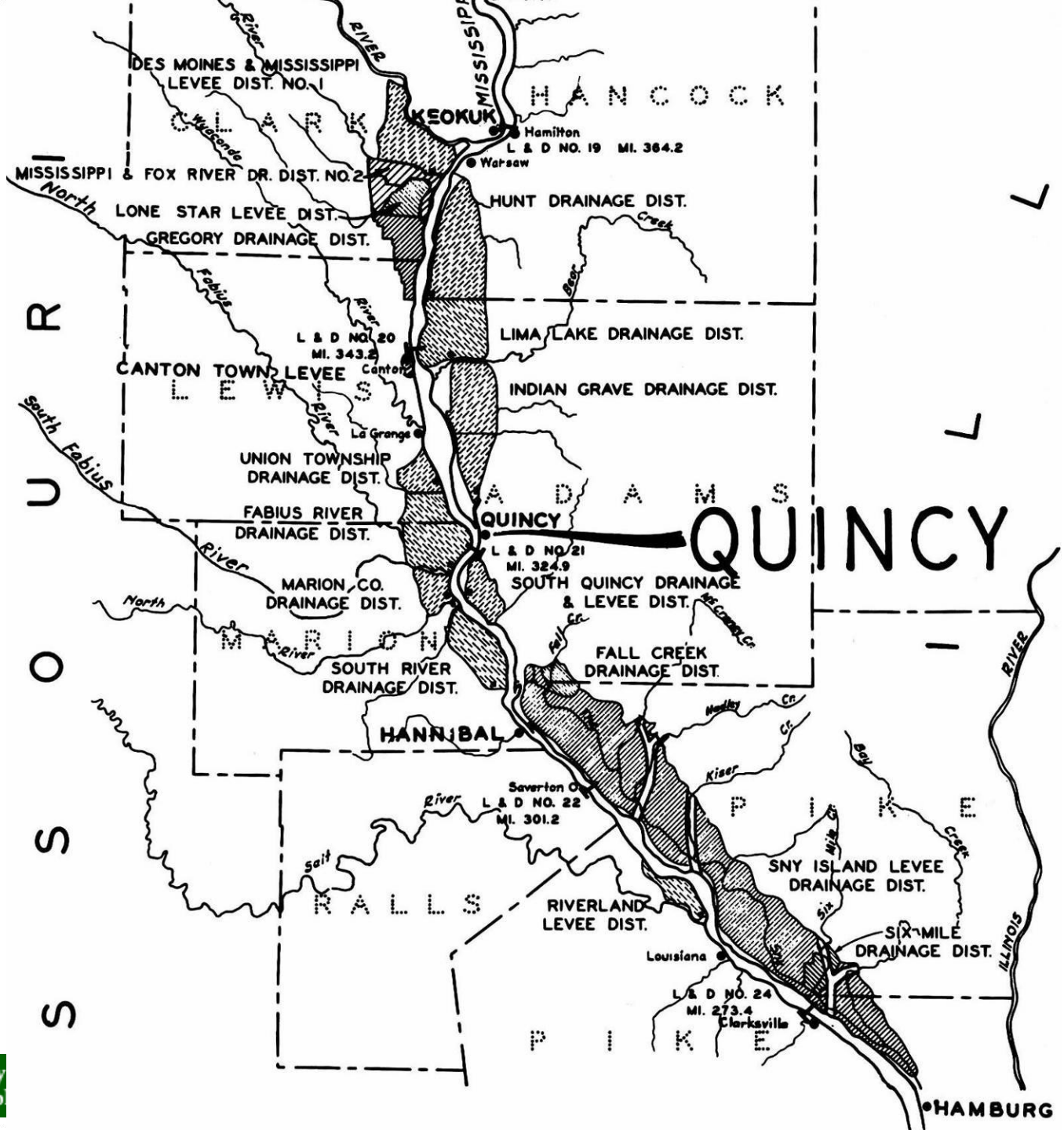
- **The breach along the southern bank of the lower Iowa River in the Two Rivers area southeast of Wapello, IA was one mile long. This break was a result of another break about 10 miles upstream, where US Hwy 61 crosses the river, which bifurcated the maximum flow, which re-joined at this location.**

- **View looking westerly, down the former axis of the right bank levee of the Iowa River, in the Two Rivers Levee & Drainage Association. This was the worst levee breach that occurred in the 2008 Midwest floods.**

Scour holes in a shale foundation testified to a large volume of water sweeping through, leaving almost no trace of the levee behind

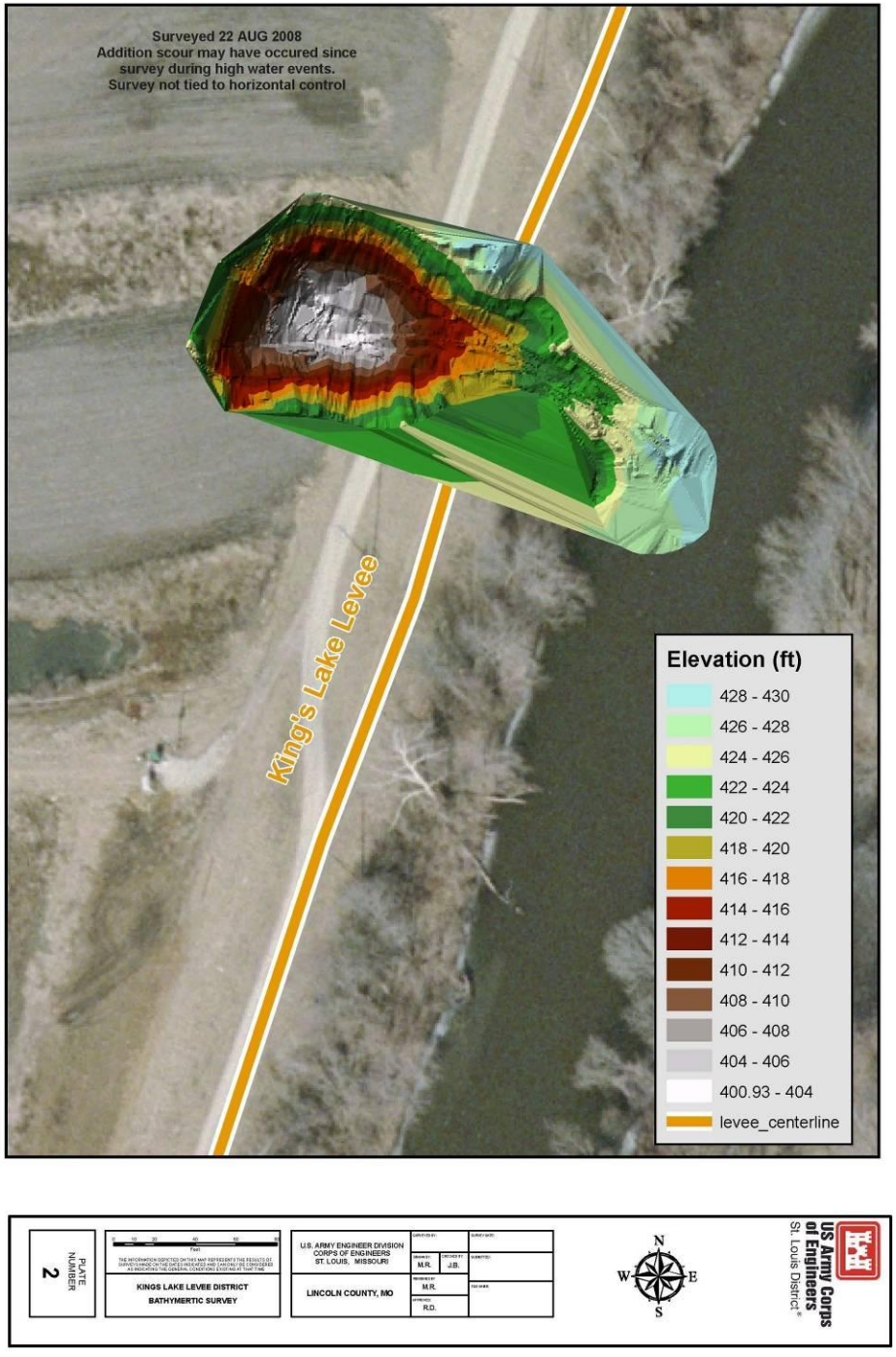
Two Rivers Blow-out

- **Sand push-ups were used to raise the Iowa River dike about 3 feet.**



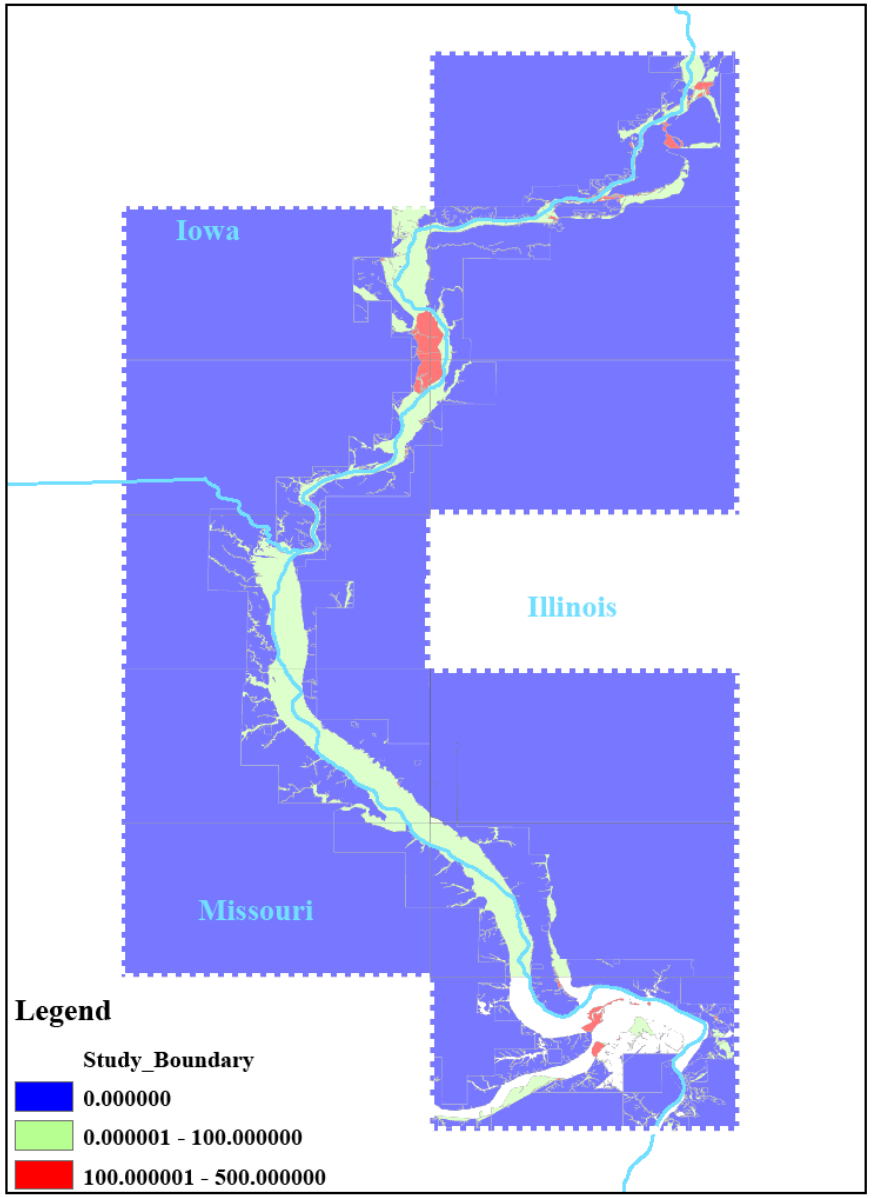
- **FEMA pays fro the sand push-ups, but does not pay to have them removed after flooding subsides. This cost is born by local levee districts**

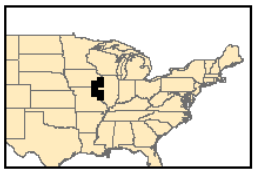
- **1300 ft wide breach at Indian Grave, near Quincy, IL. Failures have occurred here in 1947, 1965, 1993, and 2008. Four floods in 61 years is once every ~15 yrs. These agricultural levees are rated by the Corps of Engineers as 14-yr flood protection structures.**



Biggest Repair Problem

- Deep scour holes are perhaps the biggest engineering challenge in repairing dikes.
- These hole can be up to 40 ft deep and are backfilled with dredged sand
- A 5 ft thick clay cap is compacted over the sand fill to provide a semi-impervious seepage ‘blanket’





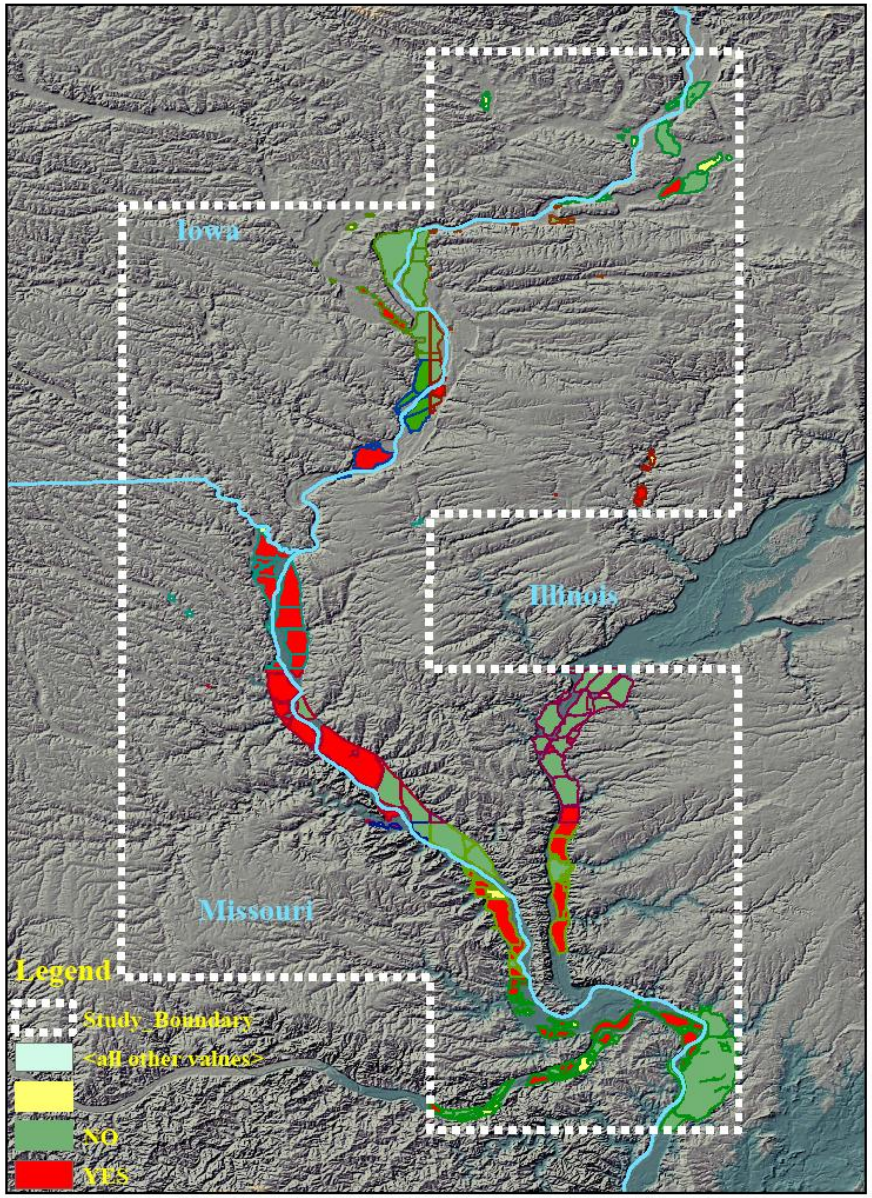
2008 Midwest Levee Investigation
Estimated Flood Return Period(??)

50 25 0 50 Kilometers

N W E S

Return Periods

- The great majority of the affected area experienced runoff frequencies less than 1-in-100
- The lower Iowa River watershed appears to have suffered an extreme event, likely close to 1-in-200



2008 Midwest Levee Investigation
1993 Levee Breach Locations

50 25 0 50 Kilometers

N
W E
S

Making levees more resilient – and survivable

- The NSF-funded team is focusing on areas where levees have repeatedly failed
- And, places where levees survived sustained overtopping, sometimes for several weeks

With Much Appreciation

- **National Science Foundation**
- **U.S. Army Corps of Engineers, St Louis and Rock Island Districts, who provided many of the images used herein, flow data, and historical background**
- **Local levee and drainage districts**
- **University of California, Berkeley geotechnical disaster reconnaissance team**
- **Texas A&M University Geotechnical Engineering Program**