THE DEVELOPMENT OF HAZUS BASED LIQUEFACTION MAPPING FOR EMERGENCY PLANNING

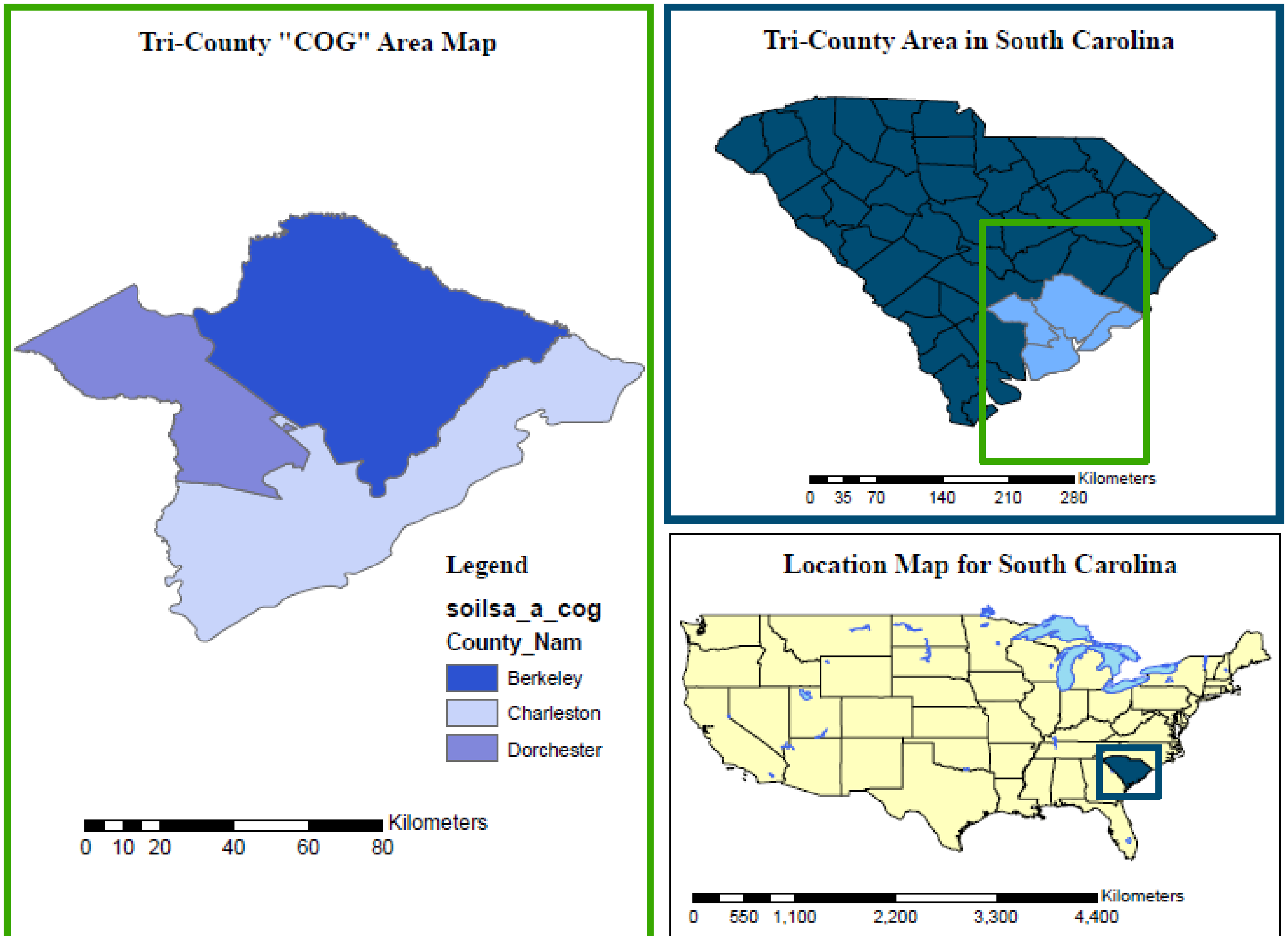
GSA Wilmington 2011
Paper No. 12-8

Waters, F. E. III, Spivey, B., Levine, N. S.

Outline

- Purpose of talk
- Relevance to South Carolina
- Liquefaction
- Applications of HAZUS
- Geographic Information Systems (GIS)
- Liquefaction Model
- Model use in Emergency Planning

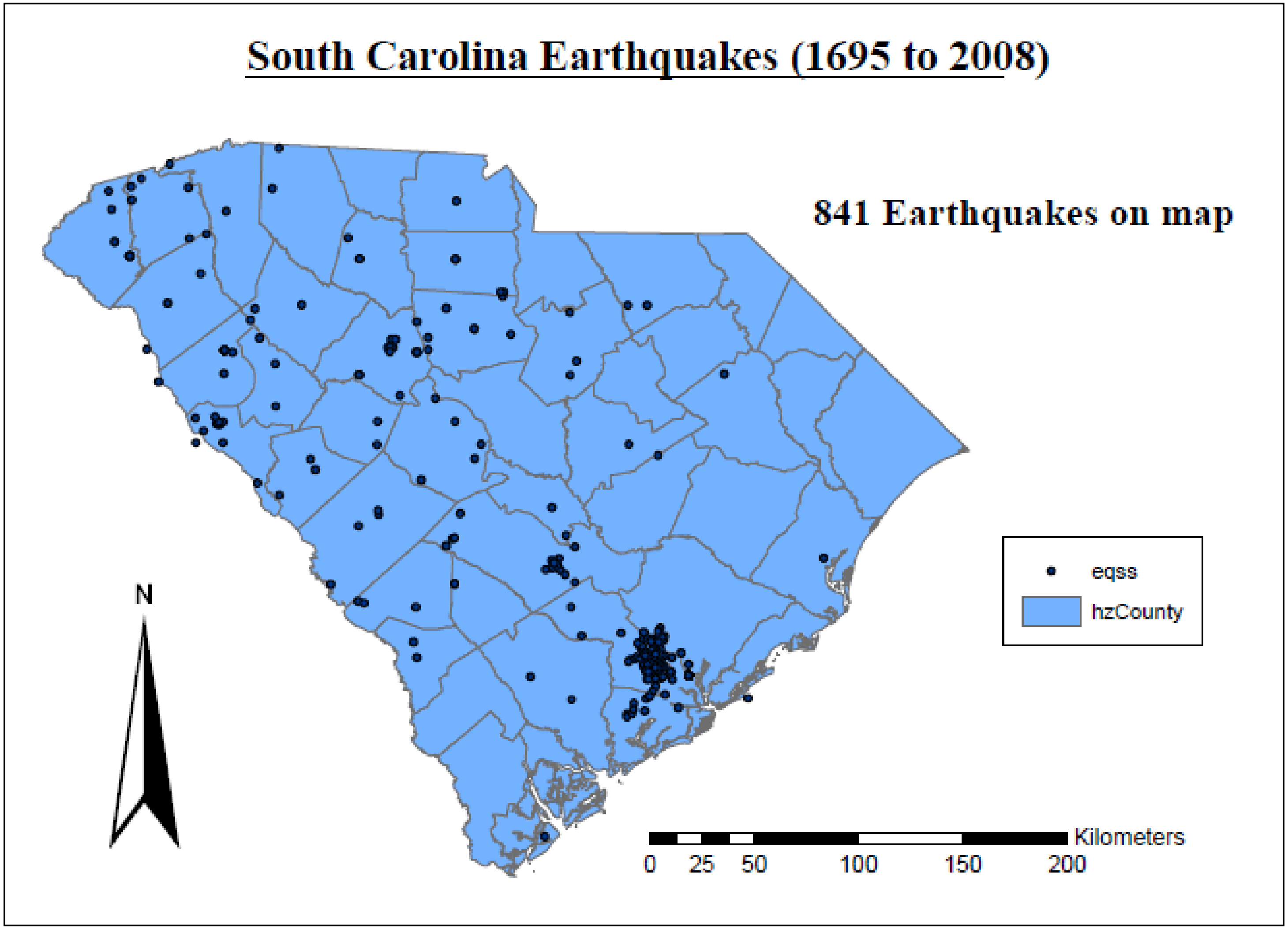
Location of Study Area



Data sources:
National and State Data
ESRI
and
County Data
USDA NRCS

Author:
Frank Earl Waters III
Date:
21-03-2011
Projection:
GCS_North_American_1983

Relevance to South Carolina



Source: Emergency Management Division of South Carolina

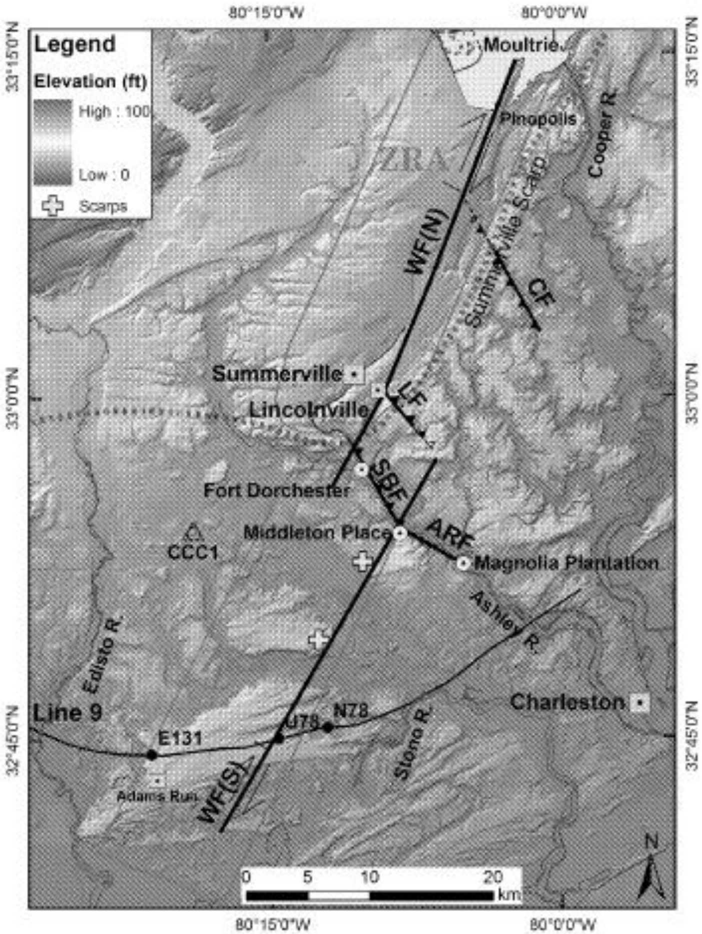
Relevance to South Carolina

- Middleton Place- Summerville Seismic Zone (MPSSZ)
  - Where most earthquakes are located
- Just north of the greater Charleston area
- Usually 10-30 earthquakes are recorded annually in MPSSZ

Talwani and Gomez 2009

http://www.dnr.sc.gov/geology/images/Fault_Map_Generalized.gif

Relevance to South Carolina



Talwani and Gomez 2009

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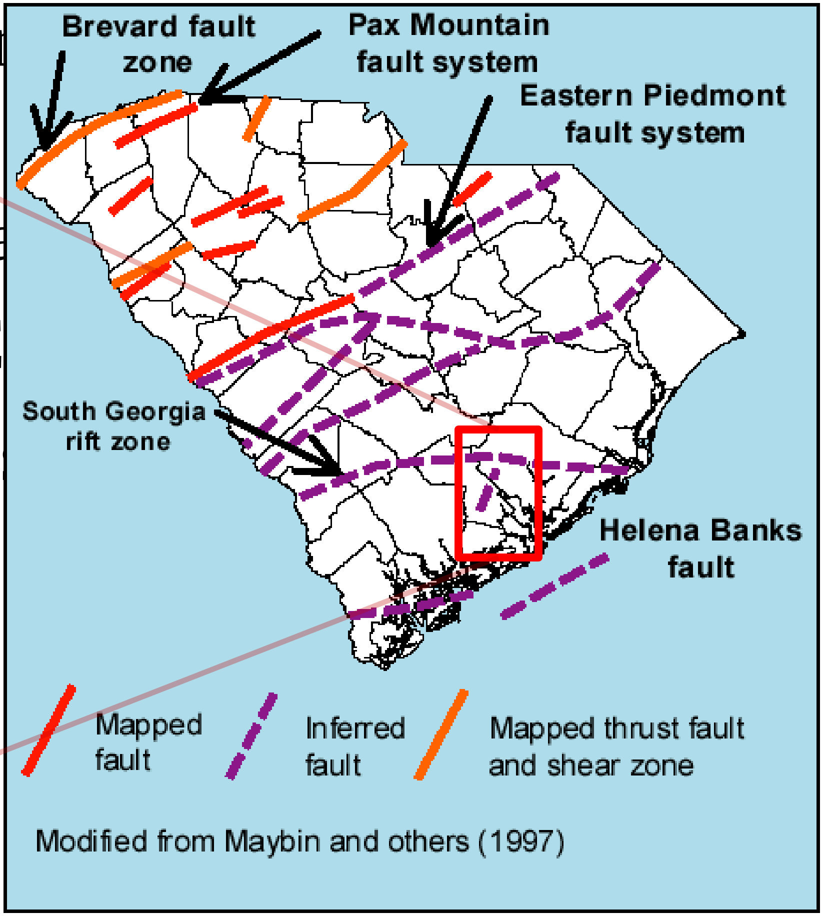


http://www.dnr.sc.gov/geology/images/Fault_Map_Generalized.gif

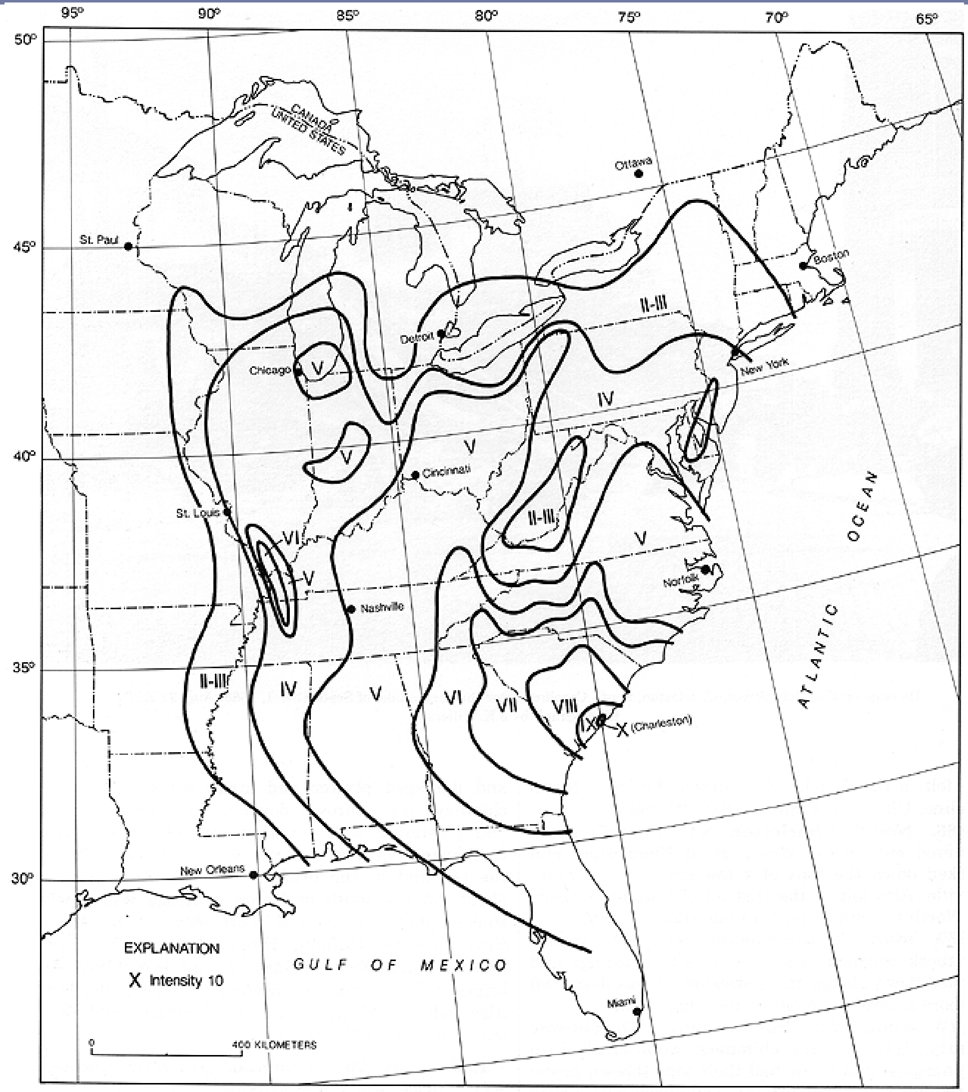
Relevance to South Carolina

- The majority of SC earthquakes do not pose a threat to local populations or infrastructure
- However larger earthquake have occurred
- At least 5 major earthquakes in the past 5000 years
- 40-60% of Magnitude 6 In Eastern US in the next 30 years
- Recent example: 1886 (Magnitude 7)

August 31,1886

- 6.9-7.3Magnitude
- Felt from Cuba

  to New York
- Extensive damage to 1000s of structures
  - 90% in Charleston
- 1,300 square kilometers of liquefaction events



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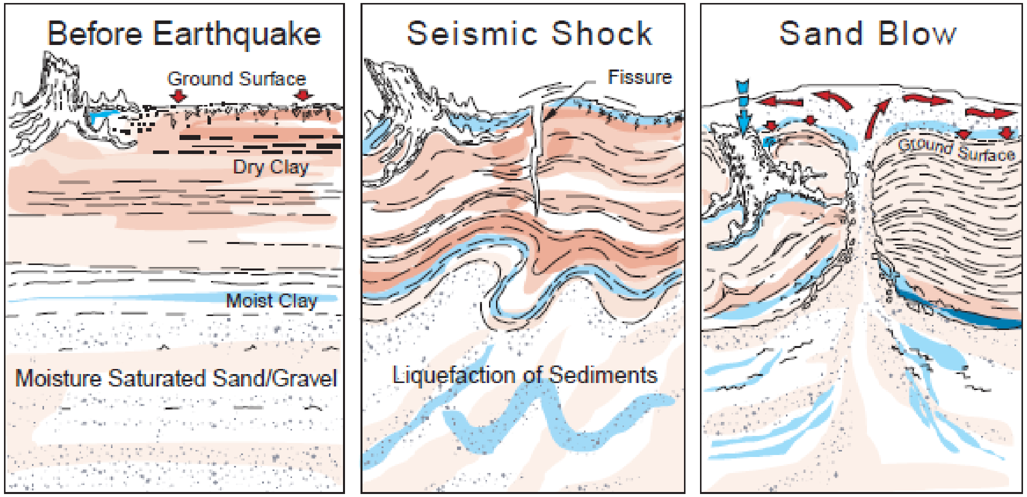
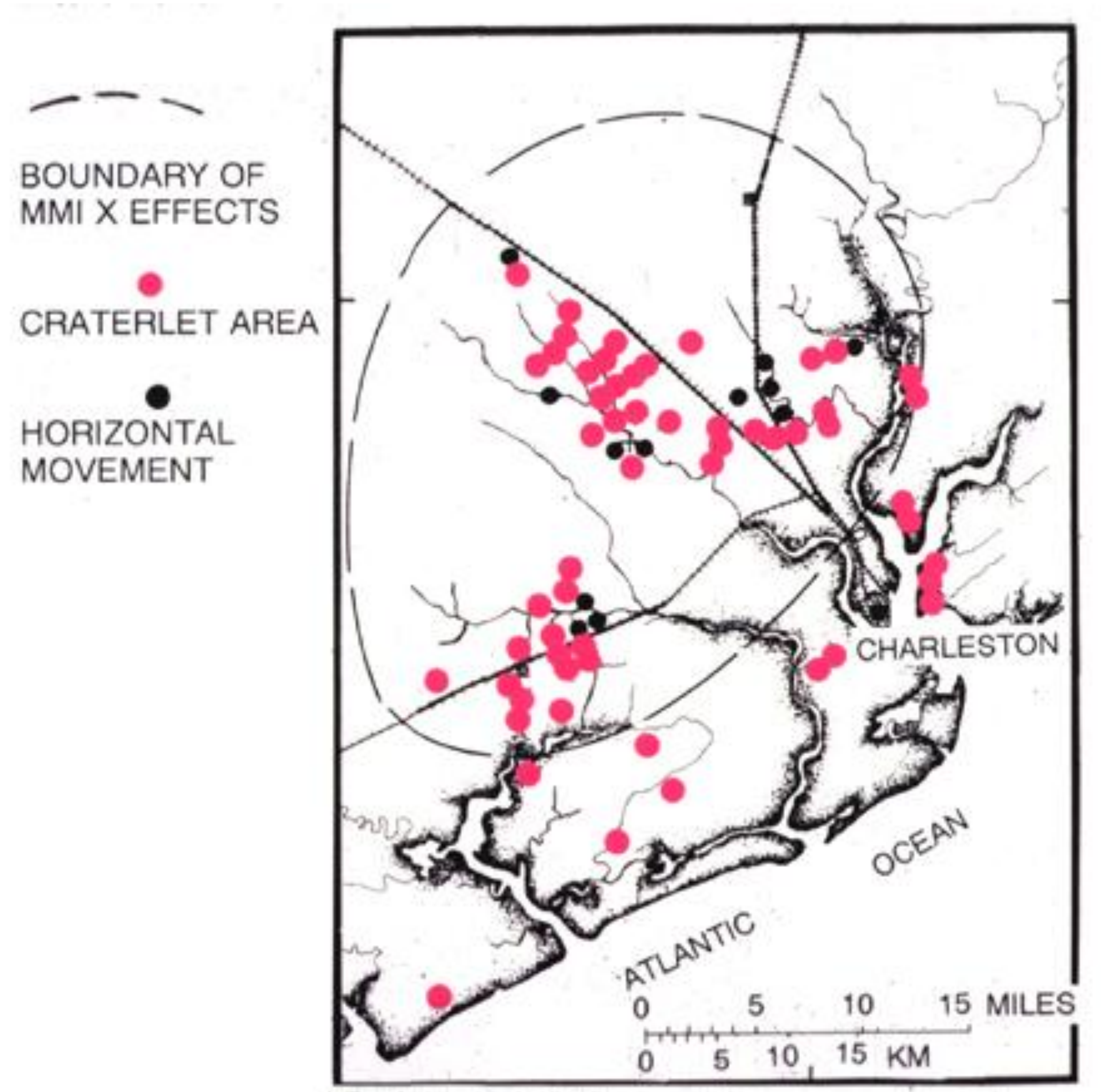
Liquefaction Basics



- Strong shaking causes water saturated sediments to begin to behave like pressurized liquid
- PGA- pore pressure- gravity- sinking and sand blows
- Worst case: young, unconsolidated, saturated sediments or artificial fill

Liquefaction Basics



- Strong ... nts to begin t...
- PGA- p... d blows
- Worst ... sediments or artif...

1886 Liquefaction

Liquefaction feature Produced by a sandblow that was 15 feet tall

1886 Liquefaction

What is HAZUS?

- HAZUS-MH is a collection of risk assessment methodologies that analyze potential losses from common natural disasters such as floods, hurricanes, or earthquakes
- Before loss calculations the event must be modeled (in terms of geographic spread and intensity)
  - This uses data gathered and implanted by the user
- These methods can be realized most readily in a GIS environment

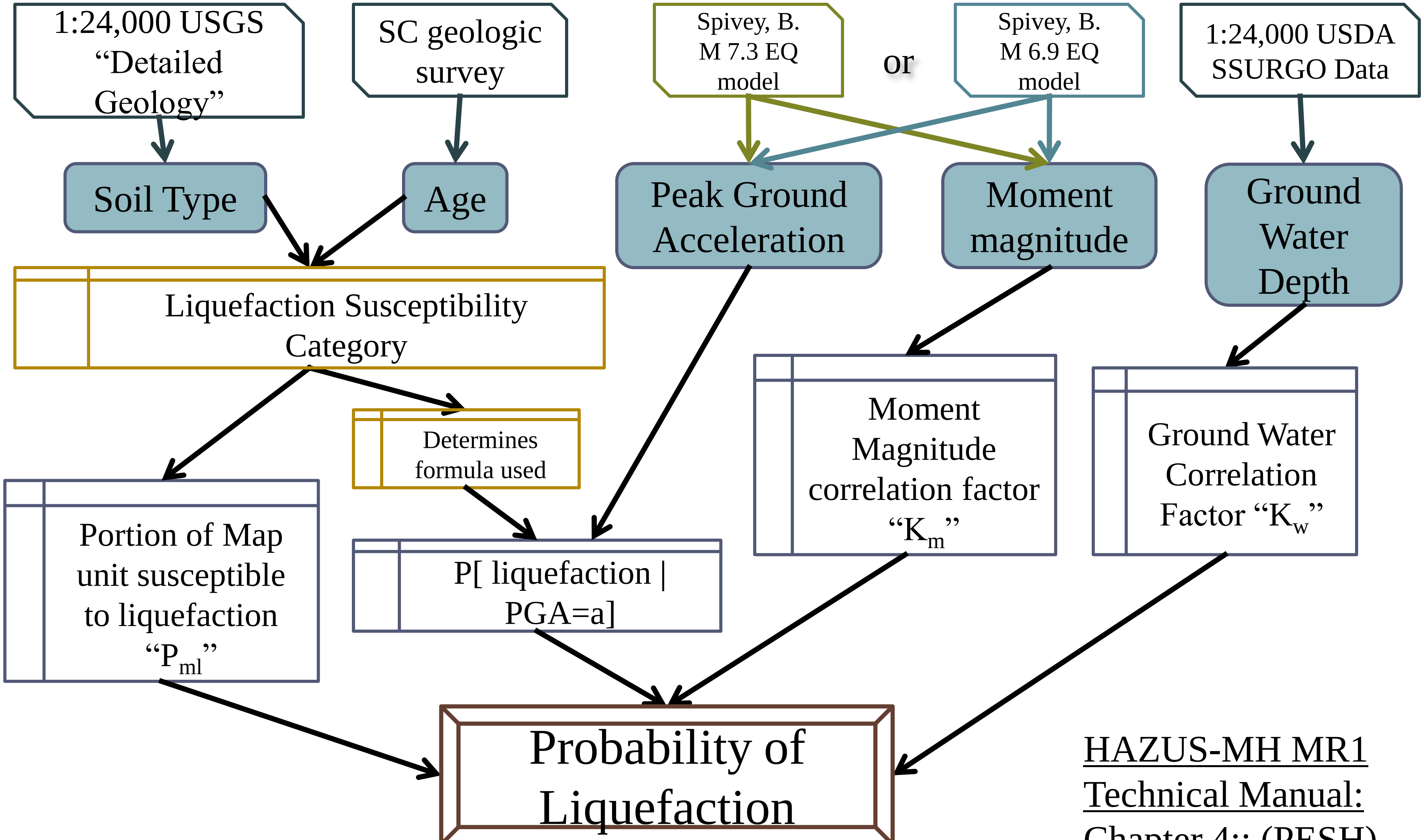
What is a GIS?

- Geographic information system-
  - “A computer based information system for integrating, analyzing and managing databases and spatial information.”
- In English:
  - A computer program and user duo that can process mapable data sets to uncover new information

Liquefaction Modeling

- Requires the input of several variables
  - Most of the information is published by USDA NRCS
    - Ex: SSURGO and STATSGO
    - Or USGS geologic maps
  - Other variable sets have to be modeled using another part of HAZUS
    - ex: PGA- how violent and earthquake is

Liquefaction Modeling



HAZUS-MH MR1 Technical Manual: Chapter 4:: (PESH)

Liquefaction Susceptibility Map

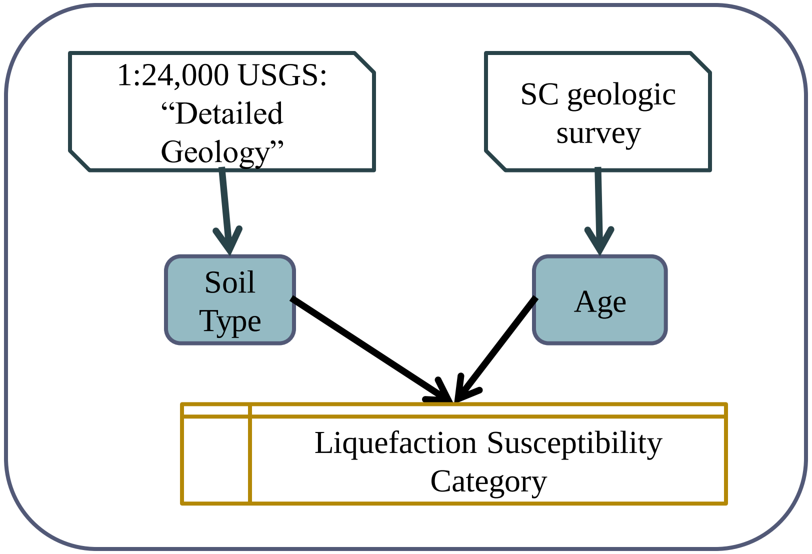
Soil type: Need to change data in to a numbering system: 1,2,3,… (new field to this)

Soil age: Numbering system:
- "100": <500 yrs
- "200": 500-11,000 yrs
- "300": 11,000-2 million yrs
- "400": > 2 million yrs

Table 4.10 Liquefaction Susceptibility of Sedimentary Deposits (from Youd and Perkins, 1978)

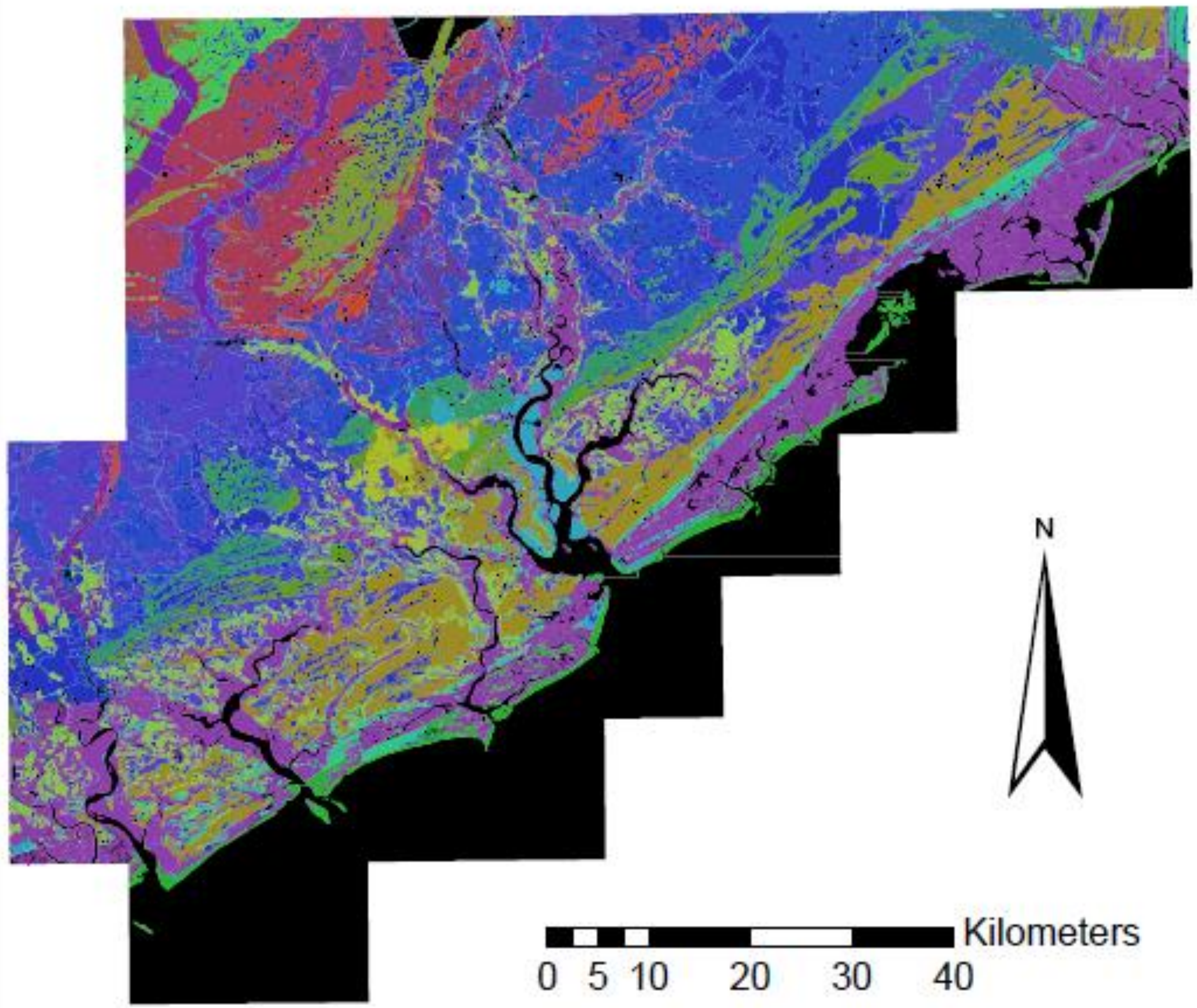
#1 → 23

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated would be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka - 2 Ma	Pre-Pleistocene > 2 Ma
(a) Continental Deposits					
River channel	Locally variable	Very High	High	Low	Very Low
Flood plain	Locally variable	High	Moderate	Low	Very Low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very Low
Marine terraces and plains	Widespread	---	Low	Very Low	Very Low
Delta and fan-delta	Widespread	High	Moderate	Low	Very Low
Lacustrine and playa	Variable	High	Moderate	Low	Very Low
Colluvium	Variable	High	Moderate	Low	Very Low
Talus	Widespread	Low	Low	Very Low	Very Low
Dunes	Widespread	High	Moderate	Low	Very Low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very Low	Very Low
Tuff	Rare	Low	Low	Very Low	Very Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very Low	Very Low
Sebka	Locally variable	High	Moderate	Low	Very Low
(b) Coastal Zone					
Delta	Widespread	Very High	High	Low	Very Low
Esturine	Locally variable	High	Moderate	Low	Very Low
Beach					
High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
Low Wave Energy	Widespread	High	Moderate	Low	Very Low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Fore shore	Locally variable	High	Moderate	Low	Very Low
(c) Artificial					
Uncompacted Fill	Variable	Very High	---	---	---
Compacted Fill	Variable	Low	---	---	---

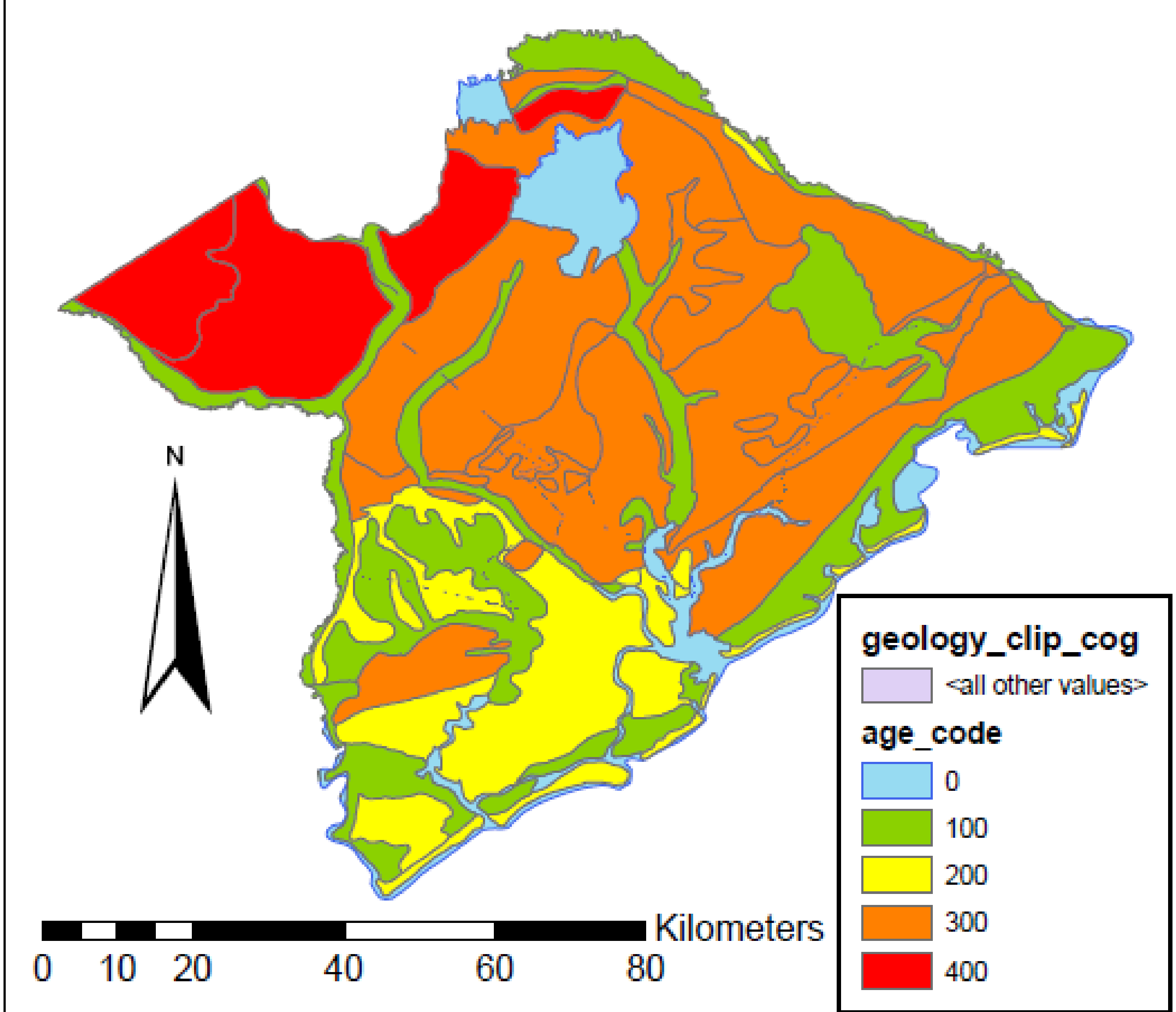


HAZUS-MH MR1 Technical Manual: Chapter 4:: (PESH)

Detailed Geology Layer

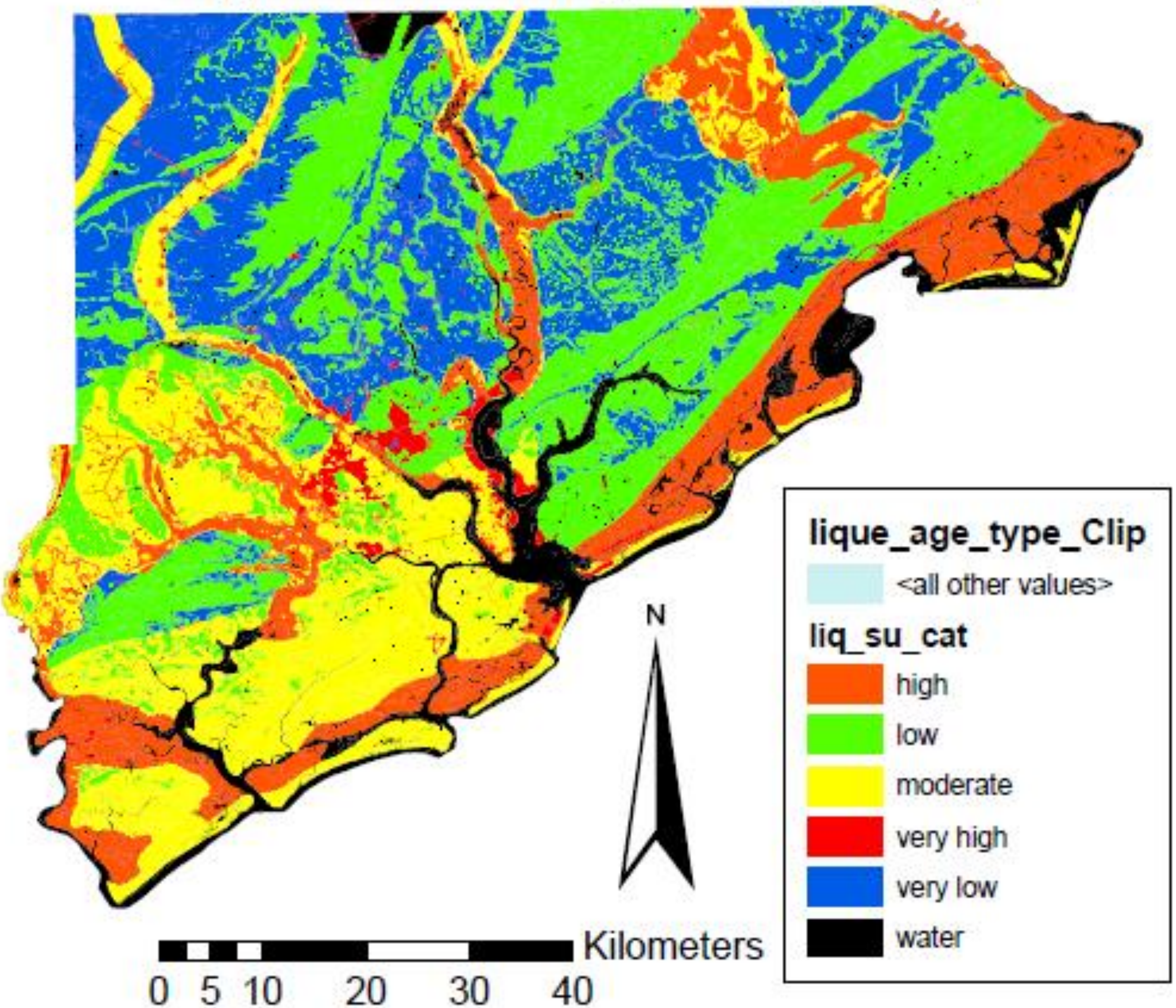


Sediment Age Layer



Source: SC Seismic Network

Combined age and surface geology layer: Liquefaction Susceptibility (rough)

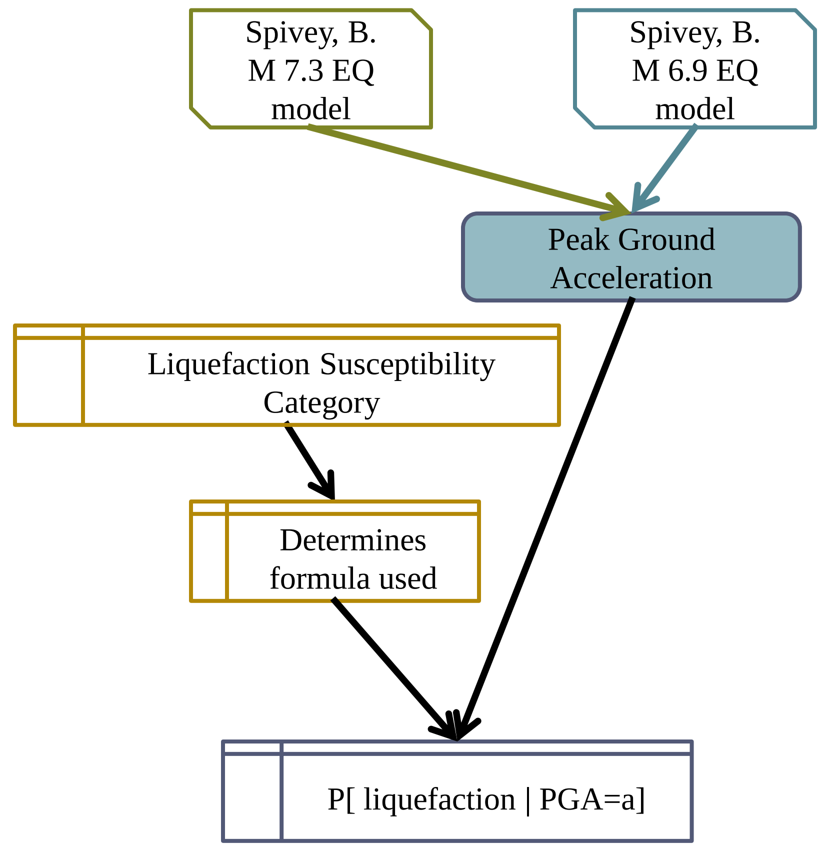


Formulas for P[liquefaction | PGA=a]

$P\left[\text{Liquefaction}_{SC} \mid PGA = a\right]$ is the conditional liquefaction probability for a given susceptibility category at a specified level of peak ground acceleration (See Figure 4.8)

Table 4.12 Conditional Probability Relationship for Liquefaction Susceptibility Categories

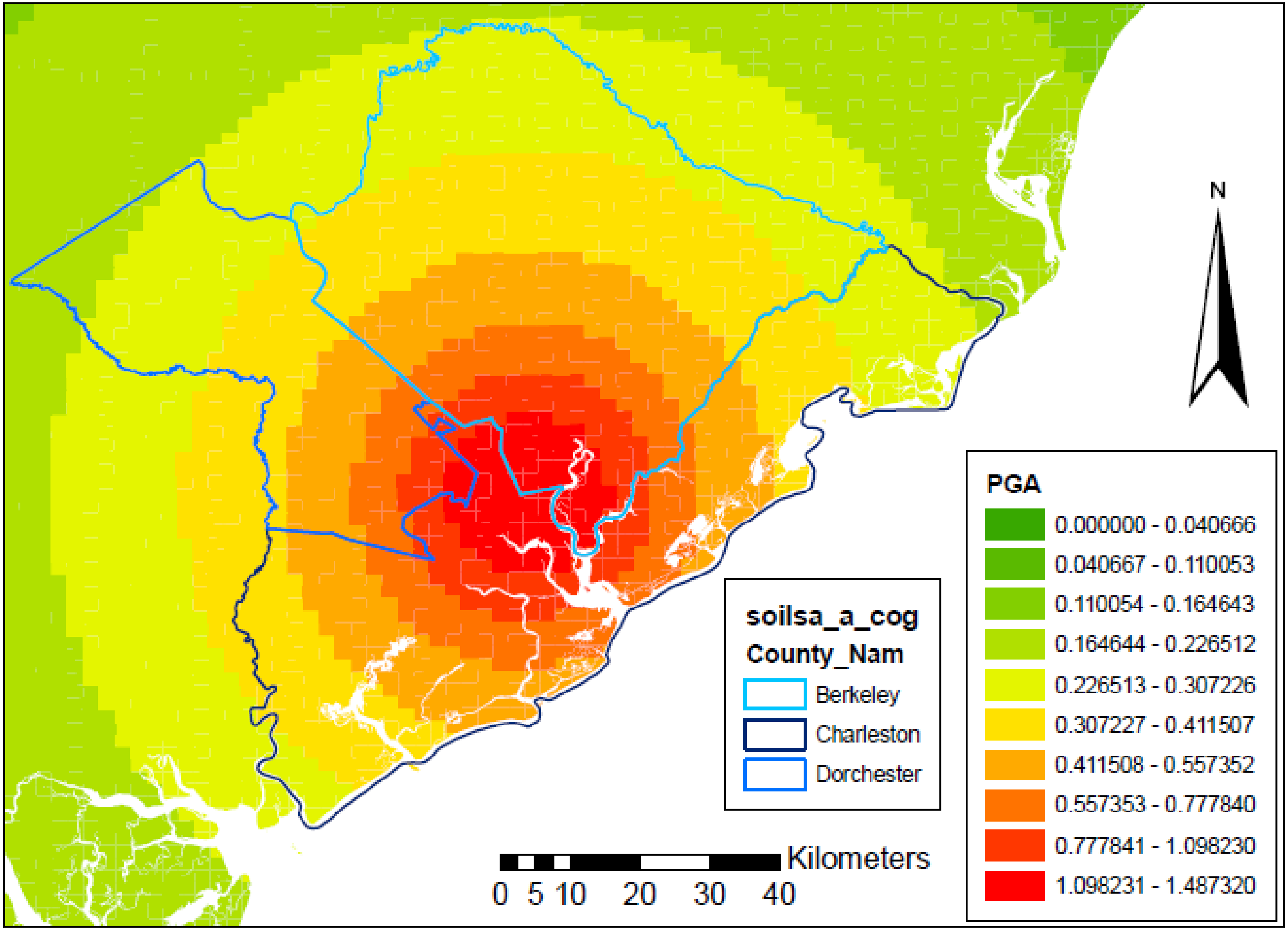
Susceptibility Category	$P\left[\text{Liquefaction} \mid PGA = a\right]$
Very High	$0 \le 9.09\,a - 0.82 \le 1.0$
High	$0 \le 7.67a - 0.92 \le 1.0$
Moderate	$0 \le 6.67a - 1.0 \le 1.0$
Low	$0 \le 5.57a - 1.18 \le 1.0$
Very Low	$0 \le 4.16a - 1.08 \le 1.0$
None	0.0



Gives probability for liquefaction assuming worst case conditions at every site

HAZUS-MH MR1 Technical Manual: Chapter 4:: (PESH)

Peak Ground Acceleration (g); M=7.3



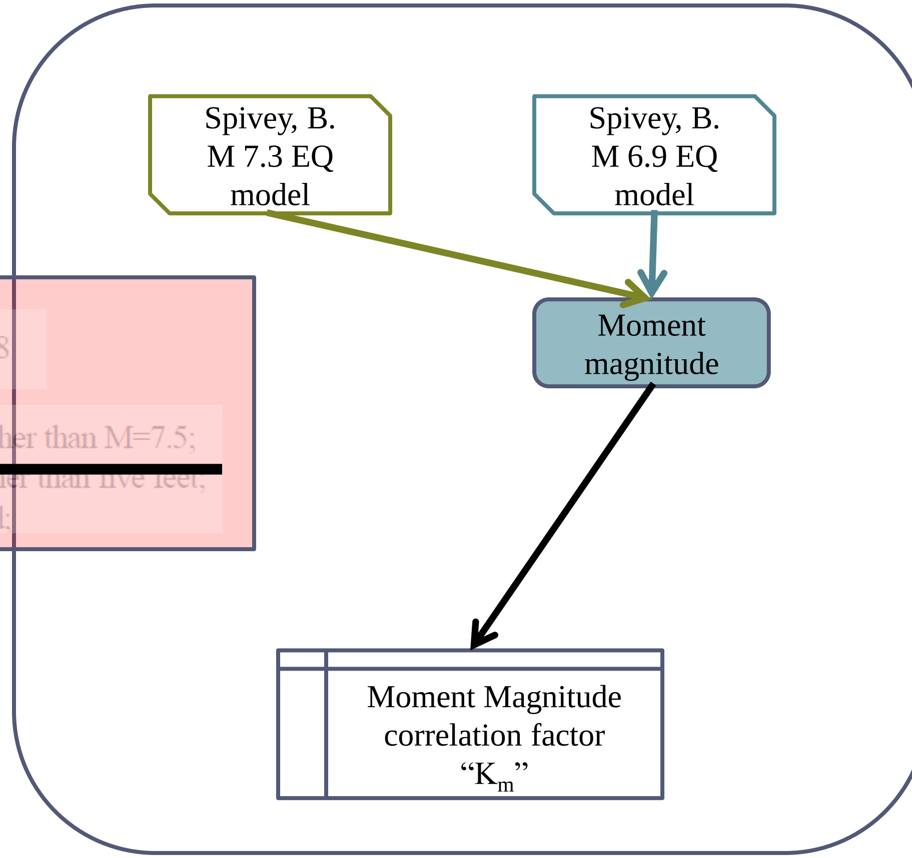
Sources: FEMA- HAZUS

Spivey, Brooke

Moment Magnitude correlation factor "K_m"

$$K_m = 0.0027M^3 - 0.0267M^2 - 0.2055M + 2.9188$$

where: K_m is the correction factor for moment magnitudes other than M=7.5;
K_w is the correction factor for groundwater depths other than five feet;
M represents the magnitude of the seismic event, and;



*No map, just a number in a table

HAZUS-MH MR1 Technical Manual: Chapter 4:: (PESH)

Ground Water Correlation Factor “K_w”

$$K_w = 0.022 d_w + 0.93 \qquad (4\text{-}22)$$

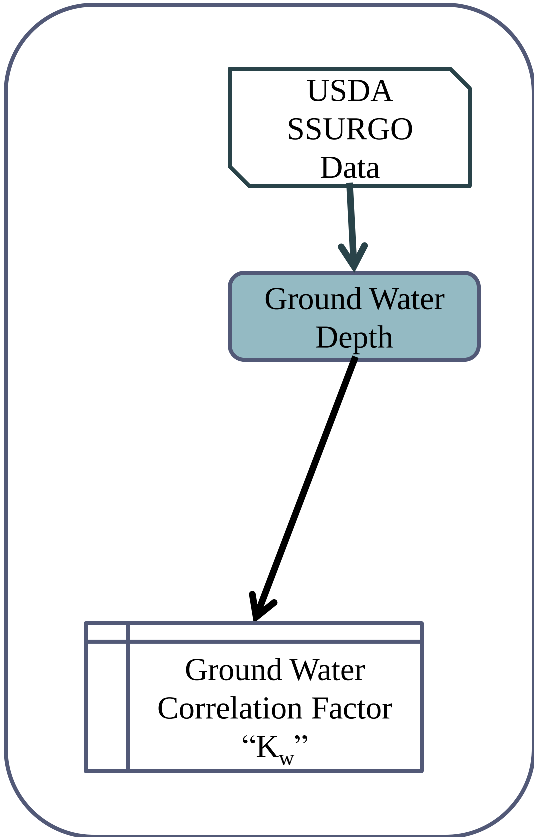
where: ~~K_m is the correction factor for moment magnitudes other than M=7.5~~;

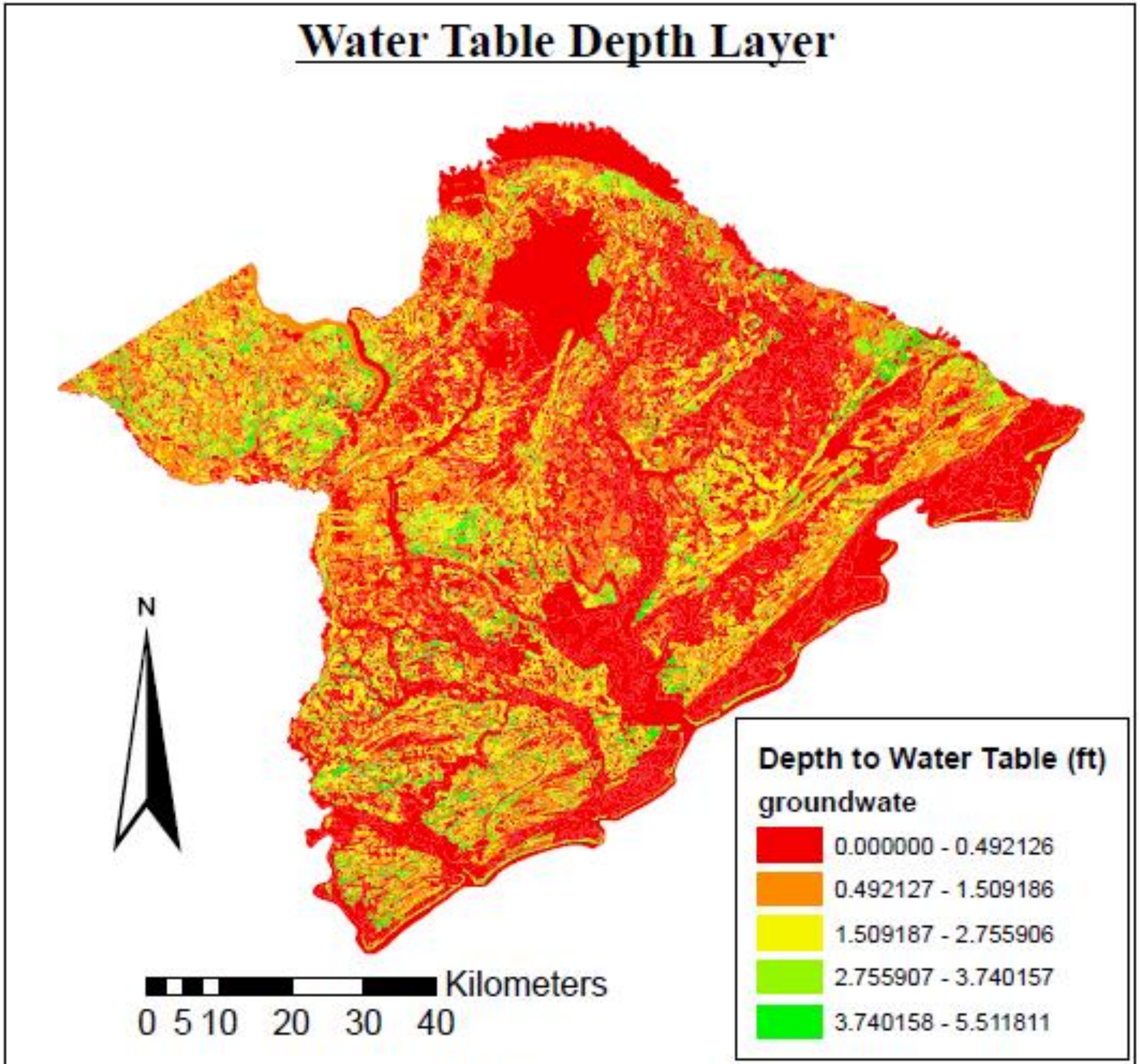
K_w is the correction factor for groundwater depths other than five feet;

~~M represents the magnitude of the seismic event, and;~~

d_w represents the depth to the groundwater in feet.

Liquefaction needs water to occur





Source: USDA-NRCS-SSURGO 2.2 data

Portion of Map unit susceptible to liquefaction (Pml)

Table 4.11 Proportion of Map Unit Susceptible to Liquefaction

Mapped Relative Susceptibility	Proportion of Map Unit
Very High	0.25
High	0.20
Moderate	0.10
Low	0.05
Very Low	0.02
None	0.00

- Last little control to ensure realistic model.

Liquefaction Final Formula

$$P[\text{Liquefaction}_{SC}] = \frac{P[\text{Liquefaction}_{SC} | PGA = a]}{K_M \cdot K_w} \cdot P_{ml} \quad (4\text{-}20)$$

where

$P[\text{Liquefaction}_{SC} | PGA = a]$ is the conditional liquefaction probability for a given susceptibility category at a specified level of peak ground acceleration (See Figure 4.8)

K_M is the moment magnitude (**M**) correction factor (Equation 4-21)

K_w is the ground water correction factor (Equation 4-22)

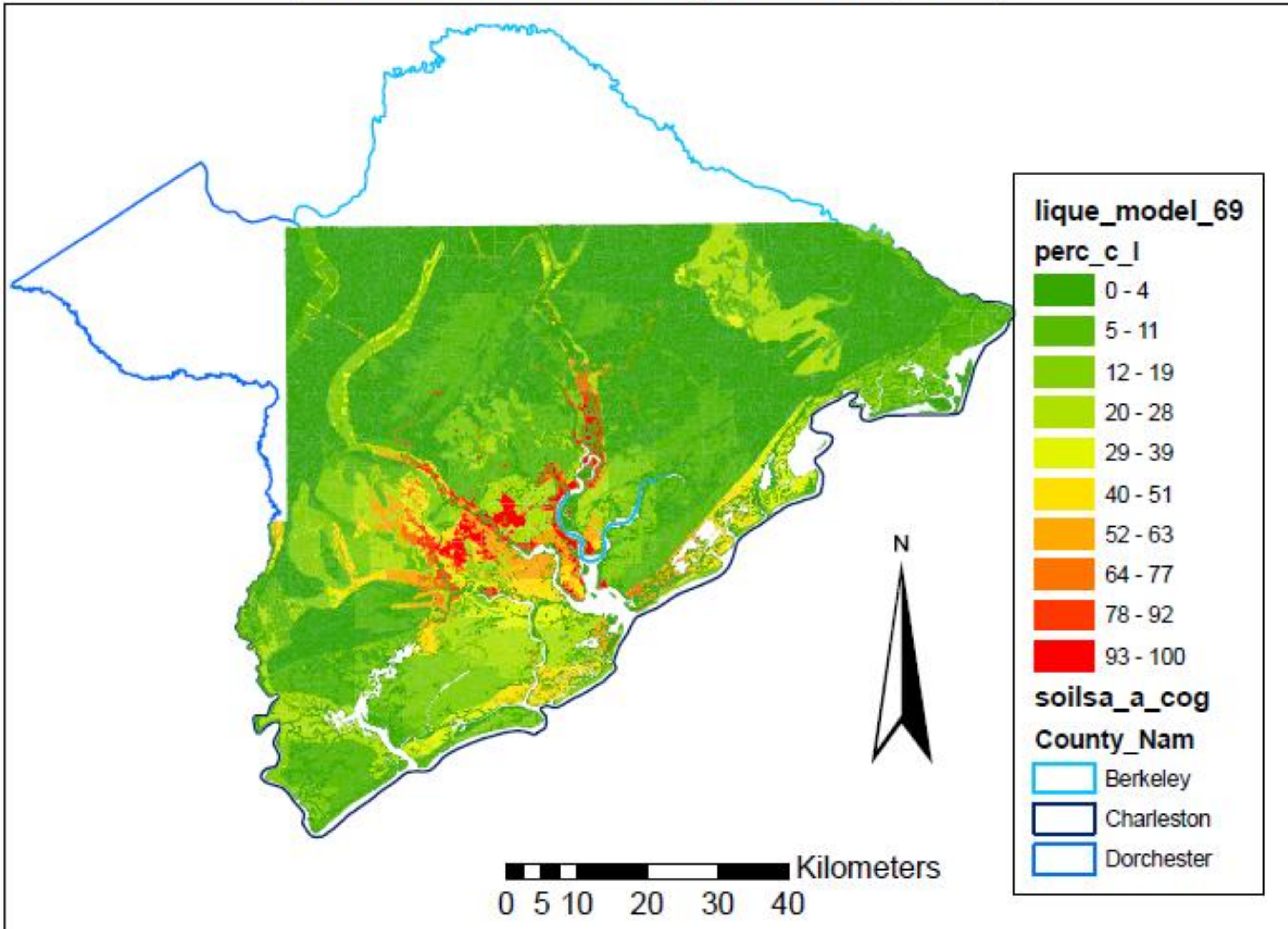
P_{ml} proportion of map unit susceptible to liquefaction (Table 4.11)

Methods and Formulas outlined in:

"HAZUS-MH MR1 Technical Manual: Chapter 4: Potential Earth Science Hazards (PESH)"

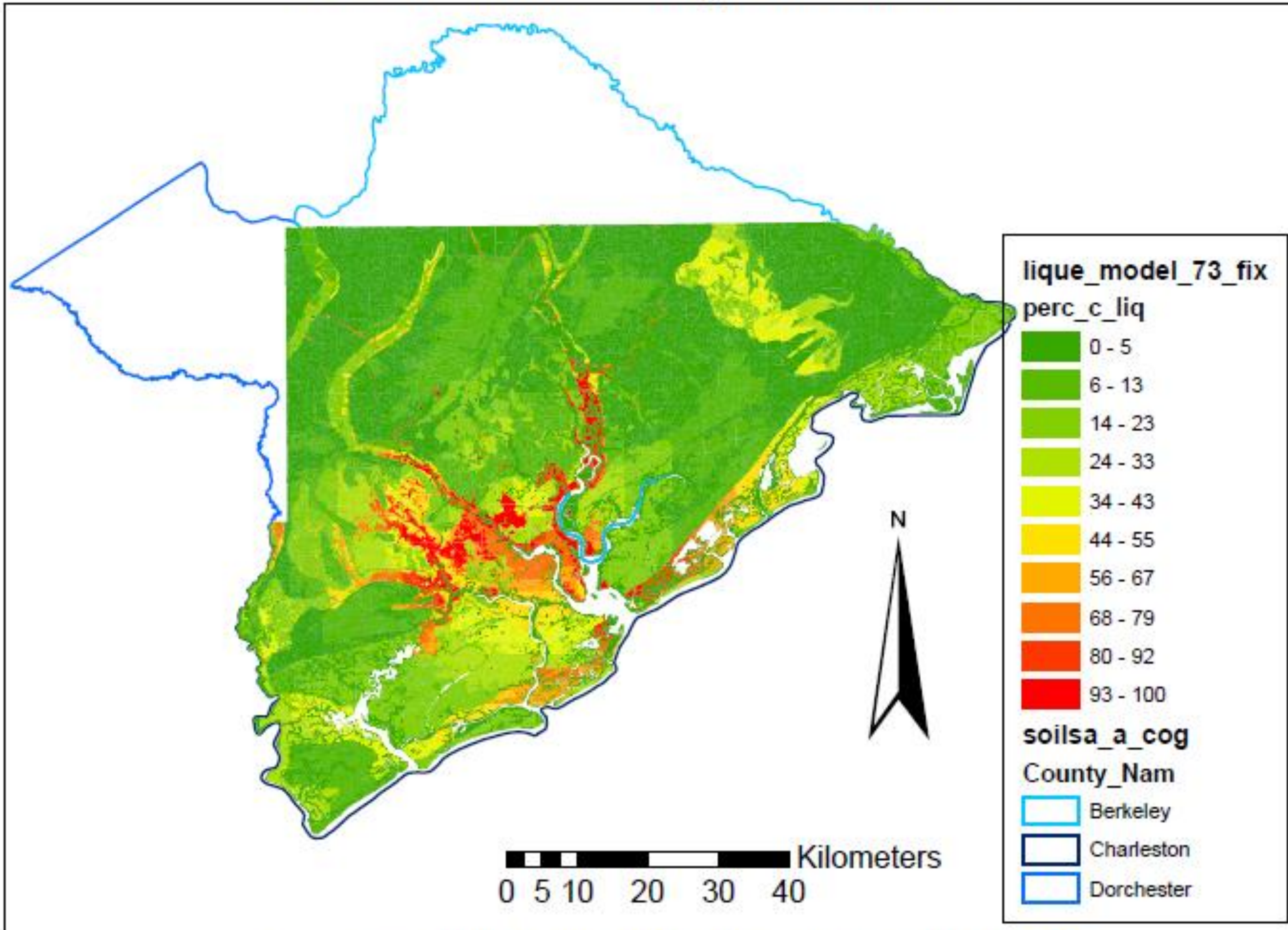
- Multiplying the result by 100 gives the percent chance that a given plot will liquefy
- The soil plot will not liquefy
  - Maximum about one fourth of it

Percent Chance of Liquefaction; M=6.9



Sources: SC Seismic Survey, USDA NRCS- SSURGO, FEMA- HAZUS

Percent Chance of Liquefaction; M=7.3



Sources: SC Seismic Survey, USDA NRCS- SSURGO, FEMA- HAZUS

Application of model

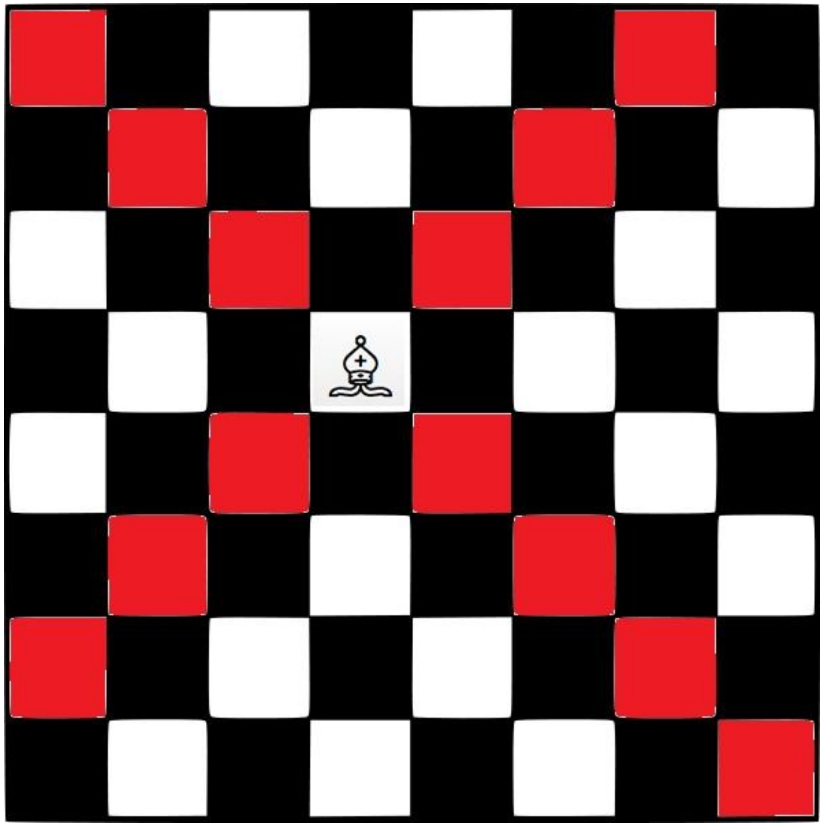
- We have an idea of were the liquefaction will happen and to what degree.
- So now what?

Emergency Planning

- Some human populations reside in areas that have a high natural hazard risk
  - When these naturally occurring events cause damage and loss of life the are ‘natural disasters’
- Emergency planning has one function: decrease the loss of life and property by
  - preemptively taking action (Hospital placement)
  - and establishing procedures after the event (Red Cross)

Using a hazard layer in planning

- Hazard layers like this are limiters not determiners
- Its like an opponents Bishop chess piece
  - You really should not move into its line of attack.



Examples for this study

- Determine the transportation systems effected (HAZUS main purpose)
  - Bridges
  - Roads effected
- FEMA POD placement (limits viable location)

Ideas on slide ‘borrowed’ from fellow students.

Model imperfections

- Data holes:
  - SURRGO will not have data heavily urban areas
  - Impossible values- here they stem from the P[liquefaction |PGA]
- Fixes:
  - Fill in the data using best judgment and knowledge of area
  - Set anything above 100% equal to 100 and any negative to 0

In this study:

(polygons)

M= 7.3 model		**M= 6.9 model**	
Greater 100%	2.9%	Greater 100%	1.5%
Greater 200%	.7%	Greater 200%	.3%
Negatives	0%	Negatives	.1%

Question?